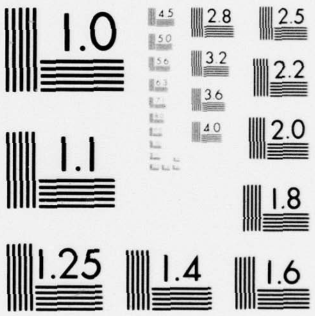
AD-A064 122   ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT--ETC   F/G 1/4
TECHNICAL EVALUATION REPORT ON THE SPECIALISTS' MEETING OF THE --ETC(U)
OCT 78   K J STAPLES
UNCLASSIFIED   AGARD-AR-126   NL

1 OF 1
AD
A064122

END
DATE
FILMED
4-79
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LEVEL II

2 NW

AD A064122

DDC FILE COPY

AGARD-AR-126

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

AGARD ADVISORY REPORT No. 126

Technical Evaluation Report on the Specialists' Meeting of the Flight Mechanics Panel on Piloted Aircraft Environment Simulation Techniques

by

K.J. Staples

DDC
RECEIVED
FEB 2 1979
D

NORTH ATLANTIC TREATY ORGANIZATION

DISTRIBUTION AND AVAILABILITY
ON BACK COVER

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

79 01 31 076

LEVEL II

(14) AGARD-AR-126

(2)

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

(9) AGARD Advisory Report No.126

(6)

TECHNICAL EVALUATION REPORT
on the
Specialists' Meeting
of the
FLIGHT MECHANICS PANEL
on
PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES

A063850

by

(10) K.J. Staples
Flight Research Division
Royal Aircraft Establishment
Bedford MK41 0AL
Beds, UK

(11) Oct 78

(12) 29p.

White Section	☒
Buff Section	☐
UNANNOUNCED	☐
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	

Dist.	AVAIL. and/or SPECIAL	
A		

D D C
RECEIVED
FEB 2 1979
D

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

The Proceedings of the Specialists' Meeting of the Flight Mechanics Panel on Piloted Aircraft Environment Simulation Techniques, which was held in Brussels on 24–27 April 1978, are published as AGARD Conference Proceedings CP 249, October 1978.

LB

400 043   79 01 31 076

THE MISSION OF AGARD

The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Exchanging of scientific and technical information;
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The content of this publication has been reproduced
directly from material supplied by AGARD or the author.

Published October 1978

Copyright © AGARD 1978
All Rights Reserved

ISBN 92-835-1299-5

Printed by Technical Editing and Reproduction Ltd
Harford House, 7–9 Charlotte St, London, W1P 1HD

CONTENTS

PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES

K.J. Staples, RAE Bedford, UK

1 INTRODUCTION

Piloted simulation has achieved spectacular advances in technique during the last decade. It now penetrates all aspects of aerospace activity. Whereas previously a comparable analogue, the wind tunnel, could define the performance and aerodynamics of the aircraft, from which the flight dynamics could be identified, and by comparison with previous experience, the acceptability of the handling to the pilot could be deduced, now the introduction of sophisticated control techniques means that the matrix of possible aircraft behaviour is so great that only pilot participation can separate the acceptable from the unacceptable. So simulation provides a tool for the research worker to investigate new aircraft characteristics, and to optimise them in the operational task, and it allows the designer and development engineer to 'fly' a complex vehicle incorporating many configurations, throughout its operational envelope, and beyond, and with all the failure modes.

But simulation is now much more than that. It permits the study of various piloting tasks and operational tactics, the development of guidance systems, displays, weapons systems, cockpit layout, and in fact all aspects of the operation of aircraft which impacts upon the pilot both as a controller and as a manager. Perhaps the widest use of all is in the training of aircrew, leading in the civil field to 'zero flight time' conversion to new aircraft, and in the military field towards complete mission training on the ground (not yet successfully achieved).

The first specialist meeting of AGARD on simulation was entitled simply 'Simulation', and was held at NASA, Ames Research Center, in March 1970. Only one paper specifically addressed environmental simulation, though a number of others touched on the topic, particularly in the context of the choice of simulator or the assessment of its validity. A second, joint symposium, on Flight Simulation/Guidance System Simulation was held at The Hague in October 1975. Many of the papers were concerned with simulation trials involving specific aircraft, and others with specific tasks, military operations, or missions. There were however two sessions devoted to the simulation of the environment, specifically on motion and visual cues and on turbulence models.

The third specialist meeting, the subject of the present evaluation, was devoted exclusively to 'Piloted aircraft environment simulation techniques'. It was held from 24-27 April 1978 at the Royal Library (Albertina) in Brussels. The Programme Chairmen were Professor O.H. Gerlach of the Netherlands with, initially, Mr W.S. Aiken Jr of USA and, finally, Dr I.C. Statler of USA. The programme as conducted is appended to this report and the individual papers will appear in AGARD Conference Proceedings 249.

2 REVIEW OF THE TECHNICAL PROGRAMME

The numbered sessions of the meeting were preceded by a survey paper identifying many of the deficiencies in simulation for training.

After outlining the function of the Aircrew Training Devices organization of the USAF Tactical Air Warfare Center, the paper describes the simulators procured, or being ordered, by the Center including modifications to existing simulators. Of particular interest was the intention to adopt a competitive procurement; two contractors would each provide full field-of-view, visual systems on two interactive A-10 simulators, allowing a 'fly-off' between the competing systems. The winner would be chosen to produce both A-10 and F-16 simulators, which are ultimately intended to be Weapon System Trainers with fields of view duplicating that of the aircraft and including representative ground features and targets (static and moving) as well as airborne targets.

Before one can identify the deficiencies in simulators for training in general terms (ie other than specific defects in a particular simulator), it is necessary to be able:

to define what it is that has to be taught
to measure how well it has been taught

To accomplish the training efficiently it is necessary to establish the minimum cue requirements for the training device. To this should be added the need to adapt the training technique to make optimum use of the device provided. At present none of these needs can be met. It is efficiency and not effectiveness which is at stake. Even assuming it is possible to replicate the characteristics of the real weapon system the cost would be excessive, and it is a dubious aim since the aircraft itself might not anyway be a particularly efficient training device.

An example of an attack on minimum cueing is the experiment on the Simulator for Air-to-Air Combat (SAAC) in which training was conducted with and without operation of the six degree-of-freedom motion platform. There was no discernible difference in the performance in the air between students trained with and without motion. Consequent upon this, and other reviews, the A-10 and F-16 simulators are being procured without motion platforms, though provision is being made for retrofit. However, as we shall see later[18], the actual quality of the motion cue may be crucial in determining its contribution to the level of performance in the simulator, and we have no evidence on the quality of the SAAC system.

Complementary to this example were tests on a low fidelity simulation of A-10 obtained by modifying, in a relatively unsophisticated way, the Advanced Simulator for Pilot Training (ASPT), normally a T-37 simulator. Apart from evidence of transfer of training in the landing manoeuvre there was an exceptional performance by the simulator-trained students on their first, airborne gunnery, trials.

The overall conclusion is that the training simulator world is fragmented. The trainer overspecifies in terms of fidelity from lack of knowledge of what is enough, the researcher rarely has the resources in terms of funds and aircraft and aircrew to conduct effective trials, the designers and producers never see the use of their product. Consequently, the balance between cost and effectiveness is never really assessed.

2.1 Requirements on simulation of the environment

Of the four papers in this session, two concentrated exclusively on visual requirements[2,3] whereas the other two[4,5] considered also motion platform needs and, to a lesser degree, wind, turbulence, visibility and ground effects.

Of the many factors relating to visual information the two dominant ones are field of view and resolution. For a given bandwidth of the video signal these two factors are interchangeable. By increasing the number of video channels, the field of view can be increased without a corresponding reduction in resolution, but for any reasonable field of view from any one channel the technology is not yet available to match the resolving power of the eye. However, computer generated imagery (CGI) can now produce a factor of 2 or 3 improvement on earlier model-board/TV camera systems. This improved resolution emphasizes the lack of picture content in CGI systems, and especially the absence of textural information. The interaction of the computer output with the line scan of the raster display, needed for daylight scenes, causes various visual anomalies which are attenuated by edge smoothing (anti-aliasing). The result is a reduction in the nominal resolution of the system.

Luminance intensity usually receives rather less attention though it is normally well below real life. Contrast ratio is clearly overriding but lower contrasts are detectable at higher luminance. Collimation of the scene is considered important, not only to add realism and a feeling that the world is 'out there', but because refocussing from the instrument scan to the outside world, and back again, takes time, and this time is a function not only of the duration of close visual observation, but also of the level of illumination. Collimation always sets the image at a fixed range and an argument can be advanced that poor performance in landing, where judgement of true range is critical, may be due in part to this feature. More important, probably, in this manoeuvre is the effect of visual system distortions and dynamic lags. The assessment of location is critically dependent on the judgement of perspective and the accurate angular location of features. An incorrect angular displacement following a rotation, or the transfer of the visual target from one window to another, is confusing and difficult to diagnose. In the dynamic situation a distortion can be aggravated by a lag. What is an acceptable lag is the subject of some debate, and confusion in definition. It clearly depends on the task and the vehicle dynamics in that task; it will be a minimum in a tight-loop control task with a responsive aircraft. The need for less than 100 ms lag between pilot's control input and correct visual response is unlikely to be required; but this does not define an acceptable lag in the visual system since it includes a variable lag due to both the frame time of the computation of the aircraft mathematical model and the time taken to provide the visual system computer with the coordinates of the new scene location. It follows, for example, that if it is really necessary to have accuracies of 1 or 2 minutes of arc in pitch, roll and heading information, during landing, the presence of a lag of 100 ms implies maximum manoeuvre rates of well under 1 deg/s. In fact, while the relative locations of objects may need to be this accurately defined in forward vision, clearly there is some more relaxed criterion for absolute position in the dynamic case.

Many other factors are involved in the choice of a suitable visual system. The scientific aspects are very thoroughly covered in one of the papers[3]. Other criteria may aid in the practical selection, eg the time for which certain objects are required to be visible during specified manoeuvres, the gaming area required, the necessary depth of field, the versatility and ease of changing the data base, the simulation of visibility and the use of vision aids, and so on.

Motion platforms, whether by coincidence or otherwise, are mentioned in the context of helicopter simulation[4,5]. The emphasis is greater in the research and development context but the point is made that in the shipboard trainer, ship motion can be very confusing in the absence of a motion system, presumably due to the inability to distinguish between aircraft induced motion and ship induced motion of the visual scene. Turbulence and vibration input via the motion system is also important and in this respect it would be highly desirable to represent the turbulent wake from the ship; a model of the latter does not exist but is under study.

More important, however, is the proven effect of a motion platform on the gain and phase of pilots' control inputs. By the choice of suitable washout algorithms it is possible, by 'flying' extreme manoeuvres, to determine the required performance (excursion, velocity, acceleration) of the motion platform. In the case of the helicopter this results in a substantial, 6 axis system, where the ability to achieve large excursions in several axes simultaneously is important. As examples, rotational travels of ± 0.3 rad or more, and heave total travel of over 20 m result from such an exercise. A similar analysis for fixed wing aircraft might be expected to result in a similar requirement but with rather higher maximum accelerations. As for the visual display, dynamic response is also important, leading to a rather high critical frequency of about 20 rad/sec. At the other end of the spectrum an attempt is made to ensure a smooth system, free of bumps and jerks, by specifying threshold performance.

The emphasis in helicopter operations on nap-of-the-earth flying leads to particular consideration of ground effect. Adequate modelling of this feature has not been achieved. It has a large effect on aircraft trim and power and when it is changing dynamically, eg when flying over undulating terrain or crossing the deck edge of a ship, causes general unsteadiness. An added complication is the need to tie the ground effect model intimately to the visual scene.

2.2 Simulation of the atmospheric environment

Four papers were presented in this session. One[7] was concerned exclusively with modelling turbulence, or representation of movement of the atmosphere at what might be called the microscopic level, another[6] considered movement due to windshear, the macroscopic level, whereas a third[8] covered the complete spectrum of winds, turbulence, gusts and windshears - however these might be defined. One[6] of these papers also considered, briefly, the simulation of precipitation and also, more fully, of visibility, the sole concern of the fourth paper[9] in the session.

The relatively uniform distribution of variable disturbances in the gaussian representation of turbulence has long been recognised as a deficiency of such a model, particularly so in the context of piloted simulation. A non-gaussian approach has introduced new terms, patchiness and intermittency. Conceptually these terms are difficult to differentiate, but imprecisely, and probably inaccurately, patchiness is the property describing the random alternation of periods of low and high activity, whereas intermittency is the property of high and low peaks within a patch. Practically they are identified respectively by the non-gaussian probability density distribution of turbulence velocities, and the non-gaussian probability density distribution of turbulence velocity changes.

These non-gaussian characteristics can be contained within a model of turbulence which still conforms to the von Karman or Dryden power spectral distribution. A useful description of a non-gaussian distribution is the fourth order central moment, or Kurtosis, of the distribution. This takes the value 3 for gaussian distributions whereas values up to about 6 are found in measurements of turbulence. Further the Kurtosis for intermittency is generally higher than that for patchiness.

Non-gaussian characteristics can be produced by multiplying together two, filtered gaussian white noise sources and adding a third. By adjusting the gain of the contributions and the ratio of the cut-off frequencies of the filters it is possible to select the Kurtosis and the 'average patch length'. By this same process the intermittency can also be adjusted but is always lower than the Kurtosis of the turbulence velocities, contrary to experience. To overcome this it is necessary to manipulate the phase angles of harmonic signals generating the model, and there is evidence that this works though a complete mathematical description is not yet available.

Simulator experiments, which took particular account in the aircraft model of the spatial distributions of turbulence inputs, both symmetrically and asymmetrically, have been made to compare a gaussian and the non-gaussian model. The workload, as measured by the skin resistance, was significantly increased for the non-gaussian case, though pilot performance was little changed.

As a result of recent accidents, windshear has become of increasing importance. Models contain horizontal (fore-and-aft and crosswind) and vertical components as a function of ground-distance and altitude and there is adequate data for the definition of these models, some of which contain very severe conditions which are beyond the capabilities of many aircraft to counteract. Representations of thunderstorm, frontal, stable layer, and low level jet phenomena are typical. An airborne simulation of a STOL aircraft[8], which also recorded the turbulence and wind for use on a ground simulator, showed that the windshear phenomenon, and the presence of relatively isolated large gusts, was of prime importance in determining the pilot's assessment of the difficulty of the approach task. Even though the task was conducted with a strong backside-of-the-drag-curve condition, the increased workload due to windshear was not apparent in the performance as measured by airspeed holding, which nevertheless showed a deterioration with increased turbulence. This is presumed to be due to the lower frequency of control input required to counteract the shear compared with turbulence. The trends in the ground based simulator using the same, recorded, turbulence and windshear as airborne were very similar, though the influence of turbulence on pilot rating was rather more pronounced. Conventional, gaussian, turbulence was not adequate.

The importance in the training area of combining these atmospheric wind phenomena with an adequate visual representation of low visibility conditions cannot be overrated. The need is to produce a proper density gradient of fog, clearly defined in one of the papers[9], with broken cloud and scud, realistic individual clouds, proper sizing of lights and relative illumination. The large range of contrast and intensity of lights in the real world cannot be simulated, particularly in the all-important low visibility conditions.

Because of inadequate resolution distant lights tend to merge, giving an unrepresentatively bright image. Blooming of strobe lights and halos on approach and runway lights are generally non-existent. Finally, precipitation in flight can be very disconcerting and cause disorientation due to false, angular orientation cues. It might be possible to simulate this using the light-generation mechanism of visual displays based on CGI.

2.3 Out-of-the-cockpit visual scenes

This session consisted of six papers. They gave a comprehensive coverage of currently available systems, with the main emphasis on CGI and TV/model board systems but with some detailed excursions into other systems, particularly on a cheap, special-purpose, research simulator employing a variety of image generation techniques[11], and expensive, wide-angle displays still under development[15].

All visual display systems have limitations. An ability to duplicate the real world in all its facets is not yet in sight. Consequently it is important to identify, for any particular application, those features of the visual scene which are of overriding importance, and to select the appropriate technique of scene generation. While the characteristics of the various display systems are well known, though some deficiencies may go undetected in use, and the physiological definition of human visual perception is well defined, unfortunately the manner in which pilots make use of their visual capabilities is much less clear, and the effect on their behaviour of the removal of information which they normally utilise, thus forcing them to substitute alternatives from the abundant redundancy often available, is even more obscure. Some work on the effect of scene content, location and dynamic behaviour is being done; much remains to be done.

The possibility of achieving a satisfactory visual display depends greatly on the objectives of the simulator. The civil trainer and the dedicated part-task simulator have a clearly defined role for the visual display. The general purpose, research and development simulator is faced with a variety of tasks on a variety of aircraft specified from a projection into an uncertain future. In between falls the full-mission, military trainer.

Until recently the large majority of visual displays were based on the TV/model board technique. This is now rapidly falling from favour. The deficiencies in terms of field of view, resolution, gaming area, flexibility and installation costs are well known, but most importantly, it appears to have approached the end of its development potential. Its primary advantage over most other systems is its capacity for high picture content, and, provided a suitable scale can be tolerated, good textural detail. Two of the papers described systems utilising these features, one[14] for part task training with a model scale (finally) of 50:1, and the other[13] for nap-of-the-earth helicopter simulation at model scales of 250:1 and 750:1. The field of view can be improved by use of a wide angle probe and multiple cameras connected to multiple display devices. 'Area of interest', in which the display image is slaved to pilot head position is another technique, and might be combined with a helmet mounted display.

In contradistinction to the TV/model system, CGI suffers primarily from lack of picture content and textural detail, particularly in daylight scenes. Field of view and resolution remain problems, but are a consequence of the display device and thus strictly not a failing of the CGI generator. A number of display devices, which appear potentially well matched to CGI characteristics, are under development but have at present inadequate resolution. Three of the papers[12,13,14] gave detailed attention to CGI systems. One[14] required only comparatively low picture content (a cloud scene) but had the complication of inserting a TV/model image into the scene. Another[13] considered a system, still under development, for producing fully textured surfaces which are firmly locked to their appropriate faces, undergo the same perspective transformation as these faces and hence provide the correct texture gradient cues. Many different types of texture can be generated, and thus enhance the picture content of the displayed scene. The other paper[12] in this group was notable for the care taken in the identification of the requirements of the visual scene for the civil training role and the allocation of the limited elements in the picture in the most appropriate manner to meet the training needs. This was a combined engineer and pilot activity.

Visual systems based on film, shadowgraph, or epidiascope techniques seem firmly identified with special purpose functions. The shadowgraph has a wide use as a sky-earth projector where the scene content is negligible and the poor resolution of little concern. The apparent impossibility of combining a small light source with adequate brightness is a severe handicap in producing detailed scenes of any appreciable gaming area. However, a good illustration of the use of film and epidiascope systems was given in one paper[11]. This special purpose simulator is designed to study solely weapon aiming and delivery, both air-to-ground, and air-to-air, but only over a narrow field. The simulator also contains a pair of TV systems, one in conjunction with a small model board at a scale of 200:1, and the other in conjunction with a glass sphere, shaded to represent sky and ground, and servo driven. Within the confines of dedication to particular tasks it is a highly versatile and cheap system.

At the other end of the spectrum, the last paper[15] in the session described two visual systems, still being developed, and both aimed at helicopter nap-of-the-earth training, using novel scene pick-up and display devices. Both used a model board for the data base. The primary objectives were high resolution and a continuous, wide, field of view. One of these systems uses a scanned laser to illuminate the model board, the reflected light being sensed by photomultipliers whose output is used to modulate the output of the laser projector which provides the displayed scene on the inside of a spherical screen.

The field of view is 175° x 60° and is earth stabilised, pitch and roll of the aircraft being represented at the display rather than pick-up end of the chain. Resolution should be 5 minutes of arc. Eventually the scene will be in colour, will have control of atmospheric visibility, etc, and ground lights. Illumination of the landscape can be controlled by suitable placing of the photomultipliers. Eight levels of focus control are provided at the 'camera'.

The other system utilises an annular optical probe gathering a 360° x 60° image from an illuminated model board. Through a series of optical elements the annular image is rotated on to 12 charge coupled devices providing 12 parallel channels of video information which modulate 12 lasers. These are scanned via a multi-facet, rotating mirror and projected on to a spherical screen via an annular projection lens. In this system attitude variation will be at the optical probe. Resolution is a nominal 9 minutes of arc but is expected to be degraded at depressed angles below the horizon. A colour system should be possible.

Both systems are due for demonstration, in monochrome, later in the year.

The systems represent a potentially substantial improvement over the TV/model board system while retaining many of its disadvantages, eg limited gaming area, installation overheads. But the display techniques of both systems could clearly be used with CGI, rather than a model board, if desired. The laser 'camera' system at least removes the high power model lighting and promises improved depth of field, by focus control, when near to the model surface. The laser 'camera' has a reduced field of view in azimuth,but compensatory better resolution, than the annular system. Speckle is a potential problem with both systems.

2.4 Visual versus non-visual motion cues

This session comprised only two papers of a rather different nature, though both were concerned with the dynamic motion of the visual scene, as distinct from its static content, and the influence of a motion platform on pilot behaviour in this dynamic environment. The first paper[16] gave a concise and full description of the characteristics of movement cues induced visually and by a motion platform, whereas the second[17] described particular experiments comparing the two.

Many features are involved in the definition of visually induced motion whereas the description of platform induced motion via the vestibular organs is less complex, although other non-visual information, such as proprioceptive and tactile inputs, is much less well defined. Additionally, to resolve the debate as to whether or when a motion platform is required in simulation, it is necessary to identify the characteristics of the interaction between the sensors. A brief description of visually induced motion is bound to be deficient in many important respects. However, certain prominent characteristics are worthy of mention.

While the high acuity, central field or foveal region is well able to detect velocity it does appear necessary, for a strong sensation of movement, to have also peripheral visual information, where high scene content is irrelevant. Consequently a relatively large field of view is necessary, and the peripheral field dominates. There is an onset delay between the visual scene appearing to move and the perception of self movement in a stationary scene; this delay is a function of degree of exposure, mental expectation, and the acceleration of the visual scene. It may be several seconds.

The essential contribution of a motion platform is that it can lead to a rapid onset of visually induced motion, which is then maintained by the visual information after the vestibular cue has been removed (by washout). Once visually induced motion is established it appears to bias the vestibular threshold, so that more rapid washout of the motion platform is possible.

Vestibular cues dominate at high frequency and visual cues dominate at low frequency. However they exhibit a non-linear interaction so that when both are present it appears that the time constant of the motion sensor is lower than that of the vestibular, semicircular, canals and there is a higher than expected use of visual cues at high frequency. Sophisticated modelling techniques are being used to try to identify the precise contributions of visual, vestibular, proprioceptive and tactile sensors to the appreciation of movement.

Evidence of the relative importance of peripheral visual and motion platform cues was presented[17] from experiments of the control of a V/STOL aircraft with an unstable lateral oscillation. The addition of motion caused a marked reduction in the bank amplitude, particularly under instrument flight conditions. Peripheral vision, provided by a shadowgraph skyscape, had a similar, but less marked effect. The addition of the skyscape to the motion, though providing a powerful rolling cue, gave little additional help to the pilot. It was also noted that a sharp, as distinct from a hazy, horizon caused overcontrol, even with the motion platform operational.

This paper[17] also highlighted the importance of a motion platform in a task which was not strictly handling. The objective was the assessment of alternative head-up displays for use in the landing approach of a partially jetborne, V/STOL aircraft under instrument flight conditions. It is suggested that an incorrect result was obtained (as compared with flight trials) in a task with a very high visual workload, due to the absence of a surge cue. It is concluded that for research and development activities it is not sufficient for the pilot to achieve the same performance as in flight, it is also necessary that he adopt the same control strategy.

2.5 Motion simulation

There were five papers in this session, three[19,20,21a] concerned solely with motion platforms, but each from a very different point of view, and of the remaining two, one[18] was concerned mainly, and the other[21] exclusively, with 'g' seats.

The 'g' seat was originally conceived as a means of simulating sustained linear acceleration, particularly normal g, which is impossible with a conventional (non-centrifuge) motion platform. Perhaps partly as a consequence the early versions had very poor response, no better, and generally worse, than the motion platform, making them unsuitable for onset cueing. Since the payload of the seat is orders of magnitude less than that of the motion platform this is illogical. The later seats have adequate response to 10 Hz or higher. The main effort then has to be directed towards suitable drive laws to accommodate the various sensations available (somatic, vestibular, and even positional - eye location relative to cockpit). Seats generally allow movement of the seat pan, or complete seat, vertically and an associated means of varying the pressures on the buttocks, together with adjustment of the lap belt. One of the seats described[18] goes much further in providing additionally: roll, pitch and surge of the seat pan; pitch, yaw and surge of the backrest; roll and surge of seat/backrest bladders - a motion system in miniature, with 15 actuators. The need to design the seat to suit the varying physiometry of pilots is important. It is to be expected that the manner of usage of the 'g' seat, and the balance between onset and sustained cues will depend on any additional g cueing devices. The most common in this category is the g suit. However, particularly at high 'g', many other factors are important, for example head-helmet loading and limb loading, aural effects and visual effects. Dimming of the visual scene is often employed but cannot be modified by any physical, alleviating action the pilot may take. Methods of implementing these additional cues are under study. The technique of using 'g' seats is still in its infancy.

Turning now to motion platforms, the manner in which they are driven, and their response is of vital importance. For example, a study[18] of the effect of roll motion delay relative to the movement of a narrow field-of-view visual system in a simulation of aircraft dynamics appropriate to a high performance fighter, showed that 200 ms delay produce tracking performance similar to the no motion case. A longer delay produced degraded performance. Zero delay was best but 50-100 ms might be tolerable. Another study[19] was concerned solely with effect of break frequency of the linear, second-order, washout filter of the motion drive, on the ability to null disturbances in pitch and roll of the aircraft (DC9). The visual scene was a narrow angle, above cloud, display with a sharp division between white and blue. Break frequencies in both pitch and roll of 0.1, 0.25, 0.5, ∞ (fixed base) were tested. Analysis on the basis of pilot describing function, pilot model parameters, and error score, showed no effect of break frequency (0.1-0.5), but all were significantly different from fixed base. Pilot opinion indicated that 0.5 required somewhat, and fixed base very much, more effort than the lower frequencies.

Apart from techniques of providing motion cues the quality of the motion input is of vital importance. The Flight Mechanics Panel has set up Working Group 07 to define the important dynamic characteristics of motion systems and devise techniques for measuring them[20]. It will not specify acceptable characteristics. The study is still in progress but members of the group have measured on their systems the recommended factors, namely performance limits, linearity, describing functions, threshold, backlash, hysteresis and noise. Acceleration is considered to be the characteristic sensed by the pilot and the other major factor - jerk or smoothness - often mentioned is considered to be subsumed by noise. As a result of preliminary measurements certain modifications to the original techniques have been indicated, but a solution to the proper measurement of backlash has not been found.

An attempt to provide a motion system[21a] with good noise and threshold characteristics uses unusual hydraulic jacks with long stroke (2m), hollow rods and hydrostatic bearings. It is a six jack, synergistic system with comparatively good frequency response and good acceleration capability, rather greater than could often be utilised within the velocity limits, particularly in the rotations. However, it was intended to increase the velocities for the largest motion system. Initial tests have indicated favourable reception of the system.

2.6 Up and away mission phases

Each of the four papers in the session considered air combat simulators, though sometimes known by other names. The conceptual basis of these simulators is identical though the details of individual items of equipment vary. All contain one or more domes, on to which are projected 'targets', either computer controlled, or flown by another pilot, providing a narrow angle image which can be presented anywhere over a large field of view. A wider angle, relatively featureless, sky/earth scene using the shadowgraph principle, is universally provided. None have motion platforms though limited cockpit motion is sometimes installed to give buffet and vibration. The use of 'g' suits is universal. Representation of grey or black out is by dimming of the visual scene.

Rather elaborate operator consoles[22] are generally provided to allow the progress of the 'fight' to be followed, to record for subsequent playback, and to print out key events, eg firing opportunities or 'hits'. But the simulators are often used for other than air combat purposes, some completely unrelated[24] and others[25] indirectly aimed at producing a better combat aircraft. Even within the air combat application a number of uses are evident, ranging from parametric studies of the effect of differing aircraft characteristics through the evaluation of tactics for specific aircraft[24] and missiles[22], to the training of pilots in air combat[24].

The presentation of a ground target[23] of narrow angular extent anywhere within a large field, is also possible though the validity of such a presentation against a featureless background, when the background should be rich in detail, does not seem to have received much attention. The main consequence of the lack of ground detail is the inability to conduct realistic combat at low altitude due to the complete absence of height cues. Lights[23] in the cockpit, which flash, below a certain altitude, with increasing frequency as the ground is approached, have been tried but are not very effective and distract the pilots. Another defect in the visual presentation[23] is inability to detect the use of after-burner or speed brakes by the target, which gives the attacking pilot advance notice of his opponents' manoeuvres. The use of a stylised, CGI, target aircraft[22] was considered to be inferior to the TV model system.

A crucial question is whether the absence of a motion platform is important. Some claimed[24,25] that the lack was scarcely noticed whereas a particularly frank exposition[23] listed a number of areas of difficulty such as tracking and roll control and the use of speed brakes or throttle. Also the onset of buffet was judged as too severe, due to the complete absence of prior motion cues. However, other motion inputs which were lacking could not in any event be overcome by a conventional motion platform, eg apparent excess pressures of the 'g' suit due to lack of blood pooling in legs and abdomen, incorrect feel of stick forces due to lack of hand and arm 'g' forces.

The air combat simulator has clearly established a firm place for itself in the simulation world. More than one-on-one combats are now possible and two-on-eight[24] have even been accomplished, though most are radar targets of which only two can become visible.

3 ROUND TABLE DISCUSSION

The Panel, Chaired by Dr I.C. Statler, had as members Professor O.H. Gerlach, Dr L.R. Young, Mr D.R.Gum, Professor K.H. Doetsch, Dr C.L. Kraft and Mr A.G. Barnes. Apart from ten minute dissertations from the members of the panel, there were frequent contributions from the floor. An attempt will be made here to summarise the discussion, with all its contradictions, without identifying the contributors.

One of the problems in the past has been an over emphasis on attempts to duplicate reality. There is now a much better understanding of the limitations of simulation. However, it is important to identify how much success had been achieved in understanding the problems. Some of the questions which need answering are:-

> Which aspects of environmental simulation are particularly important to which missions?
>
> How does one discuss the trade-off between various techniques of environmental simulation?
>
> How and to what extent should the new techniques described during the Symposium be employed?

The advances in the discipline have been substantial during the last decade and will continue for some years. It might then be possible to meet any reasonable specification. The problem will be to draw up the specification. We are far from having the fundamental knowledge on which to base a reasonable decision on cost/effectiveness. Amongst other things answers are required to:

1 What exactly is a cue?

   Define a visual cue, a motion cue, an onset cue in such terms as allows a quantitative measure to be attached to them.

2 How does a pilot use such cues?

   Are they all used in the same way when they are in central vision; in peripheral vision; from vestibular sensors; from tactile sensors; from proprioceptive sensors?

   An alternative division may be into

   a Continuous usage

   b Alerting fashion, which may also include smell and sound, and has a different function from closed loop control cues.

The answers to the questions will require a closer collaboration between psychologists and engineers.

One of the basic questions, having considerable financial implications, is whether a motion platform is needed in the presence of a wide-angle visual scene. It is unlikely that motion can be discarded without some effect on behaviour. Clearly there are some cases where motion is essential and the question then is: how much? A strategy for evaluation has to be devised. The worst answer would come from engineers; the next worse would be to ask a pilot flying the simulator. Pilot ratings of a task are slightly better. Next came measurements of performance compared with flight. Measurements of control activity is nearest to providing satisfactory validation. There are relatively few cases where motion is not needed as a limited displacement, onset cue. But before the motion requirements can be defined it is necessary to obtain a very detailed description of how the system is to be used. Training requirements may be different from research requirements and a particular answer has to be produced for each.

The difficulty with training is the description of transfer of skill identified by specific small items. The training and engineering communities do not really understand each other. There is a tendency to talk about tasks when the real need is to describe the skills required. If the latter could be achieved it might be possible to transfer skills in one or two tasks to many others. For example, those trained in air-to-air combat can easily transfer to air-to-ground attacks; to go in the opposite direction is very difficult.

On a helicopter IFR task a visual display is irrelevant and the only question is whether or not motion is required. In order to answer this one need only look at the frequency domain in which the pilot is operating. With a very stable vehicle and a single loop task there is little need for motion. But as soon as the pilot closes an inner loop, particularly where the task is multiloop, motion becomes absolutely essential. If the pilot describing function indicates that either lead or lag has to be generated, then it is quite clear that motion is needed.

Clearly no definitive answers were obtained to the initial questions. Other questions are:

What problems limit the advance of simulation?
What additional requirements needed to be met?
Can CGI meet all the needs of the visual display?

Any impression that there is not much left to be done would be false. The data base is the fundamental limitation. The current state of the art is adequate for procedural and initial flight skills; the potential is much greater, including readiness training, mission exercises and assessment capability. Readiness covers all threats and skills of actual combat. Mission exercises and assessment go even further, covering tactical refinement and development of combat effectiveness. To allow this, visual display improvement is primarily required. Motion requirements are too emotional a topic and the biggest obstacle might be the lack of an open mind.

There are two main deficiencies in the visual scene. The first is a lack of information density of targets and their surrounds. Targets are obvious in stark backgrounds, precluding training in identification and acquisition. Recently reported developments may go a long way to overcoming this deficiency, once operation in real time has been realised. The second lack is adequate resolution to allow identification of objects at the limits of visual range. Liquid crystal, light valve projectors may overcome this display problem.

Another question is: what research programme is needed to define a required facility?

One way is to build a state-of-the-art simulator and steadily degrade it while conducting transfer of training experiments. This is the ASPT concept which provides little feedback to the developer who consequently contributes little in the way of needed improvements. The simulator quality then falls behind by the state-of-the-art. The other way is to try to define the cueing requirements for the simulator and then to design to these. More cues than the pilot can use may not then be provided. This requires an analytical approach but lacks the final proof of accurate definition. Both approaches are probably needed.

Artificial imagery (CGI) certainly appears to be the future basis for visual displays. However, texture is still missing. Apart from giving the scene an appearance of correspondence with reality, texture might contribute additional peripheral cues. The use of 'streamers' in the peripheral field might give useful speed information. Considering flight tasks in the future, it could be argued that those with a control content at high frequency would be handled automatically, and that there would then be less need for a motion cue. Hence even more stress would be placed on the visual scene. On the other hand, with a greater emphasis on automatic control, reversionary modes may only be experienced in the simulator and it is well established that a more or less rapid change in the dynamics of the vehicle placed a premium on motion cues for pilot adaptation. Nevertheless, there may be alternative techniques. CGI is still in its infancy and needs to be used in an imaginative way. Consideration could be given to accelerating the picture and then washing it out, or the texture could be moved relative to the outline to give a motion cue. However, these techniques could be dangerous until the manner of analysing and processing information is understood. Pilots are very perceptive and trained in observation. Quickening of a skyscape display has been tried but the conflict with the HUD Symbology, which was being studied, was quite unacceptable. These artificial techniques may be more easily adaptable to training simulators, where the only concern is the transfer of training. But for research and development they could be misleading; the pilot would be evaluating the combined transfer function of the display and the aircraft.

Further questions were:

What are the field of view requirements and how are they related to task, or mission, or skills to be learnt?

What is the value of colour, how much is needed and is the need different foveally and peripherally?

Foveal vision is primarily effective in pattern recognition; it is slower at detecting velocity. For a straight in approach, the detail is required in front of the aircraft; for a circling approach it is also required to the side. Since it is not certain that a good display over the complete visual field can be provided the solution is an area of interest display coupled to head position. It has been shown by experiment that bombing accuracy is affected by field of view.

Colour is needed in take off and landing. Differentiation between fields is aided. Also colour temperature affects the response time. But it is expensive and complex and good convergence is essential. Five colours, in the range 450-650μm are probably enough. Using multiple displays, to increase the field of view, presents great difficulty in matching if adjacent displays are too close together; a 20° gap is about the minimum. With regard to the use of lasers, about 25% of the population cannot focus on monochromatic light. Speckle may also be a difficulty, which can be overcome by oscillating the viewing screen.

Some work should be done to measure the difference between individuals. For example, pilots seem to have smaller eyes than average, with a greater depth of field.

Three window displays were generally inadequate in field of view. For navigation tests it is necessary to lower the side windows so that the top of the display corresponds with the horizon. On the other hand, for a circling approach, greater upward view is required to the side. In fact rotating the display device through 90° has some merit and improves the raster orientation. Clearly there is a need for a wide-angle, colour display. Colour is invaluable at the present level of CGI development, for example to tell the difference between clouds and trees! The lack of detail in CGI is particularly disturbing as the pilot workload increases, leaving him no time to search for information from the visual scene.

Nevertheless, there are occasions when only a limited field of view, say 30° x 40° is appropriate. For example night vision devices (light intensifiers) are in this range and so a visual display is required which can provide a suitable field of view to match the conditions.

In conclusion it can be stated that over the last 20 years or so, piloted flight simulation has gradually emerged as a recognized and widely accepted tool for aeronautical research and development while, in parallel, it has become a valuable training aid. Today's status has been achieved in the face of the fundamental criticism that, with a human pilot in the control loop, we are necessarily involved in deception and illusions; we try to make the pilot behave and react as though he were flying a real aircraft; and we expect him to suspend disbelief while doing so. The objective is simulation of the real world - not duplication.

The dictionary says that to simulate means to feign, to pretend, to sham, to trick, to deceive. Our deceptions require consideration of motion cues, visual cues, auditory cues, physiological, psychological, and proprioceptive cues, vestibular, graviceptor and tactile cues including horseshoe-shaped imprints on the nether regions. And then it is asked "What is a cue?" Perhaps Sir Walter Scott was thinking of simulation when he wrote "Oh what a tangled web we weave, when first we practice to deceive".

The fundamental problem in the use of the piloted flight simulator is that the pilot is bound to be influenced by the qualities of the simulator itself. It is relatively easy to list the potential deficiencies in a representation of the real aircraft environment but virtually impossible to say what the effects of these deficiencies will be. Thus, while simulation equipment manufacturers strive to reduce these deficiencies, we cannot say with much certainty which are the critical features most in need of improvement.

On the "hardware" side, we have noted the imbalance between the development of motion and of visual systems. As we have said previously, our objective is <u>simulation</u> of the real world - not duplication. We can readily accept that duplication <u>of motion</u> cues is neither technologically nor economically feasible although, as has been pointed out, there is much emotion in motion. It is less obvious but nevertheless equally true that duplication of visual cues is currently also not technologically feasible.

The trend with motion systems seems to be toward better quality rather than bigger scale in the sense that we do not expect to need much larger amplitudes of motion than are currently available with the exception of special simulation problems such as terrain flight of helicopters. We expect instead to see improved smoothness, better frequency response and general removal of hysteresis, jerks, rumble, noise, back-lash and so forth.

With regard to visual cues, much more research and development is required to remove the deficiencies of existing systems. The most obvious is the restricted field of view but there are practical prospects of major increases.

Each system claims some performance or cost advantage over others and it will be no easy task to choose the best system for one user's particular needs. It is to be hoped that more fundamental work will be done on the use of visual cues in the presence of motion so that the relative importance and benefit of this and the many other possible improvements to the simulated visual scene may be assessed. This also requires a closer working relation between user and researcher. We need criteria by which to evaluate cue adequacy.

There is no question that simulation has been, and will continue to be, a quite invaluable tool. The piloted flight simulator is to the flight dynamicist what the wind tunnel is to the aerodynamicist. The emphasis on the control of development costs and operational training costs suggests that flight simulators will play an increasingly important role in the future. In the training field, we can expect continued and expanding acceptance of simulation as an alternative to flying training. On the civil side, we may expect more wide-spread use of simulation for conversion training and for practice of inherently hazardous manoeuvres. This trend can be expected to continue as long as simple economic considerations show a positive benefit and as long as certification authorities are satisfied as to the relevance of the training. Militarily, there seems little doubt that the pressure to reduce the cost of training and readiness will encourage more wide-spread use of simulation for any flight or mission phases where training can be shown to transfer reliably. In the long term, we can look forward to improved understanding of the relation between the physical characteristics of the simulated cockpit environment and the validity of the particular tasks which the pilot has to assess. Not only should this point the way to improved design of simulation facilities but also to more confident use of the results of exercises on existing facilities. Inevitably, further improvements in the technology will be expensive and compromises on the basis of cost effectiveness will have to be reached. The Flight Mechanics Panel will continue to play a guiding and coordinating role in this work as a major element of its technical activities for AGARD.

4 OVERALL EVALUATION

With few exceptions the papers were of high quality, well delivered, with adequate visual aids. Participation from the audience was sufficient to keep the discussions moving and some particularly useful comments were introduced during the round table discussion.

An extensive coverage of environmental simulation techniques was achieved, which it is felt nevertheless left many of the users of simulators dissatisfied. The search was for a recipe for a simulator, or class of simulators. No such recipe was forthcoming and the overwhelming message is that there is no universal panacea. The need is for the user to specify very precisely, not in general terms, what it is he wishes to achieve, and how he proposes to achieve it, with the simulator. The supplier will then have to search the literature for the necessary attributes to meet the stated need, initiating research, if need be, into techniques where there is an apparent lack of data. The implication is that the minimum simulator to fulfil the role is required, not a device incorporating all the most advanced technology.

Consequently, descriptions of specific items of hardware, while of great interest as indicating the state-of-the-art, were of less immediate concern than descriptions of techniques of utilisation, unless they included some fundamental new concepts of usage. Of particular interest were the failings of simulators, especially when the effect on pilot behaviour of the deficiencies was clearly exposed. Much is known about this so that it is conceptually possible to design a simulator to meet a specific role, provided this is clearly defined, and to identify what proportion of the role it is capable of fulfilling.

Much less attention was directed to the simulation of the atmosphere (visibility, wind, turbulence) than to motion and visual requirements. While a model giving a perfect description of turbulence is still awaited, the various techniques appear to be converging to a common ground, and further refinement should soon lead to an adequate representation, which has for many purposes already been achieved. Similarly, descriptions of winds and shears are comparatively well documented. The parameters defining visibility also seem sufficiently established for most purposes, though the ability of the visual system to present a proper display, particularly for contrast ratio and size of lights, is less satisfactory.

The USAF is ordering training simulators with wide-angle visual systems but without a motion platform. The RAF is ordering training simulators with motion platforms but without a visual system. Both make provision for the retrofitting of the missing component. The reasoning accounts for the difference. The USAF consider that the value of a motion platform is not proven; the RAF consider that a cost/effective visual system is not available. The cost of a truly wide-angle visual system is very many times that of a motion system. Where detailed visual information over a wide angle is essential this disparity in cost, which may change in the future, is irrelevant, and the omission of a motion platform is a real saving. On the other hand, much training, civil and military, may only require a smaller visual display, and, especially in Europe, is under IFR conditions. It is indisputable that, under these conditions at least, the motion platform provides important cues, and the cost of the combination is likely to be less.

The requirements in the training and in the research and development role are different. In the latter case we are concerned with the development of the complete flying machine; in the former we are concerned with the development of the man. In the development of the machine it is important that the pilot adopt the same control strategy in the simulator as in the air. In his role as a controller in a continuous, closed-loop fashion the motion cue affects his behaviour and is generally of assistance. In his managerial role (systems etc) it may also affect him, but mostly as a hindrance. In the training role it is not obvious that an identical control strategy by the pilot is necessary for the transfer of skills.

It is therefore strongly recommended that efforts to identify the contributions of visual and motion cues to pilot behaviour be continued forcefully. For research and development simulators answers which are generally applicable on a range of tasks are most likely to be obtained by measurements of pilots' control activity and performance with a variety of stimuli and the generation of an appropriate model of the physiological and psychophysical processes involved. It is important that the interaction of all sources of stimulation to the pilot be included. In the training area the technique is less clear. Ideally a model is required of the learning process which can then be cascaded with the model of pilot behaviour to identify those parameters which are relevant to the transfer of skills. A tenable hypothesis would be that those actions which are preprogrammed, almost reflex actions, would require high correlation with reality, whereas these which are more cognitive would require strategic similarity, and not detailed identity. No such model is available and the continuation of adhoc trials on transfer of training appears to be the only current technique.

In any trials on visual and motion systems the importance cannot be overemphasised of defining the performance of the systems. In motion the magnitude of the input and, in both, the lags or time delays, both individually and relative to each other, may have a large effect on the value of the cue and the deductions drawn from the trial.

It is self-evident that a motion platform cannot exactly reproduce the inputs available from the real aircraft. The same is not so for the visual scene. On the other hand, with certain notable exceptions (eg normal 'g'), most cues which are usable, in practice, by the pilot can be reproduced by a motion platform. Again, the same is not so for the visual scene. Compared with motion sensations much less appears to be known about which elements of the abundant redundant information available in the real world are actually important to the pilot. Future CGI systems, which promise much greater picture content than those currently available, may prove useful in identifying the essential features of the scene. Because of their high cost, it is important that visual displays be the minimum required for the satisfactory pursuit of the objectives of the simulator, and greater effort on identification of the needs is required.

Future symposia on this and related topics of simulation are clearly indicated. Greater emphasis on specific capabilities and limitations pf simulation would clearly be desirable, but not easy to achieve. The Working Group (WG10) set up by the Flight Mechanics Panel are charged with this task; they are likely to produce only partial answers.

APPENDIX

PROGRAMME OF THE FMP SPECIALIST MEETING ON PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES

SURVEY PAPER

1 Current Deficiencies in Simulation for Training - Colonel C D Brown, USAF, TAWC

SESSION I - REQUIREMENTS ON SIMULATION OF THE ENVIRONMENT

Session Chairman: J Cayot, USA

2 Simulating the Visual Approach and Landing - A G Barnes, BAC, UK

3 Visual Criteria for Out of the Cockpit Visual Scenes - C L Kraft, Boeing and L W Schaffer, GEC, USA

4 Mission Environment Simulation for Army Rotorcraft Development Requirements and Capabilities - D L Key, Col B L Odneal and J B Sinacori, NASA/Ames, USA

5 Environmental Requirements for Simulated Helicopter/VTOL Operations from Small Ships and Carriers - Lt C Woomer, US Navy and R L Williams, McDonnell-Douglas Electronics Co., USA

SESSION II - SIMULATION OF THE ATMOSPHERIC ENVIRONMENT

Session Chairman: D Lean, UK

6 Proposed Advancement in Simulation of Atmospheric Phenomenon for Improved Training - W J Allsopp, Boeing, USA

7 Non Gaussian Structure of the Simulated Turbulence Environment in the Piloted Flight Simulation - G A J van de Moesdijk, Delft University, Netherlands

8 Handling Qualities of a Simulated STOL Aircraft in Natural and Computer-Generated Turbulence and Shear - S R M Sinclair, Flight Research Lab, NAE and LTC T C West, FAA, Canada

9 Visibility Modelling for a Landing Simulator with Special Reference to Low Visibility - D Johnson, RAE, UK

SESSION III - OUT OF THE COCKPIT VISUAL SCENES

Session Chairman: R Siewert, USA

10 Visual Simulation Requirements and Hardware - J C Dusterberry, NASA/Ames, USA

11 Low-Budget Simulation in Weapon-Aiming Research - P Manville and E D Whybray, RAE UK

12 The Lufthansa Day/Night Computer Generated Visual System - M Wekwerth, Lufthansa, Frankfurt, FRG

13 Recent Advances in Television Visual Simulation - B L Welch, CAE Electronics, Canada

14 A High Resolution Visual System for the Simulation of In-Flight Refuelling - M J P Bolton, Redifon, UK

15 Wide Angle Visual System Developments - C R Driskell, US Army, USA

SESSION IV - VISUAL VERSUS NON-VISUAL MOTION CUES

Session Chairman: O H Gerlach, Netherlands

16 Visually Induced Motion in Flight Simulation - L R Young, MIT, USA

17 Motion Versus Visual Cues in Piloted Flight Simulation - J R Hall, RAE, UK

SESSION V - MOTION SIMULATION

Session Chairman: K H Doetsch, FRG

18 Motion and Force Cuing Requirements and Techniques for Advanced Tactical Aircraft Simulation - W B Albery and D R Gum, Wright-Patterson AFB, USA, G J Kron, Singer Co., Link Div, USA

19 Influence of Motion Wash-Out Filters on Pilot Tracking Performance - M F C van Gool, NLR, Netherlands

20 Dynamic Characteristics of Flight Simulator Motion Systems - Col P Kemmerling, USAF, USA

21 The Development and Evaluation of a "G Seat" for a High Performance Military Aircraft Training Simulator - N O Matthews and C A Martin, CIT Cranfield, UK

21A Plateformes à six degrés de liberté de grandes dimensions pour simulateur de vol - M Baret, LMT, France

SESSION VI - UP AND AWAY MISSION PHASES

Session Chairman: J Renaudie, France

22 Simulateur de Combat Aérien du CELAR - (Centre d'Electronique de l'Armement à Bruz - Y Fouche and Y Hignard, France

23 Differences between Simulation and Real World at the IABG Air to Air Combat Simulator with a Wide Angle Visual System - E Vogl, IABG, FRG

24 Manned Air Combat Simulation - A Tool for Design, Development and Evaluation for Modern Fighter Weapon Systems and Training of Aircrews - R H Mathews and J D Englehart, McDonnell Aircraft Company, USA

25 Use of Piloted Simulation for Studies of Fighter Departure/Spin Susceptibility - W P Gilbert and L T Nguyen, NASA-Langley, USA

ROUND TABLE DISCUSSION

Chairman: I C Statler

Members:
(Mr Arthur Barnes, UK
(Prof Karl Doetsch, FRG
(Prof Otto Gerlach, Netherlands
(Mr Donald Gum, USA
(Dr Conrad Kraft, USA
(Prof Laurence Young, USA

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's Reference	3. Further Reference	4. Security Classification of Document
	AGARD-AR-126	ISBN 92-835-1299-5	UNCLASSIFIED

5. Originator
Advisory Group for Aerospace Research and Development
North Atlantic Treaty Organization
7 rue Ancelle, 92200 Neuilly sur Seine, France

6. Title
TECHNICAL EVALUATION REPORT on the Specialists' Meeting of the FLIGHT MECHANICS PANEL on PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES

7. Presented at

8. Author(s)/Editor(s)	9. Date
K.J.Staples	October 1978

10. Author's/Editor's Address	11. Pages
Flight Research Division Royal Aircraft Establishment Bedford MK41 0AL, Beds, UK	18

12. Distribution Statement
This document is distributed in accordance with AGARD policies and regulations, which are outlined on the Outside Back Covers of all AGARD publications.

13. Keywords/Descriptors

Flight simulation
Environment simulation
Aircraft
Human factors engineering
Pilots (personnel)
Atmospheric models
Aerial warfare
Aircraft seats

14. Abstract

This report evaluates the AGARD FMP Specialists' Meeting on Piloted Aircraft Environment Simulation Techniques held in Brussels on 24–27 April 1978. Following an introduction outlining the role of piloted simulation, the report considers the papers presented during the meeting. This is followed by a report of the round-table discussion, including contributions from the floor. Finally, an overall evaluation of the meeting is made.

The general quality of the papers was high and a broad coverage of the topic of the meeting was achieved. Detailed descriptions of techniques, as well as of actual hardware for satisfying various needs, were given. A few papers gave a critical appraisal of the deficiencies of simulators for particular purposes. Nevertheless, criteria for judging or specifying simulators were still lacking and greater emphasis on the role of specific features of simulators in satisfying users' requirements is clearly needed. The scientific and mathematical description of atmospheric characteristics is now well advanced; the techniques of presentation to the pilot still need further refinement. A particular difficulty is the inability of current visual displays to adequately represent atmospheric phenomena via the visual channel. The role of visual displays and motion platforms in providing cues to the pilot was a subject of considerable debate and was certainly not resolved at the meeting. It is an area requiring urgent study. Also the differing requirements of simulators in the training and research and development roles need to be delineated and defined; not least of the difficulties may be the identification of the training needs.

AGARD Advisory Report No.126
Advisory Group for Aerospace Research and Development, NATO
TECHNICAL EVALUATION REPORT on the Specialists' Meeting of the FLIGHT MECHANICS PANEL on PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES
by K.J.Staples
Published October 1978
18 pages

This report evaluates the AGARD FMP Specialists' Meeting on Piloted Aircraft Environment Simulation Techniques held in Brussels on 24–27 April 1978. Following an introduction outlining the role of piloted simulation, the report considers the papers presented

P.T.O.

AGARD-AR-126

Flight simulation
Environment simulation
Aircraft
Human factors engineering
Pilots (personnel)
Atmospheric models
Aerial warfare
Aircraft seats

AGARD Advisory Report No.126
Advisory Group for Aerospace Research and Development, NATO
TECHNICAL EVALUATION REPORT on the Specialists' Meeting of the FLIGHT MECHANICS PANEL on PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES
by K.J.Staples
Published October 1978
18 pages

This report evaluates the AGARD FMP Specialists' Meeting on Piloted Aircraft Environment Simulation Techniques held in Brussels on 24–27 April 1978. Following an introduction outlining the role of piloted simulation, the report considers the papers presented

P.T.O.

AGARD-AR-126

Flight simulation
Environment simulation
Aircraft
Human factors engineering
Pilots (personnel)
Atmospheric models
Aerial warfare
Aircraft seats

AGARD Advisory Report No.126
Advisory Group for Aerospace Research and Development, NATO
TECHNICAL EVALUATION REPORT on the Specialists' Meeting of the FLIGHT MECHANICS PANEL on PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES
by K.J.Staples
Published October 1978
18 pages

This report evaluates the AGARD FMP Specialists' Meeting on Piloted Aircraft Environment Simulation Techniques held in Brussels on 24–27 April 1978. Following an introduction outlining the role of piloted simulation, the report considers the papers presented

P.T.O.

AGARD-AR-126

Flight simulation
Environment simulation
Aircraft
Human factors engineering
Pilots (personnel)
Atmospheric models
Aerial warfare
Aircraft seats

AGARD Advisory Report No.126
Advisory Group for Aerospace Research and Development, NATO
TECHNICAL EVALUATION REPORT on the Specialists' Meeting of the FLIGHT MECHANICS PANEL on PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES
by K.J.Staples
Published October 1978
18 pages

This report evaluates the AGARD FMP Specialists' Meeting on Piloted Aircraft Environment Simulation Techniques held in Brussels on 24–27 April 1978. Following an introduction outlining the role of piloted simulation, the report considers the papers presented

P.T.O.

AGARD-AR-126

Flight simulation
Environment simulation
Aircraft
Human factors engineering
Pilots (personnel)
Atmospheric models
Aerial warfare
Aircraft seats

during the meeting. This is followed by a report of the round-table discussion, including contributions from the floor. Finally, an overall evaluation of the meeting is made.

The general quality of the papers was high and broad coverage of the topic of the meeting was achieved. Detailed descriptions of techniques, as well as of actual hardware for satsifying various needs, were given. A few papers gave a critical appraisal of the deficiencies of simulators for particular purposes. Nevertheless, criteria for judging or specifying simulators were still lacking and great emphasis on the role of specific features of simulators in satisfying users' requirements is clearly needed. The scientific and mathematical description of atmospheric characteristics is now well advanced; the techniques of presentation to the pilot still need further refinement. A particular difficulty is the inability of current visual displays to adequately represent atmospheric phenomena via the visual channel. The role of the visual displays and motion platforms in providing cues to the pilot was a subject of considerable debate and was certainly not resolved at the meeting. It is an area requiring urgent study. Also the differing requirements of simulators in the training and research and development roles need to be delineated and defined; not least of the difficulties may be the identification of the training needs.

ISBN 92-835-1299-5

---

during the meeting. This is followed by a report of the round-table discussion, including contributions from the floor. Finally, an overall evaluation of the meeting is made.

The general quality of the papers was high and broad coverage of the topic of the meeting was achieved. Detailed descriptions of techniques, as well as of actual hardware for satsifying various needs, were given. A few papers gave a critical appraisal of the deficiencies of simulators for particular purposes. Nevertheless, criteria for judging or specifying simulators were still lacking and great emphasis on the role of specific features of simulators in satisfying users' requirements is clearly needed. The scientific and mathematical description of atmospheric characteristics is now well advanced; the techniques of presentation to the pilot still need further refinement. A particular difficulty is the inability of current visual displays to adequately represent atmospheric phenomena via the visual channel. The role of the visual displays and motion platforms in providing cues to the pilot was a subject of considerable debate and was certainly not resolved at the meeting. It is an area requiring urgent study. Also the differing requirements of simulators in the training and research and development roles need to be delineated and defined; not least of the difficulties may be the identification of the training needs.

ISBN 92-835-1299-5

---

during the meeting. This is followed by a report of the round-table discussion, including contributions from the floor. Finally, an overall evaluation of the meeting is made.

The general quality of the papers was high and broad coverage of the topic of the meeting was achieved. Detailed descriptions of techniques, as well as of actual hardware for satsifying various needs, were given. A few papers gave a critical appraisal of the deficiencies of simulators for particular purposes. Nevertheless, criteria for judging or specifying simulators were still lacking and great emphasis on the role of specific features of simulators in satisfying users' requirements is clearly needed. The scientific and mathematical description of atmospheric characteristics is now well advanced; the techniques of presentation to the pilot still need further refinement. A particular difficulty is the inability of current visual displays to adequately represent atmospheric phenomena via the visual channel. The role of the visual displays and motion platforms in providing cues to the pilot was a subject of considerable debate and was certainly not resolved at the meeting. It is an area requiring urgent study. Also the differing requirements of simulators in the training and research and development roles need to be delineated and defined; not least of the difficulties may be the identification of the training needs.

ISBN 92-835-1299-5

---

during the meeting. This is followed by a report of the round-table discussion, including contributions from the floor. Finally, an overall evaluation of the meeting is made.

The general quality of the papers was high and broad coverage of the topic of the meeting was achieved. Detailed descriptions of techniques, as well as of actual hardware for satsifying various needs, were given. A few papers gave a critical appraisal of the deficiencies of simulators for particular purposes. Nevertheless, criteria for judging or specifying simulators were still lacking and great emphasis on the role of specific features of simulators in satisfying users' requirements is clearly needed. The scientific and mathematical description of atmospheric characteristics is now well advanced; the techniques of presentation to the pilot still need further refinement. A particular difficulty is the inability of current visual displays to adequately represent atmospheric phenomena via the visual channel. The role of the visual displays and motion platforms in providing cues to the pilot was a subject of considerable debate and was certainly not resolved at the meeting. It is an area requiring urgent study. Also the differing requirements of simulators in the training and research and development roles need to be delineated and defined; not least of the difficulties may be the identification of the training needs.

ISBN 92-835-1299-5

AGARD

NATO OTAN

7 RUE ANCELLE · 92200 NEUILLY-SUR-SEINE

FRANCE

Telephone 745.08.10 · Telex 610176

DISTRIBUTION OF UNCLASSIFIED AGARD PUBLICATIONS

AGARD does NOT hold stocks of AGARD publications at the above address for general distribution. Initial distribution of AGARD publications is made to AGARD Member Nations through the following National Distribution Centres. Further copies are sometimes available from these Centres, but if not may be purchased in Microfiche or Photocopy form from the Purchase Agencies listed below.

NATIONAL DISTRIBUTION CENTRES

BELGIUM
Coordonnateur AGARD – VSL
Etat-Major de la Force Aérienne
Quartier Reine Elisabeth
Rue d'Evere, 1140 Bruxelles

CANADA
Defence Scientific Information Service
Department of National Defence
Ottawa, Ontario K1A 0Z2

DENMARK
Danish Defence Research Board
Østerbrogades Kaserne
Copenhagen Ø

FRANCE
O.N.E.R.A. (Direction)
29 Avenue de la Division Leclerc
92 Châtillon sous Bagneux

GERMANY
Zentralstelle für Luft- und Raumfahrtdokumentation und -information
c/o Fachinformationszentrum Energie,
Physik, Mathematik GmbH
Kernforschungszentrum
7514 Eggenstein-Leopoldshafen 2

GREECE
Hellenic Air Force General Staff
Research and Development Directorate
Holargos, Athens, Greece

ICELAND
Director of Aviation
c/o Flugrad
Reykjavik

ITALY
Aeronautica Militare
Ufficio del Delegato Nazionale all'AGARD
3, Piazzale Adenauer
Roma/EUR

LUXEMBOURG
See Belgium

NETHERLANDS
Netherlands Delegation to AGARD
National Aerospace Laboratory, NLR
P.O. Box 126
Delft

NORWAY
Norwegian Defence Research Establishment
Main Library
P.O. Box 25
N-2007 Kjeller

PORTUGAL
Direcção do Serviço de Material
da Forca Aerea
Rua da Escola Politecnica 42
Lisboa
Attn: AGARD National Delegate

TURKEY
Department of Research and Development (ARGE)
Ministry of National Defence, Ankara

UNITED KINGDOM
Defence Research Information Centre
Station Square House
St. Mary Cray
Orpington, Kent BR5 3RE

UNITED STATES
National Aeronautics and Space Administration (NASA)
Langley Field, Virginia 23365
Attn: Report Distribution and Storage Unit

THE UNITED STATES NATIONAL DISTRIBUTION CENTRE (NASA) DOES NOT HOLD STOCKS OF AGARD PUBLICATIONS, AND APPLICATIONS FOR COPIES SHOULD BE MADE DIRECT TO THE NATIONAL TECHNICAL INFORMATION SERVICE (NTIS) AT THE ADDRESS BELOW.

PURCHASE AGENCIES

Microfiche or Photocopy
National Technical
Information Service (NTIS)
5285 Port Royal Road
Springfield
Virginia 22161, USA

Microfiche
Space Documentation Service
European Space Agency
10, rue Mario Nikis
75015 Paris, France

Microfiche
Technology Reports
Centre (DTI)
Station Square House
St. Mary Cray
Orpington, Kent BR5 3RF
England

Requests for microfiche or photocopies of AGARD documents should include the AGARD serial number, title, author or editor, and publication date. Requests to NTIS should include the NASA accession report number. Full bibliographical references and abstracts of AGARD publications are given in the following journals:

Scientific and Technical Aerospace Reports (STAR)
published by NASA Scientific and Technical
Information Facility
Post Office Box 8757
Baltimore/Washington International Airport
Maryland 21240, USA

Government Reports Announcements (GRA)
published by the National Technical
Information Services, Springfield
Virginia 22161, USA

Printed by Technical Editing and Reproduction Ltd
Harford House, 7–9 Charlotte St, London W1P 1HD

ISBN 92-835-1299-5