DEVELOPMENT OF A LANDING SIGNAL OFFICER TRAINER

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SUMMARY

The Landing Signal Officer (LSO) Trainer, developed through an austere yet comprehensive research and development program at Vought, will provide another first in naval aviation training. It will provide simultaneous simulation training, with performance evaluations, for LSO's and pilots in a closed-loop mode. LSO on-the-job training requirements for the control of actual aircraft are eased. JP-5, aircraft flight hours, aircraft maintenance, and time in the training of an LSO are direct savings. In an era of more restrictive budgets and reduced operations, the opportunities to teach and learn aircraft control are more limited. The Landing Signal Officer Trainer will increase the training opportunities and provide a closed-loop pilot/LSO training relationship.

INTRODUCTION

One of the most demanding tasks imposed upon the navy pilot is to make a night landing aboard an aircraft carrier. To help ensure a safe landing and to aid the pilot in making his approach to the carrier is the responsibility of the LSO. His task is even more formidable in a night environment due to the few visual cues available.

Today the training and qualification of an LSO can take as long as three years and with the diminishing aircraft inventory of the future, smaller operating budgets and longer deployments, the time honored on-the-job LSO training curriculum will become more unmanageable and more costly. No other aspect of carrier aviation training has remained as static as LSO training despite the fact that, with the exception of the carrier approach itself, no other task is more demanding or complex.

Accordingly, a Landing Signal Officer Trainer utilizing audiovisual training aids has become a viable requirement and is within current state-of-the-art simulator technology. This paper (Figure 1) describes the development of a Landing Signal Officer Trainer incorporating the dynamic night visual cues, carrier platform environment, and other significant information used by LSO's in controlling aircraft recoveries.

BACKGROUND

The Vought Corporation developed the first A-7 Night Carrier Landing Trainer (NCLT) for the Navy in 1971. Two of these part task simulators were delivered to the Navy in 1972, one to NAS Lemoore, CA and the other to NAS Cecil Field, FL. Since that time the NCLT's have provided invaluable training to Navy pilots in performing night carrier landing training and in general night carrier operations. The basic NCLT, Figure 2, consists of an A-7E cockpit mounted on a three-degree-of-freedom motion system, a collimated cathode-ray tube (CRT) visual display of the carrier scene presented to the pilot, and an instructor station with repeat visual display, operated by an instructor-qualified LSO.

During the development of the A-7 NCLT, Vought engineers realized the benefit of providing the LSO platform view for the possible training of LSO's. Currently in the NCLT, the instructor LSO has a repeat visual display of the pilot's view of the carrier landing scene. Because of his experience as a carrier pilot, he can relate the visual cues of that scene, Figure 3, as if he were in the cockpit with the student, to his instructional technique. However, in the real world at the LSO platform, he uses a totally different set of cues to monitor and control the approach. Were he to have those same real world cues in

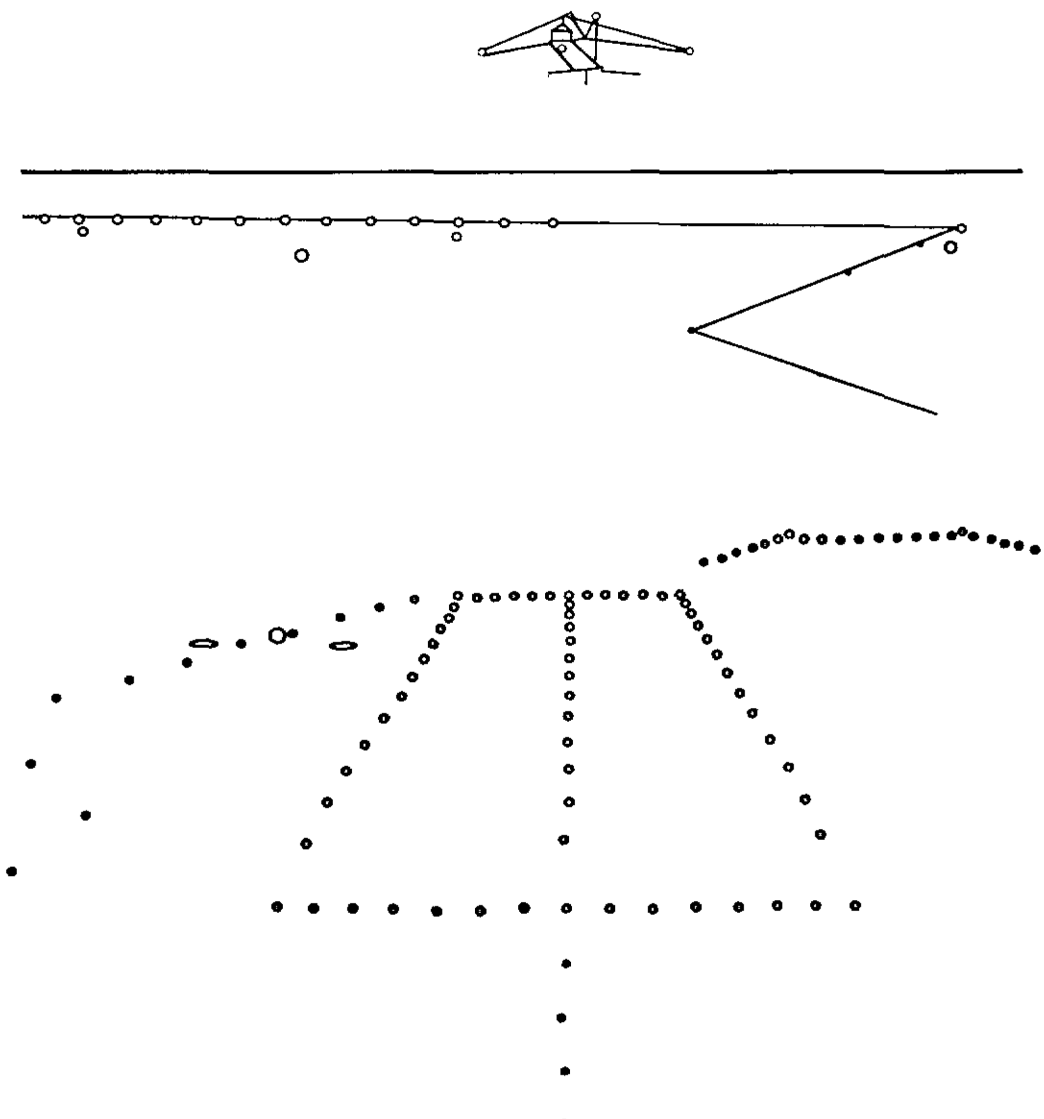

Figure 1 The Pilot/LSO Platform Scene

a simulation and use them successfully to control a simulated carrier approach, he would have a device to teach these skills to an LSO trainee.

These thoughts led to the development of a simulation to explore an LSO trainer concept (Figure 4). A simulation of a carrier landing as viewed from the LSO platform was implemented on an interactive graphics terminal. A color movie of the simulation was prepared for demonstration of the concept and shown to LSOs at the Naval Air Station (NAS) Lemoore, NAS Cecil Field, and Chief of Naval Technical Training (CNTECHTRA). The endorsement of the concept subsequently led to a concept feasibility study using the A-7E Night Carrier Landing Trainer (NCLT) in which the LSO platform view was presented on the instructor station visual display. The following paragraphs will discuss the development of the interactive graphics simulation, the concept feasibility study, and conclude with a discussion of the present development of a stand alone LSO trainer station to be incorporated into the existing A-7E NCLT facilities at NAS Lemoore and NAS Cecil Field.

INTERACTIVE GRAPHICS SIMULATION

A visual simulation of a carrier landing as viewed from the LSO platform was required to explore the feasibility of a visual training device for LSO's and to help define the requirements of such a device so that it would

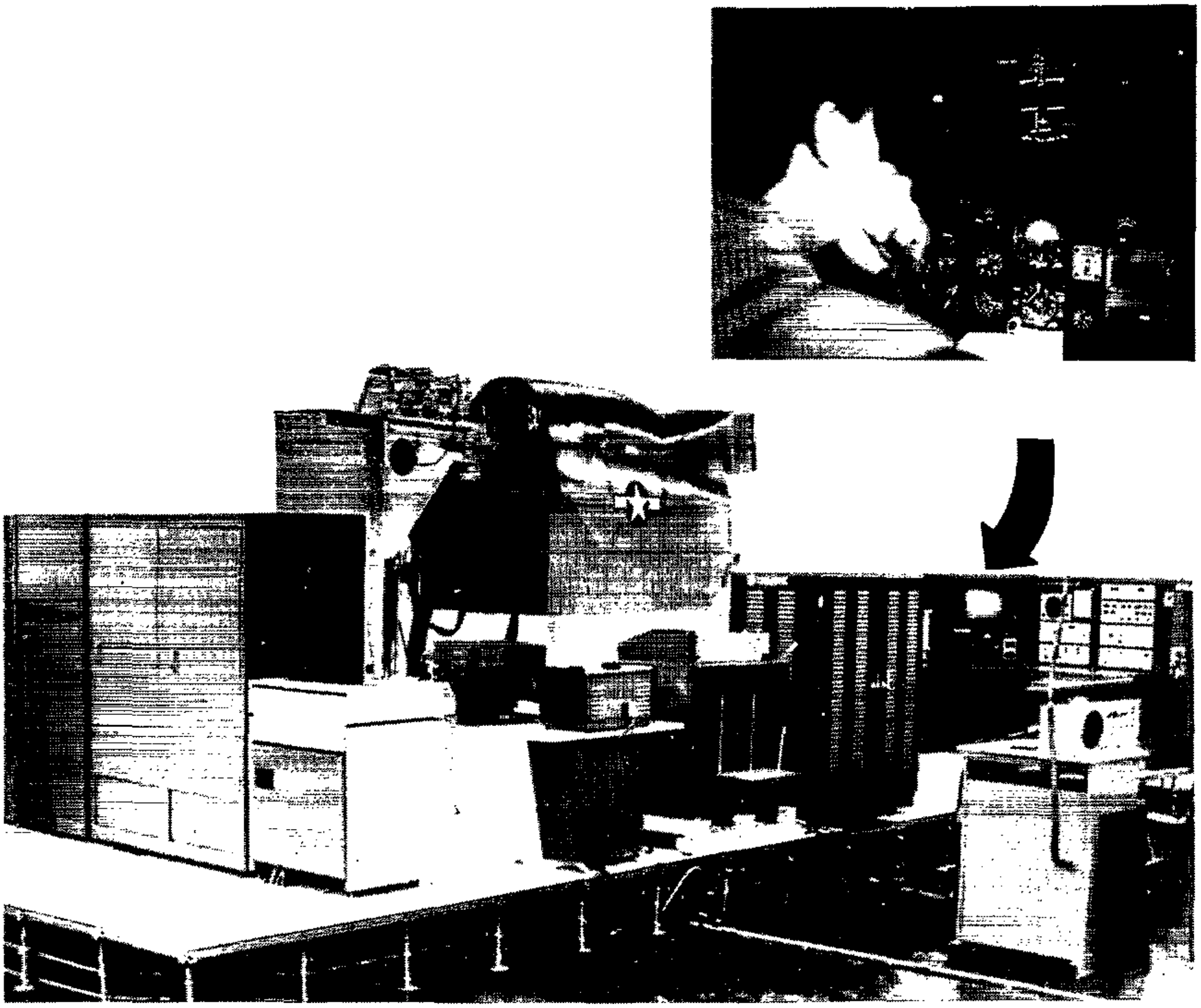

Figure 2 The A-7E Night Carrier Landing Trainer

convey maximum realism to the trainee. The philosophy in the development of the visual simulation was to provide a realistic view of an aircraft making a night landing aboard an aircraft carrier without the cost in time, hardware, and software of producing this simulation in real time. Vought's CDC 6600 computer with a CDC 274 interactive graphics system provided the key in that it could directly present a visual end display of a simulated event, generated from simple fortran routines, at a relatively low operating cost. Figure 5 shows the main components of the interactive graphics simulation. This method of simulation provided another benefit because program modifications or corrections could be made as quickly and easily as changing cards in a fortran source deck.

A vector diagram of the approach problem is shown in Figure 6. The inertial, aircraft, carrier, and LSO "eyepoint" axis systems are shown with relative position vectors and orientation angles referenced to the inertial (fixed) axis system. For the graphics simulation, the carrier orientation angles $(\psi_S, \theta_S, \phi_S)$ were assumed zero to simplify vector transformations. This would correspond to a carrier heading of 0^o (due north) relative to the inertial axis system and a calm sea state (0^o carrier roll and 0^o carrier pitch angle). The aircraft's position relative to the carrier and angular orientation (ψ, θ, ϕ) were provided by a time history. This requirement was fulfilled by obtaining a line printer time history which had been produced on Vought's Carrier Approach

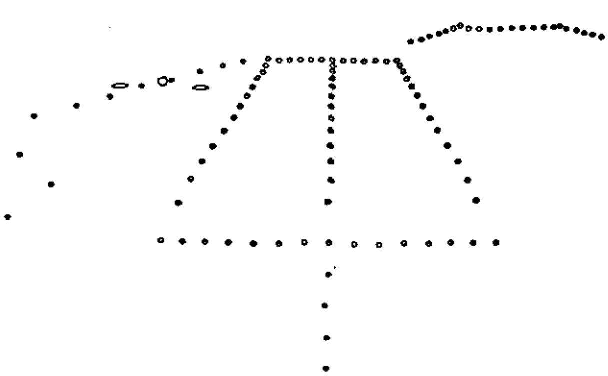

Figure 3 The Cockpit Scene

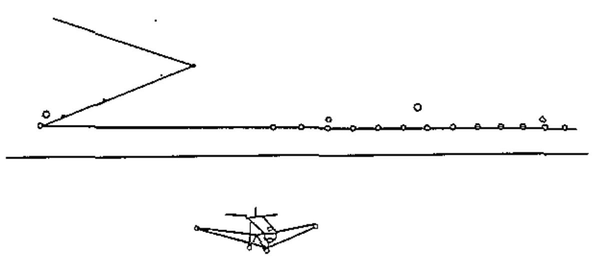

Figure 4 The Platform Scene

Simulator. The time history presented the aircraft's position relative to the carrier axis system and the aircraft's angular orientation (Euler angles) versus time. The approach time history commenced at two nautical miles from the carrier deck and terminated at deck contact. To complete the time history, the aircraft's pitch down and roll out dynamics at wire engagement were added. A data file was then created from this time history and stored on disc in the CDC 6600 computer system (the host computer of the CDC 274 system) for use by the simulation routine. The position of the LSO eyepoint axis system is defined by a simple bias vector from the

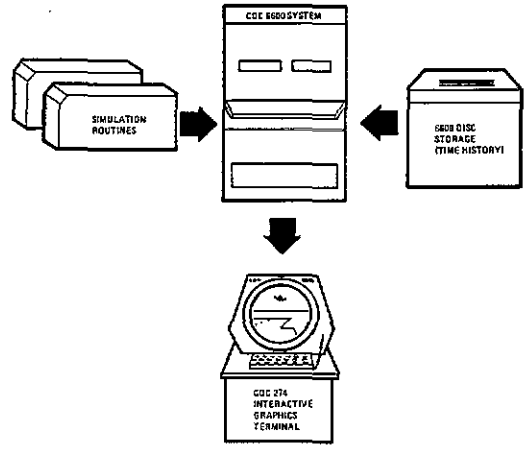

Figure 5 Interactive Graphics Simulation

ship's axis system. The orientation of the axis system (the direction of look of the LSO "eye") is defined by an azimuth angle (ρ) and an elevation angle (γ) measured relative to the inertial axis system. The control of the direction of look will be discussed in a later paragraph.

The development of the simulation proceeded quickly due to the existing interactive graphics library routines. Routines were selected for determing the three-dimensional position and the orientation of one or more objects as viewed from an observer's reference point and displaying these objects on the interactive graphics two-dimensional CRT grid system. In this case, the observer's reference point was the LSO platform and the objects were the approaching aircraft and the carrier deck. Other routines were written to produce a model of the A-7E aircraft with wing tip, tail, and approach lights including a ghost outline of the aircraft; a model of the carrier USS Enterprise including a ghost outline of the deck and angle deck centerline lights, a horizon line, and a selectable cross-hair index for identifying the glideslope. Figures 7 and 8 show the models of the A-7E aircraft and the USS Enterprise, respectively, that were used in the simulation. The remainder of the simulation routine produced the frame-by-frame sequence of the approach utilizing the above mentioned routines and accessing the disc file for the position and orientation data of the aircraft.

To change the initial conditions and control various aspects of the simulation, two data arrays were established in the routine and displayed on the CRT. The initial conditions array provided a means of controlling the field of view of the presentation, LSO eyepoint position and orientation,

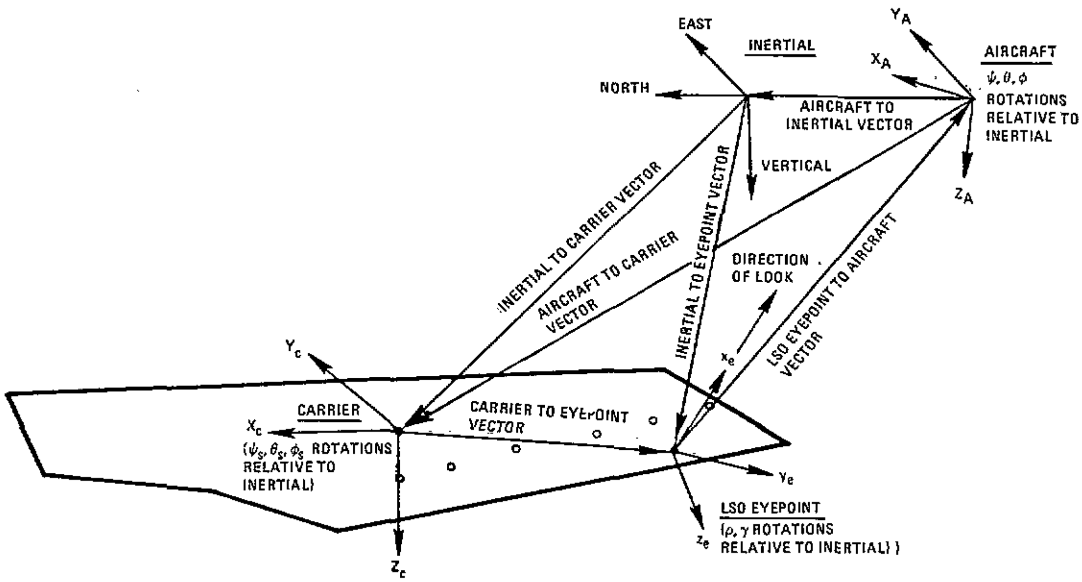

Figure 6 Vector Diagram of Approach Problems

width of the simulated CRT outline (rectangular CRT outline drawn on the graphics CRT), and a control for determining the mode of observation of the approach. The ABCDE array was used for selecting the initial and final time of an approach (for running all or part of the data file), selecting the step size at which to view the approach (i.e., every half-second, every second, etc.), selecting the brightness of the aircraft outline and horizon line, and selecting a gain for controlling the size of the approaching aircraft as a function of range to the carrier.

Four primary modes of observation, Figure 9, were programmed into the simulation by controlling the values of the azimuth and elevation angles of the LSO eyepoint axis system. Mode 1 is a staring mode in which the LSO's "eye" is held fixed in a selected azimuth and elevation. Mode 2 allows the eye to rotate in azimuth only to keep the aircraft in the azimuth field of view. Mode 3 allows the eye to rotate in azimuth and elevation to keep the aircraft in the geometric center of the CRT. Mode 4 fixes the center of the CRT on the azimuth and elevation of a point on the prescribed glideslope at the horizontal distance of the aircraft from the carrier. This gives the LSO the ability to detect lineup and glideslope errors during the aircraft approach. All modes of observation analyzed, except Mode 1, provided scene rotation to

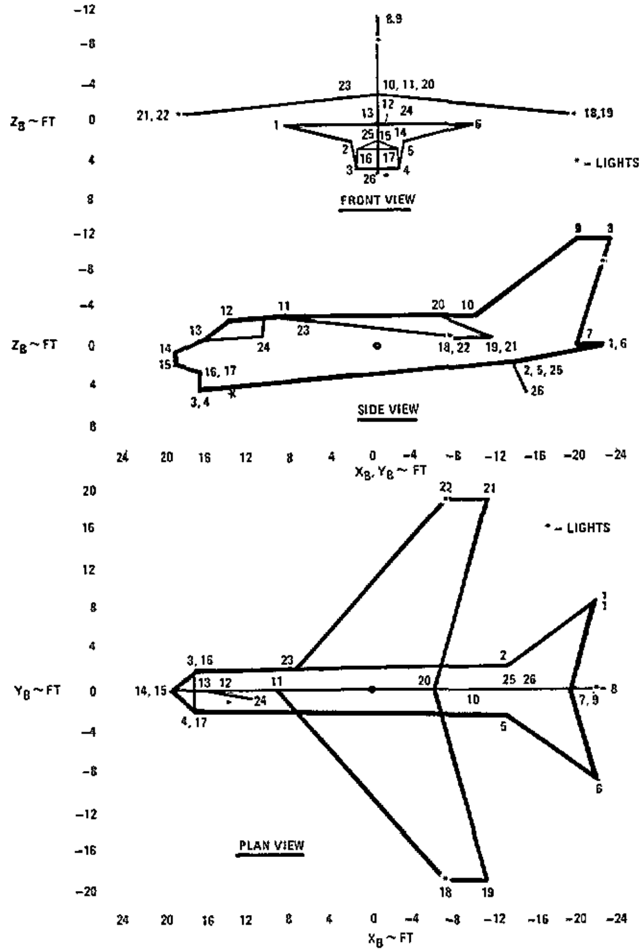

Figure 7 A-7E Model

allow viewing the aircraft through the entire approach.

Another important feature of the graphics system was the hard copy printout. This allowed making permanent records of various scenes of the approach as various program parameters were varied. This provided a means of comparing observing modes, fields of view, model configuration and other elements of the visual scene simultaneously. One of the primary goals of the simulation was to determine the best observing mode and the best field of view for conveying realism. The operational features of the program controlled through the data arrays provided the means of analyzing the approach in many different ways such that this goal could be met. Mode 4 at a

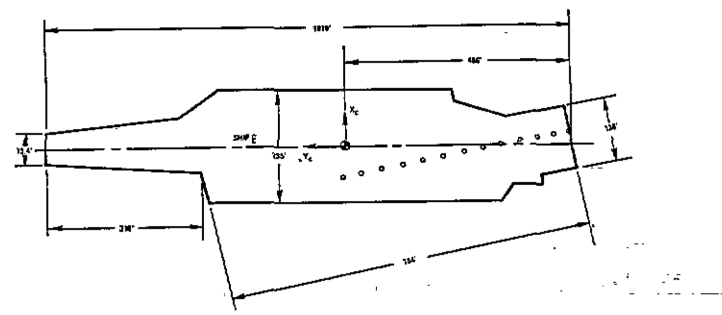

Figure 8 USS Enterprise Model

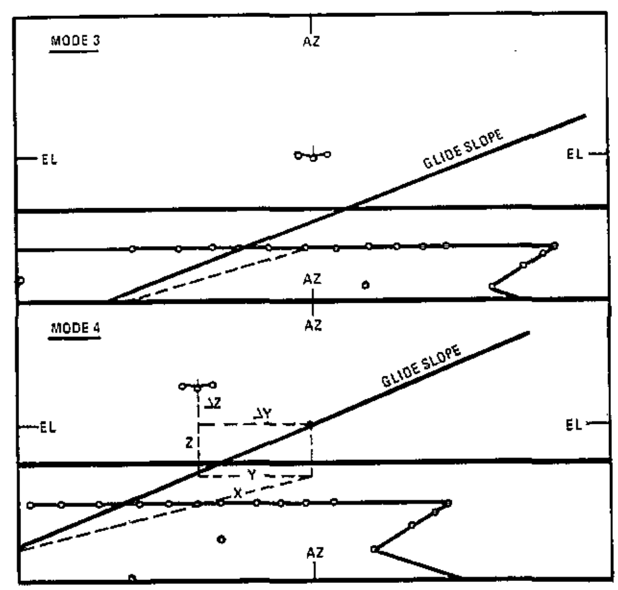

Figure 9 Platform Scene Observing Modes

30^0 horizontal by 20^0 vertical field of view provided the most useful and realistic approach available from this simulation. It should be noted that although the interactive graphics system could not present a new frame on the CRT at a sufficient rate to eliminate "stepping" and in general could not maintain real-time motion, the frame rate was fast enough to make the simulation and the analysis possible.

Then,a color movie was made of the simulation. This required the ability to manually display each frame of the approach so that a movie camera with a single frame capability could be employed. This was accomplished in the program by using the light pen key (located at the graphics console) to sequentially step through the time history data file, not just once, but as many times as there were to be different colors in the movie. The problem was to create five identical exposures for red, blue, amber, green and white colors, one frame at a time, *for a two mile approach. Then, the color movie* could be constructed by multi-printing an exposure for each color and adding the sound track. The time history data file stored on the disk was generated in 1/24 second intervals. Therefore, when the movie is projected at a 24-frame-per-second rate (the standard rate for 16 mm projectors) the resulting motion is in real-time. The result is a real-time simulation of the carrier landing as viewed by the LSO in color on a CRT system; the primary goal of the interactive graphics simulation (3-minute film clip).

CONCEPT FEASIBILITY STUDY

The color movie of the interactive graphics simulation was screened for the Landing Signal Officers at NAS Lemoore, NAS Cecil Field and CNTECHTRA. After a unanimous endorsement of the LSO trainer visual concept by the LSO community, Vought proposed a concept feasibility study to be performed using one of the existing A-7E NCLT facilities. By modifying the NCLT to provide the LSO platform environment, and using the basic NCLT capabilities, the LSO would be able to control simulated carrier approaches from the platform. The pilot in the NCLT cockpit would be *controlled by the LSO at the platform, just* as in real life. If he could do this successfully using simulated real world shipboard cues and techniques, then the merit of an LSO training station would be established. The proposal by Vought to accomplish this study was approved by the Naval Air Systems Command (NAVAIR) in November of 1976 and work was started in December of 1976.

The feasibility study required software and hardware additions to the A-7E NCLT to provide the necessary cues to simulate the LSO platform environment. The visual scene of the carrier approach from the LSO platform was provided on the instructor's station visual display while the pilot view functioned normally in the cockpit. Most of the scene content for the LSO platform view was obtained from the graphics simulation models. Also, the logic for controlling the scene orientation was obtained from Mode 4 of the graphics simulation. Although the instructor visual display (CRT) had only a 30° horizontal by 20° vertical field of view, the aircraft could be followed through a waveoff maneuver and bolter pattern entry by scene rotation. The LSO platform environment was further enhanced by providing the sounds of the approaching aircraft, as heard from the platform, using a hardware modification of the normal aircraft sound system at the instructor station and an additional speaker. The additional software modules required to *present the platform visual display* and provide sound system controls were assembled into the main NCLT program in the central host computer. A small electronics cabinet containing all the required hardware for the feasibility study was mounted just above the visual display on instructor's station. All new control switches required for controlling the simulation during the feasibility study were mounted on the front panel of this cabinet in easy reach of the LSO, and the additional speaker for the platform sound was mounted on top of the cabinet. The installation of the interface controls is shown in Figure 10. All basic NCLT controls were functional including weather conditions (ceiling, visibility, sea state, wind), problem FREEZE, and problem REPLAY in which all or a part of the last approach could be replayed.

The LSO platform visual-scene elements for the feasibility study included an A-7E aircraft model, carrier models of the USS Range or USS Roosevelt, a horizon line, and

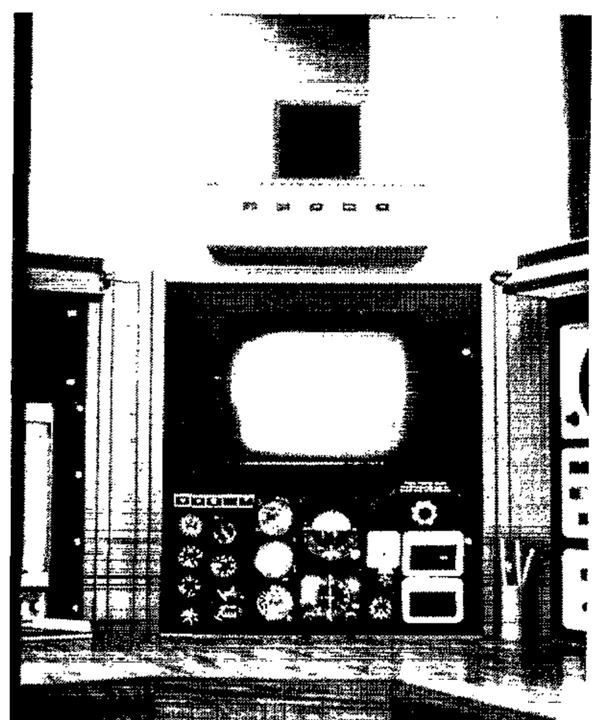

Figure 10 Interface Controller

a selectable cross hair index centered on the glideslope. A representative view of the platform approach scene is shown in Figure 11. The pilot has just been given a waveoff from the LSO and is responding accordingly. The airplane model was similar to the model used in the graphics simulation including the left and right wing tip lights, the approach indexer light, tail light, and a faint ghost outline. In addition, the model included a conditionally generated tail hook and engine exhaust plume. The red left wing tip light and green right wing tip light were displayed at all times. The white tail light was displayed when not occulted by the vertical tail. The approach light, located on the nose gear door, was displayed when the landing gear was down and could be red, amber or green depending on aircraft angle of attack. If the landing gear was down but the tail hook was up, the approach light would flash at 1 HZ. If the landing gear was up,the approach light was extinguished. All the aircraft lights increased in intensity with decreasing range to the carrier. These lights provide much of the information available to the LSO on the platform such as landing gear and tail hook position (from the approach light), approach speed (from approach light color) and distance and bank attitude from the wing tip lights. The ghost outline, including the tail hook, was drawn with a series of faint-blue line segments that increased in intensity with decreasing range to the carrier. The tail hook was erased if the pilot had the tail hook up. An engine exhaust plume was drawn with faint-blue line segments at the tailpipe of the aircraft to simulate smoke that can be seen on clear dark nights due to engine power changes. This provides information to the LSO about the response of the pilot to a call for power from the LSO.

The carrier models of the USS Ranger and USS Roosevelt were already provided in the basic NCLT software for the pilot's view. The models consist of the red deck-edge lights, white runway edge and centerline lights, white runway athwartship lights, red vertical dropline lights, and the fresnel lens optical landing system (FLOLS) lights. These models were used to generate the portions of the carrier visible from the LSO platform by using the "eyepoint" position of the LSO relative to the carrier axis system. A foul/clear light and a faint-blue deck-edge were added to the basic models to improve the platform environment and perspective. The foul/clear light can be red (foul) or green (clear) and is located at the deck's edge near the LSO platform within the LSO's field of view. This light provides information to the LSO about the condition of the landing area. If the light is red, indicating a foul deck, the LSO will wave-off the approaching aircraft. The faint-blue, deck-edge outline was

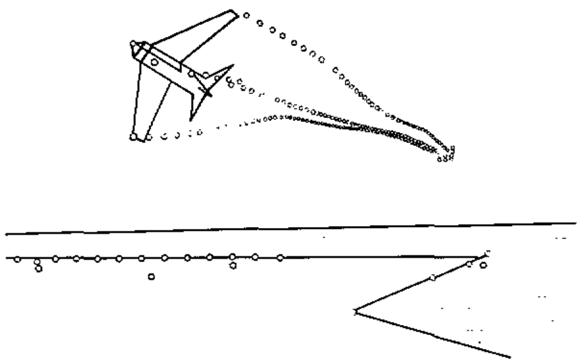

Figure 11 Platform Scene Photograph

added to better define the carrier deck surface. This was important because the LSO uses the relative position of the lights of the approaching aircraft to the deck surface in his field of view to determine whether the aircraft is high or low on the glideslope. The horizon line was drawn across the entire horizontal dimension of the visual display (CRT) with a blue line at the proper depression angle from the LSO eye. The cross-hair index was drawn as a small green plus sign that was positioned on the glideslope at aircraft range when selected by the LSO. The index provided lineup and glideslope error information since it represented the correct position for the aircraft and is envisioned as a training aid for the LSO trainee. Existing continuous controls (variable pots) at the instructor's station were reprogrammed to provide intensity control over various scene elements of the LSO platform scene including aircraft lights, aircraft outline, and the horizon line. This allowed the LSO to accurately establish the environment based on his experience on the platform.

The electronics cabinet shown in Figure 10 contained five alternate-action control switches on the front panel for controlling the instructor's station visual display. The PILOT/LSO switch presented either the normal pilot scene to the instructor LSO or the LSO platform scene. The FOUL/CLEAR deck switch controlled the color of the FOUL/CLEAR light. The PLUME switch activated the engine exhaust plume and the CROSS-HAIR switch displayed the cross-hair index. The fifth switch was a spare. If the PILOT/LSO switch was placed in PILOT position, the remaining switches were deactivated and the NCLT was returned to its standard operating configuration. The remainder of the electronics cabinet contained the hardware required to modify the normal aircraft sound system in the NCLT. The normal system provides engine and aerodynamic sounds heard by the pilot in the cockpit. The engine sounds vary with power setting (RPM) and the aerodynamic sounds vary with aircraft speed. However, the sounds of the approaching aircraft, as heard from the platform, are attenuated as a function of range and delayed as a function of range and speed of sound. In addition, the frequency shift or doppler effect is present as the aircraft passes the LSO platform. The hardware to provide these realistic sound cues was developed by Vought's Computer Hardware Technology Department. It utilizes an electronic digital memory in the form of a series of dynamic shift registers to provide the required delay function and a separate analog multiplier to provide the attenuation effects. The output of the NCLT sound system was routed to this hardware as input without affecting the sound output to the pilot. Software equations were required to provide two digital-to-analog (D/A) signals to the hardware to control clock frequency and attenuation. The frequency equation was a function of aircraft speed, range, speed of sound, and the size of the shift register. The attenuation equation was an inverse square function of range. By controlling the digitization and shift rate of the sound input with the clock frequency equation, the delay and doppler effects are achieved. By controlling the analog multiplier with the attenuation equation, the attenuation with range is achieved. The resulting LSO platform sound was output on the speaker mounted on the top of the electronics cabinet as shown in Figure 10. This system takes advantage of state-of-the-art, low-cost electronics to provide a capability not previously developed for simulation of sound cues.

The concept feasibility study was performed on the A-7E NCLT at NAS Lemoore, in March of 1977. Vought engineers completed installation and check-out of the hardware and software additions to the existing system on March 28 and a Landing Signal Officer's conference was convened on March 29 with representatives from AIRLANT, AIRPAC, and CNTECHTRA attending. After all attendees had become thoroughly familiar with the concepts of the feasibility study, a simulator demonstration was conducted. LSO attendees were afforded the opportunity to fly the NCLT and control approaches using the platform view. Since the LSO instructor station presents only a two-dimensional display, a carrier approach was recorded and replayed on the collimated display in the NCLT cockpit. The infinity optics of the cockpit display provided depth of field and the additional dimension needed for a truly realistic display.

After the demonstration, the LSO's unanimously concluded that the LSO platform simulation very closely approximated the aircraft recovery environment from the platform, and a high degree of realism was displayed in aircraft image and performance. Furthermore, the incorporation of a standalone LSO trainer with collimated optics, into existing facilities, would provide excellent training for LSO's and pilots in a closed-loop mode. The Commanding Officer of Attack Squadron 122, based at Lemoore, stated in his Landing Signal Officer Conference Report of 29 - 30 March 1977 that the demonstration "clearly establishes the feasibility of an LSO trainer. The realism achieved with the limited view from one nineteen-inch,cathode-ray tube is truly phenomenal ...." The message from AIRLANT to NAVAIR regarding the simulator demonstration stated "Feasibility meeting NAS Lemoore 29 March 1977 extremely successful ... display was real and accurate. Present state of art technology makes such a trainer feasible to train LSO's ...." Similar endorsements were also provided by AIRPAC and CNTECHTRA.

LANDING SIGNAL OFFICER TRAINING STATION

The immense success of the concept feasibility study and the support and recommendations of the LSO community provided the basis for a proposal by Vought to design and build a complete LSO training station incorporating the dynamic night visual cues, carrier platform environment and other significant information used by LSO's in controlling aircraft recoveries. The LSO training station will be integrated into existing A-7E NCLT facilities at NAS Cecil Field and NAS Lemoore, utilizing maximum commonality of NCLT hardware and software. The station is light tight and soundproof, providing isolation from outside distractions (as does the cockpit for the pilot trainee) and it will provide a more realistic night shipboard environment.

During Vought's preparation for the concept feasibility study at NAS Lemoore, an in-house mockup of an LSO shipboard platform was built employing a light tight-cylindrical enclosure. The mockup included a simulated visual scene of the approaching aircraft on two dummy CRT's, an LSO shipboard console and perspective murals on the walls to simulate the angled deck landing area to the left of the platform, the carrier's deck-edge and escape net to the right, a black sky and star field above and a horizon line extended from the CRT horizon. The murals were drawn in proper relation and perspective to the visual scene within the CRT's to provide the complete visual platform environment. Various representatives from the LSO community were invited to view the mockup and to provide their recommendations for improving the simulated station. The final configuration that evolved for the LSO training station is shown in Figure 12. The LSO's that viewed the mockup at Vought and attended the feasibility demonstration at NAS Lemoore were able to mentally place the dynamic visual scene they had used at Lemoore into the simulated station mockup and get an idea of the realism that would be afforded by the training station.

The proposed LSO training station will *contain collimated visual assemblies, LSO* instrument console, manual optical visual landing aid system (MOVLAS) control and indicator, sound system, LSO station control panel and simulated environmental surroundings. Two 25-inch diagonal color CRT's with collimating optics will be used to provide the dynamic visual scene. The two displays will be mounted side by side to provide a large 80^{o} horizontal by 32^{o} vertical field of view. This provides over twice the instantaneous horizontal field of view of the NCLT instructor station CRT used for the feasibility study and will provide a definite improvement in the peripheral information presented to the LSO. The visual scene content will be identical to that defined in the concept feasibility study except for the possibility of an additional carrier model. *The LSO instrument console will be a duplicate* of the shipboard console and can be moveable within the enclosure. The hook to ramp, wind direction and wind velocity indicators, on the instrument console will be dynamic indications driven by the computer. The remaining instruments found on the console will be simulated as far as front appearance and dial lighting. The sound system, located in the training station, will provide both the sounds from the approaching aircraft and typical deck sounds. The hardware design developed during the concept feasibility study for providing aircraft sounds including delay, doppler, and range effects will be used and the deck sounds will be provided through a tape player/recorder. The deck sounds will be recorded at an actual LSO platform under normal landing conditions. The cylindrical/spherical shape of the enclosure provides the desirable shape for the simulated environmental surroundings which include a horizon, star field, and carrier deck.

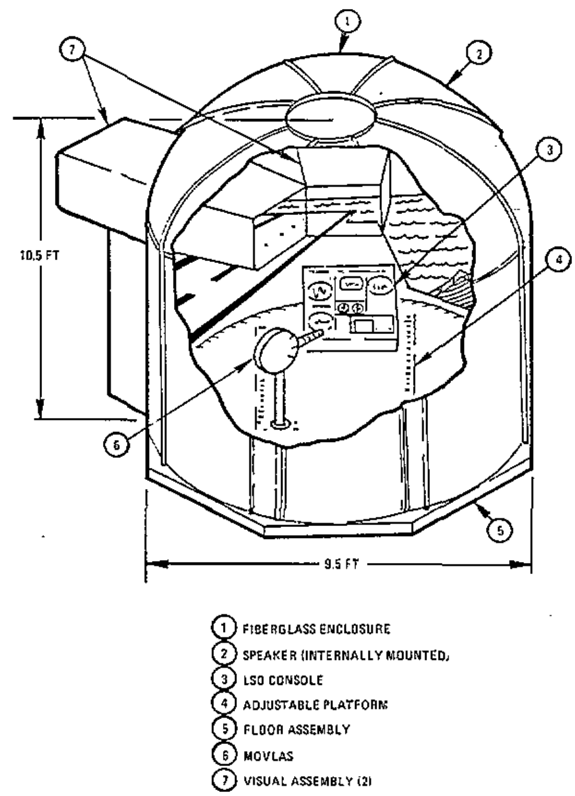

Figure 12 LSO Training Station

With the addition of the LSO training station to the basic NCLT facility, simultaneous training of pilots and LSO's in a closed-loop mode can be accomplished. In addition, a canned approach software system has been proposed as an LSO training aid. This system will store and replay up to ten previous carrier approaches of 60 second duration. The LSO instructor can select any particular canned approach during an LSO training session and display the approach to the student in the LSO training station. This feature will provide independent training of LSO's without the need for a pilot in the cockpit.

ABOUT THE AUTHORS

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