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WIDE-ANGLE, LOW-ALTITUDE FLIGHT SIMULATOR VISION SYSTEM FOR COCKPIT RESEARCH AND AIRCREW TRAINING

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SUMMARY

Westland has developed a wide field-of-view day/night simulation vision system in support of its cockpit design and research studies. The prototype system will permit simulation of night vision goggle flight over a height range of 0ft to 300ft with a lateral field-of-view of 270°. A second phase of development will upgrade the system to daylight flying.

This paper reviews the background to helicopter flight vision simulation, describes the Westland vision system (VISTASIM) and outlines how it is to be used within the Company as a research tool, and elsewhere for aircrew training.

1. INTRODUCTION

A recent FAA conference on helicopter simulation (Ref 1) concluded with a panel discussion in which the view was expressed by several commercial helicopter operators that multi-million dollar flight simulators were too expensive for them to consider purchasing. Their training requirements are just as demanding as those of the military, albeit from different points of view, and the conference discussion concluded that a more cost effective approach may be to consider part task training.

A similar situation exists in helicopter R and D. New technologies - such as speech recognition, artificial intelligence, and helmet mounted displays - are radically changing cockpit designs. Most of these innovations are aimed at permitting the crew to fly difficult missions successfully at very low altitude, by night as well as by day, and reduce the need to look down within the cockpit. By implication, a research simulator must therefore have a vision system capable of providing a wrap-around terrain image down to Nap-of-the-Earth (NOE) altitudes. Although such devices are available, they are very expensive and represent a significant capital investment. Hence there is a need for a lower cost approach.

Westland recognised both the training and R and D requirements for a wide-angle, low-altitude simulator vision system some time ago, and launched a development project to provide terrain images for various cockpit R and D programmes. The resulting device, called VISTASIM, is described in the remainder of this paper.

2. BACKGROUND

Most flight-simulator vision systems use closed circuit T.V. techniques to reproduce a terrain image outside the cockpit windows; they either employ a computer to create the image from a data base or they scan a terrain model with a T.V. camera. In order to reproduce the wide field-of-view needed by a helicopter pilot it is necessary to use several T.V. channels in parallel. However, this results in the vision system being both very complex and expensive. Furthermore, the detailed and textured terrain required for low level flight is very difficult to reproduce from a computer data base. It appears difficult to conceive of any means whereby a closed circuit T.V. system of the required performance can be developed at low cost. Consequently, an alternative approach was chosen; that of applying new technology to an old idea. In principal, the Point Source projection technique appears ideally suited to simulating low-altitude, low-speed flight. In practice, despite many attempts, no-one has suceeded in producing a practical machine. The most difficult technical problem has been to produce a high power lightsource with the required optical and mechanical properties; this is now possible using lasers. Other difficulties, such as obtaining a suitable servo-system geometry, have also been overcome. The nett result is wide-angle vision of remarkable realism at relatively low cost. (Fig. 1)

Figure 1 VIEW THROUGH COCKPIT

3. SYSTEM DESCRIPTION

3.1 General Arrangement

A point source projector uses the same optical principal as a pinhole camera, i.e. a very small aperture is used to constrain the optical geometry to enable sharp images to be produced without using lenses, with the advantage that the projection angles are not limited by lens size or geometry.

The terrain image is stored in the form of a transparent model and this is projected onto a screen surrounding the simulator cockpit by the point light source. To generate the illusion of movement the transparency is moved relative to the light source by a servo mechanism. The point source and the transparency are located directly above the observer. By placing the observer's eye as close as possible to the point source the observer's viewing angle is essentially the same as the point source projection angle and the subtended angles are essentially equal and true to size.

The design targets for a typical system are:

(a) Bright image
(b) Wide field-of-view
(c) Large gaming area
(d) Large pitch and roll angles
(e) Compact, simple, and low cost servo mechanism
(f) Low altitude flight to 0 feet.

To a large extent (c), (d) and (e) of the above are mutally exclusive, i.e. a large gaming area normally implies a large transparency, which in turn increases the size of the servo mechanism and limits the pitch and roll angles.

Low altitude flight (f) implies that the light source operates very close to the transparency and must therefore be at, or near, room temperature to prevent thermal damage occuring. Unfortunately, with conventional light sources and optics, this results in lower light output and a dim image, conflicting with (a). However, it is possible to permutate these various parameters to achieve a compromise solution which depends upon the application, and a laser powered light source can generate adequately bright images.

The configuration used in Vistasim has a flexible transparency looped around rollers, which allows continuous travel in the direction of the loop and significant lateral travel across the width of the transparency. With normal flight planning, flights of several miles can be undertaken before the scene repeats. The laser light source permits low altitude flight to 0 feet, and, importantly, 3D features cannot be damaged by the projecting probe. A parallel action linkage and gimbals are used to pitch and roll the transparency.

VISTASIM, shown in Fig. 2, therefore consists of the following 6 major components:

(i) The Servo Mechanism. This mechanism produces 6 degrees of freedom of movement of the transparency with respect to the projection screen

(ii) The Light Source. There are two forms of source, the first, a low power monochromatic laser, is a low output source for use with night vision goggles; the second uses high power lasers and is a high output source for use with the naked eye.

(iii) The Transparency. This is a full colour transparent terrain model derived from artwork or aerial photographs, model 3D features such as trees and houses are added to the transparency to give high realism.

(iv) The Projection Screen. VISTASIM has a spherical screen covering the pilot's normal field of view from the cockpit.

(v) The Servo Mechanism Support Structure. The support structure holds the servo mechanism in place above the roof of the simulator cockpit. It includes maintenance gantries and access platforms for changing over transparency cassettes.

(vi) Computer Flight Model. The necessary interface between pilot's controls and servo mechanism will be achieved by means of a computerised mathematical flight model of the aircraft.

3.2 SERVO MECHANISM

Translational motion (forward/backward, left/right, up/down) is simulated by moving the transparency relative to the light source in the x, y and z axes at a speed proportional to the scale of the transparency. Rotational motion (pitch, roll and yaw) is simulated by rotating both the transparency and the light source. (see Fig. 3)

In order to maximise the available gaming area a flexible transparency is used. Only part of the transparency is projected at any one time and the remainder is stored in a series of loops on rollers. The transparency is folded into a five sided cassette box, the part to be projected is stretched across the open bottom of the cassette. The cassettes are quickly removable from the rest of the servo mechanism so that terrains can be changed.

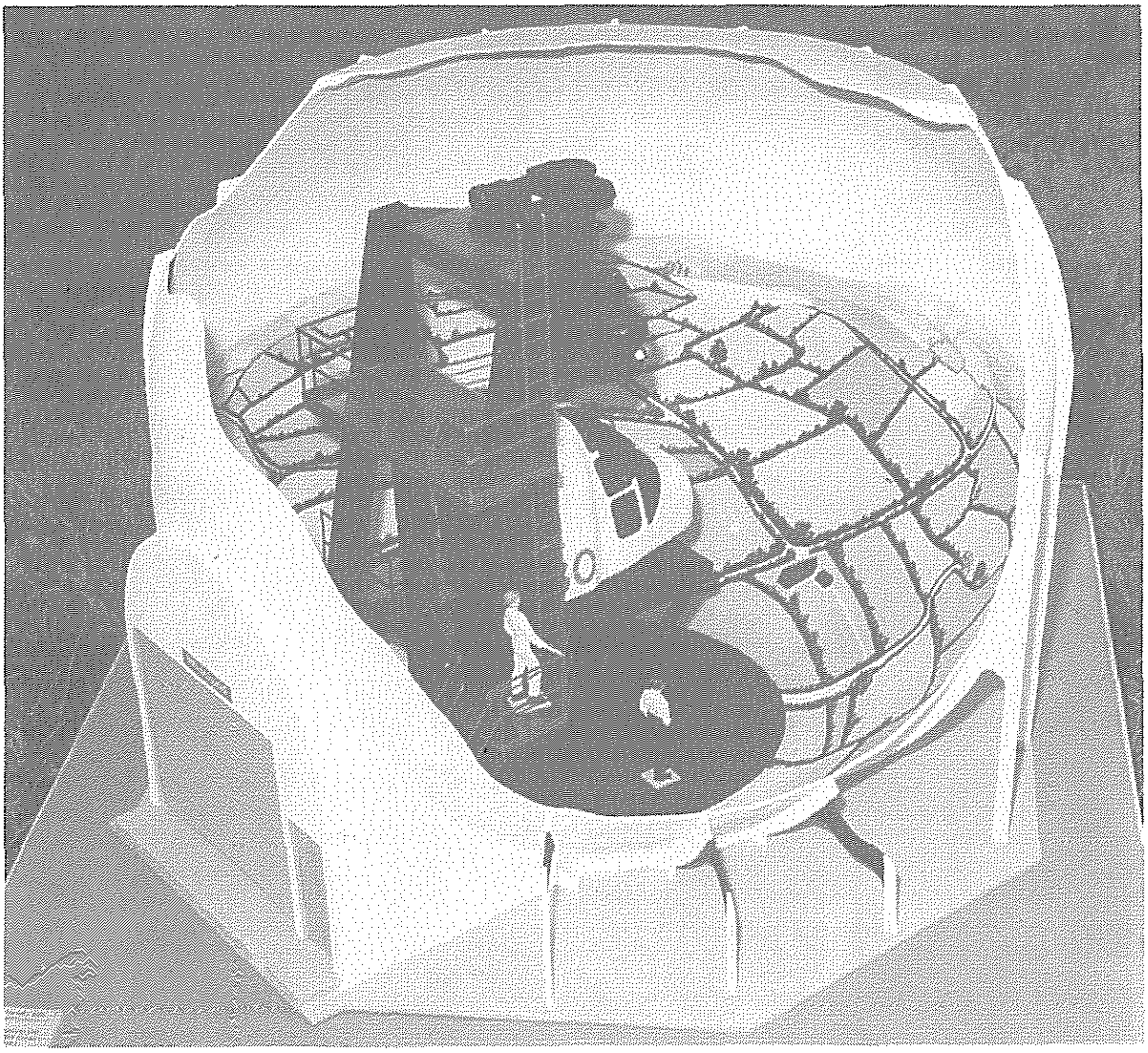

Figure 2 MODEL OF VISTASIM

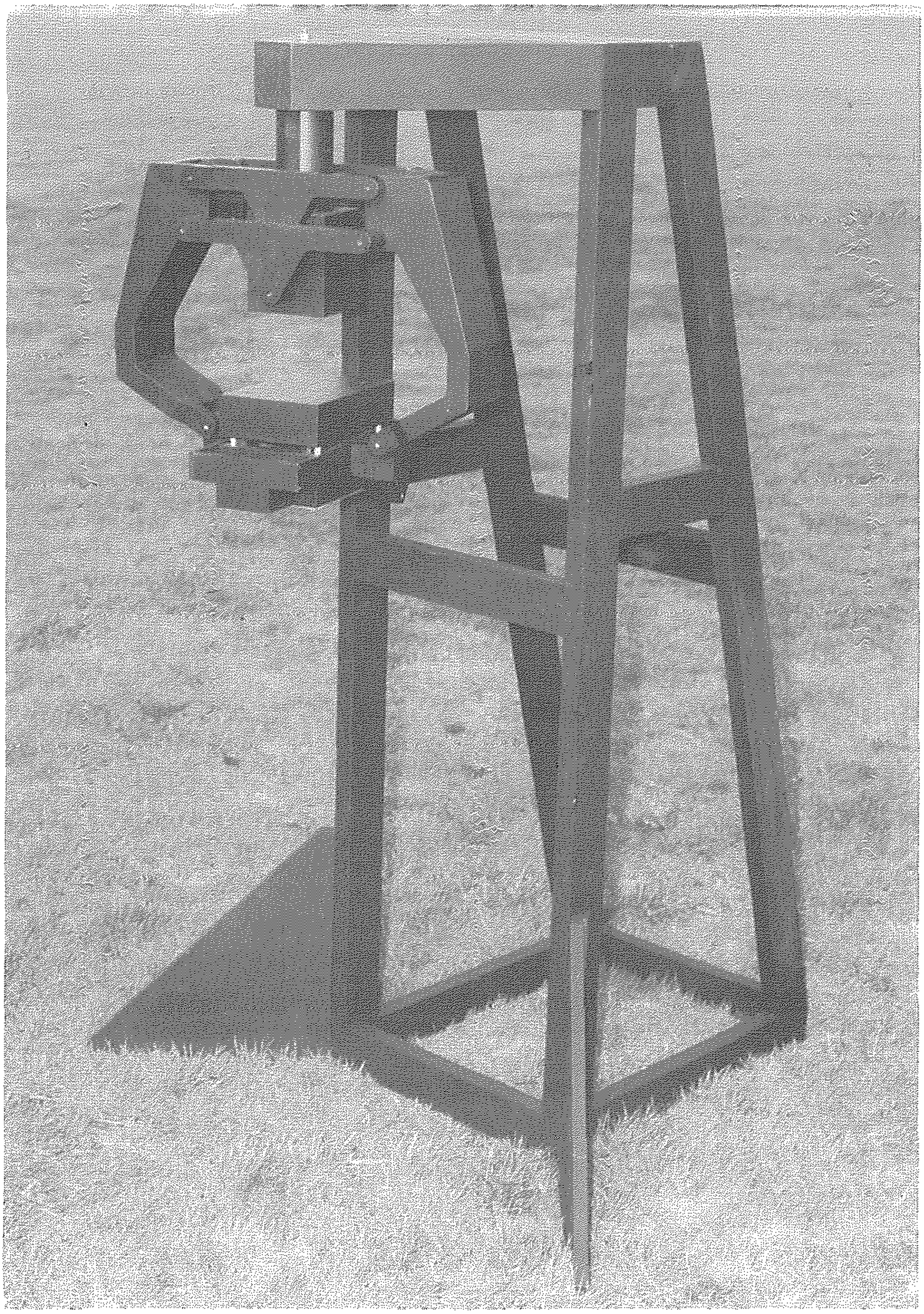

Figure 3 SERVO MECHANISM AND SUPPORT FRAME

Translation across the width of the transparency is achieved by moving the cassette laterally relative to the light source, and vertical motion of the vehicle is simulated by raising and lowering the cassette.

Pitch and roll is obtained using a parallel motion linkage and gimbals, thereby ensuring that, as the cassette rotates, the carrying linkages do not block the coverage of the light source. The yaw axis is the outermost of the six axes and connects at its upper end to the servo mechanism support structure.

3.3 LIGHT SOURCE

3.3.1 Background

The function of the light source is to project the transparency over a wide angle and provide a sharp, clear image at the required brightness level. In particular it must be capable of being brought very close to the transparency to simulate low altitude flight. The part of the source closest to the transparency must be small (so that it can approach trees and buildings at least as closely as the simulated vehicle could) and must be at room temperature.

3.3.2 Optical Principle

Each point of a transparency illuminated by a theoretical infinitely small light source will be projected onto a screen by only one ray, thus producing a sharp image

Conversely, a finite source of light e.g. a filament lamp, which may be considered as consisting of a very large number of infinitely small light sources, produces a multiplicity of overlapping images, and hence produces a blurred projected image

By reducing the size of the source the number of multiple images can be reduced sufficiently to produce an acceptably sharp image without using the wide angle focussing lenses required in a conventional projector.

3.3.3 Laser Source

The laser source generates a collimated beam of high intensity light, which is spread out over the required wide angle. Only a low power laser is needed with night vision goggles (NVG), which amplify the brightness of the projected image in the same way that they amplify the ambient light when used in the "Field", and because the image produced by night vision goggles is monochromatic the laser output can also be monochromatic (red). For daylight simulation more light output is required, and two larger lasers are used.

The disadvantage inherent in laser sources is that a speckled image is produced because of diffraction effects caused by the coherence of the laser light. This is unimportant when NVG's are used because the speckle is not resolved by the goggles.

An arrangement of mirrors has been designed which produces the point source some 12mm from the nearest optical element, and it is possible to "fly" this source to touchdown and even through 3D features without any damage.

3.3.4 Visibility

The terrain image is a circular area centred on the aircraft and is proportional in size to the aircraft height, for example it will extend to 500m at a height of 50m. Research by NASA (Ref: 2) has shown that a minimum look ahead equivalent to 3 seconds is required for obstacle avoidance during tactical low level flight. Above the corresponding speed there will not be sufficient terrain visible ahead for obstacle avoidance.

3.3.5 Coverage

Laterally	360° (projection screen covers 270°)	
Vertically	Upper Limit	5° below plane of pitch/roll axes
	Lower Limit	60° below plane of pitch/roll axes

3.3.6 Resolution

Tests made with the laser source demonstrate that the system resolution significantly exceeds that of NVG's.

3.3.7 Auxillary Projectors

Two auxillary projectors extend the field of view covered by the main light source, from within 5° of the horizon, and add the sky above the horizon. They produce a low definition image of distant terrain, the impression is given of flying in a light haze which restricts visibility.

3.4 TRANSPARENCY

3.4.1

The transparency is the storage medium for the terrain image; it is a three dimensional model including trees and buildings. It comprises a photographic two dimensional component, with additional 3D features attached to the upper surface. These are opaque and are projected as silhouettes.

The two dimensional detail contained in the transparency can be derived from artwork or from aerial photography. In the case of the latter the original photographs have the plan view of 3D features removed. Solid rubber models replace them, thereby giving the correct perspective view when projected.

The use of photographic techniques to copy a piece of terrain accurately permits very realistic scenes to be created, and laser powered sources result in very high resolution.

The transparency film can be slightly contoured to reproduce undulating terrain, but the amount of contouring possible is limited, not only because the film must flex inorder to pass around rollers, but also because if the contouring is too steep, the far side of the contour will be visible through the near side. In practice, contouring is generally limited to approximately the same height as the other 3D features (trees, buildings).

3.5 PROJECTION DOME

The screen used in the prototype is a sphere of radius 20ft covered internally with retroreflective material.

The size of the screen was determined via a trade-off between achieving maximum image brightness (influenced by the inverse square law), minimisation of distortion due to off axis viewing (caused by the separation between the light source and eyepoint, which is required for clearance between the transparency and cockpit during pitching and rolling of the transparency), providing adequate space for a cockpit and access walkways, minimisation of installation space, minimisation of cost, and focusing of the pilots eyes at effectively infinity.

The projection screen covers the pilots view through a Lynx side window, which extends to a look up angle of 38°. This is of great importance for tactical low level flight.

3.6 SUPPORTING STRUCTURE

The servo mechanism, including the light source, transparency and auxillary projectors, is supported in position above the simulator cockpit using a frame constructed from rolled steel joists. Space is left between the legs of the frame for moving cockpits (upto EH101 size) into and out of the vision system.

The section of the frame work supporting the cockpit is physically isolated from that supporting the servo mechanism, the cockpit can thus be vibrated without affecting the servo mechanism.

3.7 COMPUTER FLIGHT MODEL

Vistasim is designed as a completely self contained unit requiring only power and six input command signals, i.e. one for each axis of the servo mechanism. No feedback loops to the computer are used, the servo mechanism being commanded to a position and closing its own loop. The flight model can therefore run completely independently of the servo mechanism and can be changed to match whichever aircraft the vision system is simulating.

4. APPLICATION OF VISTASIM TO COCKPIT RESEARCH

VISTASIM provides a low cost vehicle simulator capable of reproducing very low level flight with excellent lateral and vertical field of view restricted only by shadows of the cockpit structure. It is considered that the scene content and realism of the projected image is comparable with that of conventional camera/model systems, and exceeds all but the most advanced C.G.I. systems. There are obvious limitations in the available gaming area due to the use of a physical model, and "trade-offs" have had to be made between allowable rotation angles, transparency size, dome-size, light power and image distortion. On balance, and taking into consideration the low-relative cost of the system, VISTASIM provides a considerable tool for aiding in cockpit design. The first (Four degree of freedom) prototype of VISTASIM has been in operation at WHL for two years, and has been used for testing malfunction control and display units in NOE flight, and for assessing N.V.G. compatible cockpit lighting scemes.

A new VISTASIM prototype is under construction which incorporates the full range of advances outlined in this paper. It will be linked to a simulated Lynx Cockpit, and subsequently will be used in conjunction with the Westland Advanced Cockpit simulator, which is a development of W30. Trials are planned for head up and helmet mounted displays, speech-recognition equipment, and side-arm control layouts. Further development work may add auxillary projectors to superimpose foe aircraft onto the visual field for air to air combat simulation.

VISTASIM is under evaluation for use as an aircrew training aid. It has particular military potential for NVG procedures training at tactical low level altitudes, and, in the day light role, for crew coordination training during ATGW sorties, for example. Civil applications are potentially wide spread and include non helicopter roles such as Airship and Hovercraft visuals.

In conclusion, in order to develop a low cost tool for cockpit research it has proven necessary to produce innovative solutions to problems in laser optics, servo-systems, small scale modelling and photographic techniques. The resulting simulator will add significantly to Westlands ability to develop advanced technology cockpits.

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