Author: Schade, O.H.

Title: A 60-Megacycle Video Chain for High-Definition Systems RCA Review - Vol. XXVI, No. 2, June 1965, pp. 178-199.

SUMMARY: A theoretical analysis demonstrates that low-noise pictures can be obtained with camera tubes containing electron multipliers that furnish peak signal currents of the order of 15 microamperes. Reliable noise-free video amplifier systems that have constant amplitude response in a 60-megacycle bandwidth and that can deliver peak drive signals of 50 volts to a high-definition picture tube can be built with nuvistor tubes and conventional circuit components.

The net sine-wave response of the storage surface and scanning beam combination measured on an experimental multiplier vidicon camera was found to be 55% at 1500 lines. The equivalent pass band, $N_e$ is 1050 lines horizontal or vertical. Further details on the vidicon were not disclosed.

Author: Schaper, O.F.

Title: Carrier Landing Trainer, U.S. Patent No. 2,883,763, April 28, 1959, Patent Office, Washington, D.C.

SUMMARY: This invention describes a visual simulation apparatus for simulating an environment relative to which an observer is supposedly moving. It is explained with reference to an aircraft-carrier landing trainer for flight training, although other applications are claimed.

A television system is utilized to present a picture to an observer. The scene, a composite of a seascape and an aircraft carrier, is obtained by means of television insertion techniques. It is projected on the screen by a pair of wide angle television picture projectors, such as the RCA 60° wide angle projector, each projecting approximately half of the scene, with a small overlap in the center. The projectors are mounted directly above the trainee's head on a gimbal-supported platform.

The seascope is obtained by photographing a replica of a seascape with a pair of television cameras, each photographing a different half of the scene. An aircraft carrier model is photographed with a single camera. In operation, the trainee manipulates the trainer controls as if he were actually flying an airplane. Directional signals actuate the motors which control the cameras and projectors, resulting in a non-programmed presentation. Thus, pictures simulating the landing approach of an aircraft with respect to a carrier flight deck are projected on the screen.

Author: Schlessinger, K.

Title: Design, Development and Fabrication of an Ultra-High Resolution Cathode-Ray Tube. Report No. 4, 21 February thru 20 May 1963, on Contract DA36-039-sc-90726(E) to General Electric Company, Syracuse, New York (AD-414484)

SUMMARY: This project is aimed at developing a five inch flying-spot cathode ray tube with a 0.0002" spot size.

An objective spot-size gauge was developed for the range required, and results agree with microscopic measurement methods down to 0.3 mil (8 microns). Tubes have been constructed which yield 0.3 mil spot sizes, but at less than the desired output currents of 10 to 15 microamperes. This has been accomplished with both filmed and fine grain screens.

An interesting discussion in this report shows that an inherent aberration is present in flat CRT faceplates which can cause an effective spot widening of about .15 mil. This is considerable in ultra-high resolution work, but can be eliminated from the measurement procedure by the use of a simple lens.

Author: Schwarz, A. and McCarthy, E.L. (Assigned to the Perkin-Elmer Corp., Norwalk, Conn.)

Title: Image Projection Apparatus, U.S. Patent No. 3,052,753, Sept. 4, 1962 Patent Office, Washington, D.C.

SUMMARY: This invention relates to apparatus for projecting an image to a television camera. More specifically, a description is provided of an image pickup accessory, or optical probe, for the camera.

The manner in which the invention is used shows a dolly-mounted television camera movable along a three-dimensional model of an airport runway. The scanning head of the camera includes an objective viewing lens positioned to have a field of view at right angles to the major axis of the scanning head. It is part of a "pick up" lens system. The pick up system is designed to encompass a 90° field of view and form a real image in front of a relay lens. The system is designed telecentric on the image side. Although the size of the image changes as the scanning head alters its position with respect to an object, telecentricity assures that refocusing has no influence on the size. Therefore, correct perspective is maintained even though refocusing may be introduced.

The image is transmitted by the relay lens through the optical system to the image orthicon camera tube. Since the purpose of this invention is to duplicate what a pilot would see through the window of his cockpit, the system has been designed so that all angular motions of the aircraft appear to take place about axes running through his position in the cockpit. The television camera is effectively positioned at the pivot point of the viewing lens; that is, the optical conjugate or pupil of the viewing lens is located at the

intersection of the optical system mechanical axis and the major axis of the scanning head. All motion of the pick up lens system is then constrained to rotation about one of these two axes and such rotations do not change the location in space of the entrance pupil. The net result is to offer the pilot the same view he would receive if it were possible for him to actually view the model from the entrance pupil point.

The image from the camera is projected on a screen in front of the pilot. The pilot sits in a control cabin mock-up and manipulates the aircraft controls in accordance with his visual observations. The control outputs are fed to a computer which then controls the various movements of the camera and the operation of the image-forming apparatus of the invention.

Author: Seyler, A.J. and Budrikis, Z.L.

Title: Detail Perception after Scene Changes in Television Image Presentations, IEEE Transactions on Information Theory, January 65, Vol. IT-11, No. 1, pp. 31-43

SUMMARY: Coding methods have from time to time been proposed for employing frame-to-frame redundancy to reduce the transmission bandwidth of television signals. These have heretofore been severely restricted by the large influx of new samples caused by scene changes.

In this paper, psychophysical experiments and their results are described which were designed to test the hypothesis that the human observer would not perceive a temporary reduction in spatial detail after scene changes. The bandwidth of standard TV signals was temporarily reduced after each scene change, by means of a transient controlled low-pass filter. An average recovery time of 780 msec was found permissable by even the most critical observers, when the minimum bandwidth of the new scene was 250 kc, or one-twentieth of the system bandwidth ultimately reached at the end of the recovery transient.

Author: Shelton, C.T.

Title: Study of High Definition Television Techniques Vol. 2 of Final Report on Contract DA36-039-sc-56653 to RCA, Camden, New Jersey entitled "Study of Army Television Problems" 15 May 1954.
(AD-44143)

SUMMARY: The first two sections of this report comprise a thorough discussion of Dr. Otto Schade's work in the area of aperture theory and objective methods for image evaluation and measurement.

Later sections discuss in good detail and without confusing analytical detail various types of pickup tubes, including the Image Orthicon, Vidicon, Iconoscope, and Image Dissector. Although the data are out of date, the descriptions of limiting characteristics are current, and the comparisons drawn among the various tubes are good.

The section on kinescopes is somewhat outdated since considerable progress has been made in this field in the past ten years.

Author: Sinclair, R.S.

Title: An Analysis of Directional Viewing Screens: A Comparison to a Matte-White Surface. U.S. Army Electronics Laboratories, U.S. Army Electronics Command, Fort Monmouth, N.J. Technical Report ECOM-2500, Sept. 1964. DA Subtask No. IP6-22001-A-055-03-05.
(AD-609 034)

SUMMARY: An analysis was made on viewing screens to determine the brightness of a projected image as a function of the viewing angle of an observer. A beaded screen and two hypothetical screens were compared to a matte-white surface.

The brightness of the beaded screen, assumed to be the most directional screen currently being made, was found to be 2.72 times that of a matte-white surface on the projection axis. The beaded screen is manufactured by the Radiant Manufacturing Corporation.

A hypothetical screen obeying a cosine to the nineteenth power yielded a calculated brightness ten times that of a matte-white surface. It was not ascertained whether such a screen could be fabricated. It was noted that as the screen is made more directional in its characteristics, the usable viewing angle descreases.

Title: Society of Automotive Engineers, Inc., A Survey Report of Simulators Used as Tools for Research, Design and Development, Tech. Report AIR 779, June 20, 1964.

SUMMARY: - This report summarizes the results of a survey regarding the use of simulators as tools for research, design, and development in aerospace activities. Specifically, the purpose of this report was to compile a technical catalog of existing simulator capabilities; establish an engineering base from which modifications of existing equipment can be determined to extend the present state-of-the-art; and catalog the climate of future generation simulators that will be required through 1970.

Seventy replies were received from 168 questionnaires mailed out. The information that was sought, with respect to visual simulation methods and devices, was incorporated in a long list of questions involving normal uses of simulators, unique or unusual computer techniques, simulator instrumentation, prototype instruments, types and presentation of external displays, projection screen parameters, size of visual field, suggested areas for visual R & D for the period 1961 through 1970, etc.

The results of this survey cannot be considered comprehensive, since many of the known simulator devices are not included. Nowhere is mention made of virtual image display devices or techniques.

FOCI

Author: Spencer, R. A., Jr. and Smith, C. B. (Assigned to ACF Industries, Inc., New York, N.Y.)

Title: Carrier Landing Trainer, U.S. Patent No. 3,012,337, December 12, 1961, Patent Office, Washington, D.C.

SUMMARY: This invention relates to a device for visually training aircraft pilots in making landings on an aircraft carrier. The simulation apparatus includes a scale model of an aircraft carrier mounted on a large circular turntable, which is painted to resemble the sea and the carrier wake. Television cameras are focused on the carrier model, and the resulting picture is then displayed on a portion of a hemispherical screen surrounding the student pilot. The television cameras are mounted at the center of the hemisphere, close to the pilot's head. An auxiliary projector casts a shadow over the screen to simulate the horizon and the darker sea.

The pilot has controls in the cockpit to activate the movements of the television cameras and the carrier turntable. Thus an image of the landing surface, varying in range, direction, and elevation characteristics, is projected on the screen in accordance with the movement of the flight control members.

Author: Sulpizio, T.J., Rothschild, L.I., Case, W.J., and Orzechowski, B.R.

Title: Design Study for Visual Reconnaissance Simulator. Rheem Manufacturing Co. WADC Technical Report 55-419, November 1955. Contract No. AF 33(616)-2796, Project No. 6097.
(AD-87 321)

SUMMARY: This report presents the results of a study program to define and analyze the various problems associated with simulation of aerial visual reconnaissance missions in a stationary ground-based training device. Evolution of the Visual Reconnaissance Simulator design concept was stated in three distinct, interrelated phases consisting of:

1. Research in visual reconnaissance methods, requirements, and human engineering considerations.
2. Theoretical and laboratory analysis of optical and flight simulators systems.
3. Synthesis of practical and economical operating system.

In this manner, the requirements for a valid training device were formulated. As a result of these studies, a Visual Reconnaissance Simulator design was recommended which employs direct projection of a relief-map model by reflected light.

As envisioned in the report, the ideal simulator consists of a large hollow sphere, with a cockpit mounted inside such that the student pilot's head is at near-center of the sphere. The inside surface of the sphere is a projection screen. An overhead projector projects the light reflected from a scale relief map of the design terrain upon the inside surface of the spherical screen. The projection unit is designed and mounted so as to permit the pilot six degrees of freedom of the terrain image motion with respect to the cockpit.

The relief map reflection type of projection system was decided on after a detailed study was made of each of the known techniques of image generation and presentation. These studies indicated conclusively that reflected light projection of a relief map represented the most satisfactory system for use in the proposed simulator. The other projection systems that were analyzed include the following:

1. Strip film
2. Lantern slide of film mosaic
3. Virtual image
4. TV projection
5. Point source (Shadowgraph)
6. Actual model views (Dioramic representation)

A virtual image presentation was eliminated from consideration as a possible projection system because the terrain image is incapable of simulating the pilots natural view. If a positive, or converging, lens is used, the apparent height of a ground object scale factor, instead of decreasing linearly, increases in proportion to the square of the distance away from the lens. This condition is the dramatic opposite to the law of nature, wherein parallel lines seem to converge to a single point far in the distance. If a negative lens is used, the size of the virtual image decreases as the object is drawn further away from the lens. However, the image never moves further from the lens than the focal plane, even though it does decrease in size. Special simulation of altitude is therefore defective. The infinity of space is paradoxically reduced to the focal length of the lens.

Limited lens tests were performed to find a very wide angle lens suitable for the requirements of the simulator. Several photographic lenses were tested, one of 142° and the other of 165°, fields of view, respectively. Resolution of these two lenses, while good on axis, degraded significantly towards the edges of the fields of view.

The authors state that good resolution can be anticipated with similar lenses of longer focal length and smaller relative aperture procured especially for the ground image projector. One type of lens they advise for future development is the inverted telephoto-type lens system.

Author: Taylor, D.W. (Assigned to: Motorola, Inc., Chicago, Ill.)

Title: Electronic Image System and Method U.S. Patent No. 2,944,174 July 5, 1960, Patent Office, Washington, D.C.

SUMMARY: This patent covers a magnetic lens technique for magnifying the horizontal deflection component. Usually this results in minification of the vertical dimension, when physically obtainable fields are considered.

The inventor claims that if one permits the minified dimension to run to the extreme, the picture flips over and becomes magnified.

A 21 inch receiver was constructed that had a horizontal power requirement only four percent, and vertical power requirement 25 percent of what would be required using conventional techniques.

Astigmatism is introduced by the use of this invention, but this, it is claimed, is easily removed by a corrector lens.

A further boon is that the effective deflection center is moved forward, minimizing neck shadow problems.

Author: Tucker, A.R., and Weiss, M. (Assigned to Dalto Electronics Corp.)

Title: Electronic System for Generating a Perspective Image, U.S. Patent No. 3,060,596, Oct. 30, 1962, Patent Office, Washington, D.C.

SUMMARY: A flying-spot scanner is described in which a triangular raster is generated and used for scanning while the display is a conventional rectangular raster. This results in generation of a perspective display of a plane surface from a plan view of this surface. Several details relating to the spacing of raster lines and the distribution of detail are disclosed.

Yaw is accomplished optically by means of a pechan prism; translatory motions are accomplished by physical motion of the scanned transparency; and rotary motion is proposed to be achieved by means of a separate closed-circuit television link.

The features described in this patent seem to be some of those used in the "Scanalog" simulator system manufactured by the assignee, Dalto Electronics Corp.

Author: Undersea Technology

Title: "Submarines Guided by TV Display", <u>Undersea Technology</u>, August, 1965, pp. 28-29.

SUMMARY: This article describes a synthetic TV display for the training of helmsmen and pilots of submarines. The system, developed at Norden Division of United Aircraft Corporation in Norwalk, Connecticut, is called Conalog, or contact analog, a name derived from the fact that its presentation is analogous to contact or visual flight.

Conalog is a complex, solid-state electronic system of integrated and miniaturized circuits which draws information from the vehicle's sensing instruments, such as the depth indicator. It performs computations on varied information and generates a continuous television picture of the vehicle's reference, attitude, and response. No camera is involved in presenting the display, although an actual television picture of the outside world can be superimposed on the display.

A horizon line bisects the 19-inch picture tube. The ocean's surface is represented at the top of the picture by a grid pattern, and the bottom of the sea or the submarine's depth limit is represented by a similar grid pattern. A cross symbol (+), representing the bow of the ship, is stretched along an endless roadway stretching from the horizon line. Black "tar strips" moving along the roadway at scaled intervals give the impression of speed and forward movement.

Author: Vine, B.H., et al

Title: Applied Research On High Resolution Camera Tubes
Interim Technical Documentary Report No. 5, 1 September to 31 December 1963. BPSN No. 2(670-4156-41653) Contract No. AF33(657)-7939 to RCA, Lancaster, Pa.
(AD-427824)

SUMMARY: This is a continuation of RCA work in developing an image orthicon target structure for a high sensitivity camera tube (orthicon or vidicon) capable of 1500 TV lines per inch at 50% sinewave response over a format of 2" by 2".

Nine 4-1/2 inch tubes were built and tested. It was found that the resolution of vidicon targets was approximately twice that of orthicon targets. Signal to noise ratios of 100 to 1 in a 20 mc bandwidth were obtained in a special 4-1/2 inch multiplier vidicon using a 1000 line mesh. Measurements made over a 10 x 10mm central area indicated a sinewave equivalent response $N_e$ of 15 to 21 TV lines/mm. Apparently no measurements were made in areas far removed from the center.

Much of the report is devoted to a test setup and test results obtained for about ten different lenses to be used in conjunction with the tubes.

Author: H.A. Wagner Co., Van Nuys, California

Title: Preliminary Proposal, Final Equipment Development and Construction of Prototype Trainer, Tank, Platoon Leader, Device 17-AR-1. May 1957

SUMMARY: This proposal describes a facility and installation for the training of tank platoon leaders under simulated battle conditions. A terrain model would form the external environment of an overhead gondola in a training room. A set of five interchangeable models will be utilized to represent a variety of types of terrain: typical European, mountainous, arctic, desert, and jungle. Each terrain model will be approximately 40 ft. x 60 ft. in size and represent, at a scale of 1:150, typical terrain features such as roads, hills, buildings, vegetation, etc. Infantry models and remotely controlled vehicle models would be utilized to heighten the sense of realism.

The gondola comprises the trainee's simulated tank turret, the turret's supporting structure, and a structural support for a direct-viewing periscope. The turret will duplicate the inside of a tank commander's station of the M48 tank. The turret will be stationary with respect to the gondola, but the cupola, a functional replica of that found on the tank, will be rotatable in azimuth, and the hatch will open and close.

When a trainee is in his operating position, he can view the terrain only through the optical system provided. A multipath optical periscope system would provide a realistic simulation of the viewing situation that exists when a tank platoon leader rides with his head out of the cupola for direct viewing of the terrain. From inside the cupola, the trainee views through the cupola periscope and viewing slots and through the rangefinder. The internal arrangement and mechanisms of an M48 tank turret are reproduced in the gondola and the trainee would perform all the necessary functions of the tank platoon leader

in the proper manner. The tranlations of the gondola are controlled by the trainee's tank driver who is stationed on an overhead gallery where he cannot be seen by the trainee, but from where he can observe the terrain, the gondola's position, and the position of the periscope pickup prism.

The multipath periscope is a unit-power viewing system. A successive image--relaying system pipes the light from the model terrain surface to the trainee's eyes. It provides the same visual effect as if the observer's eye were actually placed at the instruments exit pupil. A mechanical construction around the optical system will provide five degrees of freedom of head motion.

The upper viewing head will be used to deliver images to the five viewing slots in the cupola. A coincidence rangefinder would be simulated by inserting a pair of small rhomboid prisms in front of the pickup prism. At such times the periscope and viewing slots will be inoperative.

The trainer will provide an azimuth presentation of 360° and a vertical field angle of 80°.

Author: Wallace, K.F., et al

Title: Electrical Readout for Wideband Electron Beam Recording, Final Report, Contract AF30(602)-2474 to Ampex Corp., Redwood City, Calif.
Report RADC TDR-62-394 dated Sept. 27, 1962
(AD-293201)

SUMMARY: Several possible methods for obtaining wideband electrical readout of thermoplastic recordings are discussed. Practical limitations encountered with flying spot scanners and vidicon techniques are considered, and some laboratory measurements are presented.

A secondary emission readout scheme is detailed in which the fundamental frequency limitations are in excess of 100 Mc. This secondary emission readout approach lends itself to servo tracking which can be used to maintain the scanning beam in the correct position relative to the recording surface and to permit ready location of the recorded groove. Experiments show that this type of tracking is successful despite large errors in the original recording.

Photographs of a feasibility model with a sixty megacycle output are included in the report.

Author: Whitby, C.M.

Title: "Image-Related Scanning Systems for Visual Simulation". Paper presented at AIAA/AFLC/ASD Support for Manned Flight Conference, Dayton, Ohio, April 21-23, 1965.

SUMMARY: This paper was a description of three Bell techniques used for image generation in connection with space simulation work. For the generation of simple forms, the system is highly efficient, but as the array of possible generated patterns becomes more complex, the advantages decline rapidly.

The first two techniques described are used to generate a toroidal-shaped space station (used as an input to the ACF simulator) and to generate an Agena-shaped cylindrical vehicle, used as an input to the Farrand Gemini Infinity Display System. From the description of the various factors which have been considered and corrected for, it would seem that the generation would be very realistic.

Analog computer simulation is used for generation of the geometry of the subject to be displayed. The coordinate systems of the subject and the viewing vehicle are related to inertial coordinates, and corrections made for perspective, distance, illumination source, beam spot velocity, etc. The main advantage over a conventional TV system with a model is that no model, gimballing system, camera or illumination system is necessary. The main disadvantage is that the programming becomes extremely complex if even moderately fine detail is to be presented in addition to the vehicle outline. (For instance, to have the letters NASA appear on the vehicle would be highly involved.)

The advantage of setting the scan pattern to conform to the image, rather than to use a fixed raster scan is very potent for images which do not fill the television display screen. A major limitation of the technique is the difficulty in matting multiple images, or in insetting the generated image into a raster-scanned TV background.

System advantages over the probe and model type of image generator are as follows:

Improved resolution in high data portions of the scene. (This results in better-than-TV resolution in distant subjects, but poorer than TV realism for subjects closer than about seven feet.)

High contrast ratios possible, more nearly approaching the condition of the real space scene.

Full angular and positional freedom, without singular points.

Multiple window generation with modest increases in system cost and complexity.

System economy in size and cost over that using a model and TV pickup.

The Earth Orbital Scene Generator used for developing the video for the Gemini rendezvous mission simulator was used as an illustration of the synthetic generation technique. A drawing showing the major system components was presented. This included a flying-spot scanner for producing the earth scene background from a color transparency. The flying-spot scanner uses an image-related scan (rather than a rectangular raster) which is coordinated with the Agena vehicle generated by computer. This permits simple insetting of the two overlapping images.

The flying-spot scanner technique was used as an illustration of image-related scanning to pickup from a transparency. An artificially generated mid-course earth image was shown, together with the transparency from which the information was derived. The effect was very realistic, although it would seem that resolution at close ranges would be insufficient to maintain the illusion.

Author: Whittenburg, J.A. and Wise, J.E.

Title: Feasibility for Research Application of Visual Attachments for Dynamic Flight Simulators. Report No. 2: Requirements and State-of-the-Art Evaluation. Human Sciences Research, Inc., Arlington I, Virginia. HSR-RR-62/10-Mk-X, February 1963. Contract No. FAA/BRD-401, Project No. 421-12R.
(AD-401 129)

SUMMARY: This report identifies human factors research requirements for visual attachments to dynamic flight simulators, and evaluates the state-of-the-art in visual simulation techniques for meeting these requirements.

Six major techniques employed by industry were evaluated. These techniques are:

1. Computation of pictorial elements technique
2. Film technique
3. Direct viewing (model) technique
4. Optical display projection technique (Diascopic and Epidiascopic)
5. Closed circuit television technique
6. Synthetic image generation technique

Examples of systems developed or proposed, utilizing these techniques, are listed. The industries visited, as well as descriptions of their systems and techniques, are described in another report (see Wise and Whittenburg).

Requirements for visual attachments were grouped under two major criterion sources: physical fidelity and perceptual fidelity.

1. Physical fidelity: This is the capability of simulating properties of the external world. Four general properties of physical phenomena which were investigated are: photometric and colorimetric variables, ambient variables, spacial variables, and dynamic variables.

2. Perceptual fidelity: This is the capability of reproducing the phenomenologically descriptive characteristics of the "perceived" real world. Four major subdivisions of variables are: brightness and color contrast, atmospheric representation, object/contour representation, and apparent motion perspective.

The results of rating major state-of-the-art techniques in terms of meeting the physical fidelity and perceptual fidelity criterion sources are shown in the two charts which follow. Bases for rating the techniques are given in a study appendix.

CHART I: RATING MAJOR STATE-OF-THE-ART OF VISUAL ATTACHMENT TECHNIQUES IN TERMS OF MEETING PHYSICAL FIDELITY CRITERIA

0 = Poor, 1 = Fair, 2 = Good

| | Physical Fidelity Criteria | | | | |
|---|---|---|---|---|---|
| Visual Attachment Technique | Photometrics/ Colorimetrics | Ambient | Spatial | Dynamic[1] | Total |
| Pictorial Element Computation | 0 | 0 | 1 | 0 | 1 |
| Film | 0 | 1 | 2 | 0 | 3 |
| Direct Viewing | 0 | 0 | 2 | 1 | 3 |
| Optical (Diascopic) | 0 | 0 | 0 | 0 | 0 |
| Optical (Epidiascopic) | 0 | 0 | 0 | 1 | 1 |
| Closed Circuit Television | 0 | 0 | 2 | 1 | 3 |
| Synthetic Image Generation | 0 | 0 | 1 | 1 | 2 |

1. Unprogrammed "closed loop" mode.

## CHART 2: RATING MAJOR STATE-OF-THE-ART VISUAL ATTACHMENT TECHNIQUES IN TERMS OF MEETING PERCEPTUAL FIDELITY CRITERIA

0 = Poor, 1 = Fair, 2 = Good

| | Perceptual Fidelity Criteria | | | | |
|---|---|---|---|---|---|
| Visual Attachment Technique | Brightness and Color Contrast | Atmospheric Representation | Object/Contour Representation | Apparent Motion Perspective[1] | Total |
| Pictorial Element Computation | 1 | 0 | 1 | 0 | 2 |
| Film | 2 | 2 | 2 | 2 | 8 |
| Direct Viewing | 2 | 1 | 2 | 1 | 6 |
| Optical (Diascopic) | 1 | 0 | 0 | 0 | 1 |
| Optical (Epidiascopic) | 0 | 0 | 1 | 1 | 2 |
| Closed Circuit Television | 0 | 2 | 2 | 1 | 5 |
| Synthetic Image Generation | 0 | 1 | 1 | 1 | 3 |

1. Unprogrammed "closed loop" mode.

Author: Wicklund, H.P.

Title: Flight Trainer, U.S. Patent No. 2,591,752, April 8, 1952. Patent Office, Washington, D.C.

SUMMARY: This invention relates to "an apparatus and a method for producing an illusion of the effects of the flight and flying of an airplane by a person". According to the general arrangement, a pilot sitting behind the controls in a mock cockpit assembly views through an optical system an area containing a terrain model. The elements of the optical viewing system are remotely controlled, in response to manipulations of the mock control elements by the pilot in the cockpit. The resulting image of the model simulates and transmits to the pilot the illusion of seeing an actual view as would be seen from the cockpit of a real plane. An instrument panel is also introduced into the observer's field of vision through the optical system.

A prototype of the flight trainer is described in "Operating Manual (Maintenance) for Contact Flight Simulator, Device 14-L-2, (see Farrand Optical Company, Inc.).

Author: Wise, J.E. and Whittenburg, J.A.

Title: Feasibility for Research Application of Visual Attachments for Dynamic Flight Simulators. Report No. 1: State-of-the-Art Survey of the Visual Simulation Industry. Human Sciences Research, Inc., Arlington 1, Virginia. HSR-RR-62/7-Mk-X, July 1962. Contract No. FAA/BRD-401, Project No. 421-12R
(AD-298 056L)

SUMMARY: This is one of two reports which analyzes the research applications of visual simulation techniques and systems. The first report contains a compilation of current (1962) information on the state-of-the-art in the visual simulation industry. A second report, which is separately bound (see Whittenburg and Wise), describes the general requirements for a dynamic closed loop visual simulator and evaluates present visual simulation techniques and specific systems for meeting these requirements.

Report No. 1 is divided into four sections. The first section pertains to methods used in the collection of data during the field survey. It provides information pertaining to sources of manufacturer listings, manufacturers who were selected for the survey and whose facilities were visited, and the procedures that were used from initial manufacturer contact through development and utilization of technical interview questionnaire.

The second section describes the various techniques that are employed by industry in the design and manufacture of visual simulation systems. Each technique is examined by providing a general description, noting variations in technique, identifying the capabilities and limitations, and listing a sample of systems utilizing that particular technique.

Section III reports on industry itself. Nine manufacturers who either have or had background in the visual simulation field were selected for study, and these nine were

considered representative of the industry. For each manufacturer, as much relevant information as possible pertaining to systems either in production or undergoing development is given. Where information exists, the mathematical solution, complete with formulas, of a particular system is presented. Related systems or techniques that are either in production or undergoing development are also discussed.

The last section of this report consists of a system specification check list and a bibliography.

Author: Wojcik, F. A.

Title: Cubical Vision Motion Picture Apparatus, U.S. Patent No. 2,997,537, August 22, 1961, Patent Office, Washington, D.C.

SUMMARY: This patent describes a cubical vision motion picture apparatus consisting of two separately located and synchronized peripheral motion picture camera projectors mounted in a horizontal plane and in a vertical plane, respectively. Each camera sweeps through a 360° angle of view, and simultaneously projects an orthographic image onto the surface of a television camera tube. The electronic signals from the horizontal and vertical television camera tubes are utilized to form a montage comprising an undistorted orthographic television picture of the enveloping region consisting of six, 90° by 90° views arranged in a preferred pattern.

The author claims his invention to be the nearest solution to the "all seeing eye" that is indispensable in a perfect remote control guiding system, such as used in guided missiles, space ships, etc.

Author: Wolfe, C. E.

Title: "Information System Displays for Aerospace Surveillance Applications", IEEE Transactions on Aerospace, Volume 2, No. 2, April 1964, p. 204-210.

SUMMARY: This paper discusses the concepts of information system technology as related to aerospace surveillance systems. Information requirements for surveillance systems are defined, followed by a comprehensive digest of the state-of-the-art in displays. The emphasis is on the future potential of the displays to aerospace surveillance systems. Photographic and projection techniques are discussed, with examples being cited of various techniques. Most of the devices use a modified Schlieren optical system for projection.

The auther concludes that the state-of-the-art in individual and group displays has not achieved the ultimate information display requirements.

Author: Woodson, R.A.

Title: "Space Flight Visual Simulation Systems", Advances in the Astronautical Sciences, Vol. 16, Part 2, Norman V. Petersen, editor, Western Periodicals Company, North Hollywood, California, 1963, p. 188-205.

SUMMARY: This paper reviews various types of visual simulation techniques: closed circuit TV, electronically synthesized images, motion picture film, celestial projection, point light source projection, compensated offset projection, variable perspective projection, synthetic perspective image generation, and composite image viewing. Examples of systems incorporating these techniques are given. These include such systems as: Variable Anamorphic Motion Picture System (VAMP), Compensated Offset Projection System, Point Light Source Projector for Helicopter Trainer, Electronic Night Landing Visual Display System, VisuaLink Closed Circuit TV, In-Flight Refueling Display, and several others. The discussion of these systems is brief, and does not contain any quantitative data. No evaluation of these systems is attempted, either.

A description is given for an out-the-window display system which fulfills the requirements of the Edwards Space-Flight Simulator and further represents the latest state-of-the-art in visual simulation techniques. The description is applicable to the training of the student aerospace pilots of the Aerospace Research Pilot School. The display is described in terms of the required types and number of visual display inputs. The basic system approach covers the multi-phases of the flight mission and the basic displays which are required to present a full simulated mission.

As described herein, images are projected onto a spherical screen, located

at a distance of approximately 15 feet from two astronauts. Since the view points of the astronauts are 35 inches apart, it is necessary to project duplicate views of the display on the screen, separated effectively by 35 inches. Each astronaut sees objects at infinity in the same direction as the other astronaut with respect to the capsule. The two projected displays are separated by using two sets of projectors in a semi-specularly reflecting screen with lenticular surface.

Author: Xhignesse, L.V.

Title: Selective Survey of French Developments in Flight Simulators and Flight Instruments. I. Flight Simulators. University of Illinois, WADC Technical Note 57-378, June 1958. Contract No. AF 33(616)-3000, Project No. 6190-71373.
(AD-142 130)

SUMMARY: A selective survey of French developments in aircraft and missile simulation is undertaken in this paper. Several types of simulators were discussed: a flight simulator for a primary trainer with the conventional engine type; three types of helicopter simulators; and a simulator for an air-to-ground or ground-to-ground missile.

All the devices had systems for simulating aspects of the external visual environment. In addition, all simulators utilized the point light source projection technique. In general, the French simulators that were examined are less sophisticated in style than are their American countertypes. Another characteristic of American simulators is that they tend to be relatively rigid with respect to the basic aircraft type for which they provide simulation. The French simulators permit easy change of simulated flight characteristics so that the same device can be used in training for proficiency in more than one model. Extensive modifications are required to change flight characteristics of American simulators.

This report does not present an in-depth discussion of simulation techniques. The point light source projection technique which forms a basis for the French flight simulation systems has been evaluated in several American reports that are identified in this section. Since this report was written in 1958, it is questionable that the work reported here represents the state-of-the-art of the French simulation industry.

Author: Yoshiro, H.

Title: Apparatus for Photographing and Projecting a Motion Picture Image of a Very Wide Angle, U.S. Patent No. 2,928,313, March 15, 1960, Patent Office, Washington, D.C.

SUMMARY: Apparatus for photographing and projecting a motion picture film having a horizontal field angle of up to 360° is described. The camera has a fixed cylindrical drum on which film is mounted on the inside circumference, and an optical system which rotates concentric to the drum. A slit in the optical system focal plane limits the area of film which is exposed as the system rotates, minimizing the aberration of the image. Unexposed film is continuously fed to the cylinder wall while the optical system rotates.

A projector, based on the same principal as the camera, utilizes several optical systems and light sources in order to increase the luminous intensity of the image, as the image is projected on the inside surface of a concentric cylindrical screen.

# SECTION III

## BIBLIOGRAPHY

Over 400 items of literature were read and evaluated for the literature search. Approximately 120 of these were of enough importance to be abstracted; these appear in Section II. Some literature was discarded as being irrelevant to a study of visual simulation devices and techniques. The reason for ordering this material, in the first place, was due to misleading titles.

The remainder of the literature that was studied is listed in this section, and can be considered as a general bibliography of background material to a study of simulation, display, or television systems. The references are listed alphabetically by authors under selected subject headings.

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F. Photographic and Other Instrumentation

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(AD-432 459)

Section IV

# TELEVISION SURVEY

# SECTION IV

## TELEVISION SURVEY

A questionnaire was prepared for use in a survey of television manufacturers to determine the state-of-the-art of the industry. The purpose of the survey was to compile data descriptive of the latest state-of-the-art techniques in high resolution, closed circuit TV systems and their ancillary parts, such as pickups and probe optics.

Included in this section are the state-of-the-art questionnaire that was circulated, a list of manufacturers and suppliers of television system and components to whom the questionnaire was sent, and a summary of replies that were received.

## A. STATE-OF-THE-ART QUESTIONNAIRE

Gentlemen:

The Farrand Optical Company, under contract NAS 9-3678, is currently engaged in a study of advanced television systems for the National Aeronautics and Space Administration. This study will result in a set of specifications for an advanced television system in the next year. A second objective will be an outline description of the "best" system deemed possible in the coming five-year period. In addition, NASA and other Government agencies are expected to use the study report in specifying and evaluating other advanced television procurements.

You and your company may be able to help the Government in this search. (Farrand is a user, rather than a supplier, of television components and systems.)

To assist you in interpreting our request, a Technical Discussion is appended to this letter. Any pertinent data received will be included in our report to NASA, and any data you wish to mark "proprietary" will, of course, be so reported and handled.

The requirements of our study include the following:

1. Establishment of parameters and techniques of most importance in the presentation of a wide-field picture to a TV Viewer, as well as alternative trade-offs among these parameters.

2. Specifications for the most advanced Closed Circuit TV System, in the sense of (1) above, to be procurable within one year.

3. Preliminary specifications for a Closed Circuit TV System adhering to (1) above more closely, to be available in the next five years.

Any assistance you can offer by participation in this program will aid our National Space Effort. Any suggestions, comments or literature you may offer to aid us in this program will be appreciated.

Very truly yours,

FARRAND OPTICAL CO., Inc.

RWT:RH:jp

Raymond H. Bull
Project Manager

## TECHNICAL DISCUSSION

### Survey of Advanced Television Systems

The prime objective of the TV system will be to provide a realistic display when used in conjunction with a wide-angle Infinity Display System.

By the optical techniques of the Infinity Display System, the CRT face may be made to subtend any apparent angle up to $140^\circ$ or more. For a $140^\circ$ angle, the effective viewing distance from an apparently flat tube face will be less than one fifth the picture width. Any curvature of the faceplate may be removed or inverted optically.

At such a close viewing distance, picture noise becomes an important subjective consideration. In addition, to provide full realism the TV resolution should be comparable with that of the human eye - about 1 minute of arc per line-pair, or 120 TV lines per degree. A system of this resolution appears to be unattainable at present. Even 6 times poorer resolution - 20 TV Lines per degree - is difficult to attain over a $140^\circ$ wide field, since it would mean 2800 TV Lines per picture width.

A $140^\circ \times 100^\circ$ picture of 20 TV lines/degree contains $140 \times 100 \times (20)^2 = 5.6 \times 10^6$ picture elements. At 30 frames/second, the information rate is $168 \times 10^6$ picture elements/second. Using a Kell factor of .75, retrace time of 10%, and the factor of 2 picture elements per cycle, the bandwidth required to transmit this information is $(168 \times \frac{10}{9} \times 10^6)(\frac{4}{3})(\frac{1}{2}) = 124.$ mc.

Reasonably good sensitivity will also be important. Highlight illumination at the pickup tube faceplate can probably be maintained at about 1 foot-candle for small area pickup tubes.

The objects of the current search are three-fold:

1. To determine those tradeoffs in system parameters which result in the most realistic-appearing picture when not all parameters can be optimized.

2. To establish a set of specifications for the most realistic TV display system in light of the results obtained above. (These specifications must be realizable as an off-the-shelf system or as a modification, to be available within one year.)

3. To determine what is the best that can be expected in this area over a longer term effort of about 5 years. This will definitely include non-standard techniques such as special scans, mosaic and composite device systems, in addition to more advanced versions of existing sensors and displays.

Please address your reply, and any questions you may have to:

Mr. M. C. Baum
Farrand Optical Company, Inc.
4401 Bronx Boulevard
New York, New York 10470

## B. ORGANIZATIONS SURVEYED

1. Adler Westrex Comm. Division
   1 LeFevre Lane
   New Rochelle, New York

2. Admiral Corporation
   Government Electronics Division
   3800 West Cortland Street
   Chicago, Illinois

3. Akutron, Inc.
   8451 Standustrial
   Stanton, California

4. Ameco, Inc.
   P.O. Box 11326
   Phoenix, Arizona

5. American Comm. Corp.
   280 Broadway
   New York, New York

6. Amprex Electronic Corporation
   P.O. Box 418
   230 Duffy Avenue
   Hicksville, New York

7. Automation Laboratories, Inc.
   179 Liberty Avenue
   Mineola, New York

8. Avia Products Company, Inc.
   631 B South Walnut
   LaHabra, California

9. Ball Brothers Research Corporation
   Boulder, Colorado

10. Bell Aerosystems Co., Division of
    Bell Aerospace Corporation
    Box 1
    Buffalo 5, New York

11. Benco Television Associates, Ltd.
    27 Taber Road
    Rexdale, Ontario, Canada

12. Bendix Corporation
    Red Bank Division
    Highway 35
    Eatontown, New Jersey

13. Bendix Corporation
    Bendix Radio Division
    East Joppa Road
    Baltimore, Maryland

14. Bionic Instruments, Inc.
    221 Rock Hill Road
    Bala Cynwyd, Pennsylvania

15. Blonder-Tongue Labs., Inc.
    9 Alling Street
    Newark, New Jersey

16. Bludworth Marine Division
    States Electronics Corp.
    96 Gold Street
    New York, New York

17. Calvert Electronics, Inc.
    220 East 23rd Street
    New York, New York

18. Camera Equipment Co., Inc.
    315 West 43rd Street
    New York, New York

19. CBS Sales
High Ridge Road
Stamford, Connecticut

20. C-Cor Electronics, Inc.
Box 824
State College, Pennsylvania

21. Cohu Electronics, Inc.
Kin Tel. Division
5725 Kearny Villa Road
San Diego, California

22. Collins Radio Company
Dallas, Texas

23. Dage Television Company
455 Sheridan Avenue
Michigan City, Indiana

24. D B M Research Corp.
Box 521
Cocoa Beach, Florida

25. Diamond Electronics
Box 415
Lancaster, Ohio

26. A. B. Dick Company
5700 W. Touhy Avenue
Chicago, Illinois

27. DuMont Labs.
Electro Visual Department
750 Bloomfield Avenue
Clifton, New Jersey

28. Dynair Electronics, Inc.
6360 Federal Boulevard
San Diego, California

29. Elgeet Optical Co., Inc.
303 Child Street
Rochester, New York

30. English Electric Valve Co., Ltd.
Chelmsford
Essex, England

31. Entron, Inc.
2141 Industrial Parkway
Silver Spring, Maryland

32. G B C America Corporation
89 Franklin Street
New York, New York

33. General Atronics Corporation
Electronic Tube Division
1200 East Mermaid Lane
Philadelphia, Pennsylvania

34. General Electric Company
Industrial Sales Division
1 River Road
Schenectady, New York

35. General Electric Company
Light Military Electronics Department
901 Broad Street
Utica, New York

36. General Electric Tube Department
316 East Ninth Street
Owensboro, Kentucky

37. General Electrodynamics Corporation
4430 Forest Lane
Garland, Texas

38. General Instrument Corporation
Radio Receptor Division
Andrews Road
Hicksville, New York

39. General Television Network
901 Livernois Avenue
Ferndale, Michigan

40. Giannini Controls Corporation
1600 South Mountain Avenue
Duarte, California

41. Giannini Scientific Corporation
185 Dixon Avenue
Amityville, New York

42. GPL Division
General Precision, Inc.
63 Bedford Road
Pleasantville, New York

43. Hitachi Sales Corporation
666 Fifth Avenue
New York, New York 10019

44. Hughes Aircraft Company
Vacuum Tube Products Division
2020 Oceanside Boulevard
Oceanside, California

45. International Electronics Corporation
81 Spring Street
New York, New York

46. International Telephone & Telegraph Co.
3700 East Pontiac Street
Fort Wayne, Indiana

47. ITT Kellogg
Communication Systems
500 North Pulaski Road
Chicago, Illinois

48. Jerrold Electronics Corporation
Industrial Products Division
15th and Lehigh Avenue
Dept. ITE-138
Philadelphia, Pennsylvania

49. Kaiser Aerospace & Electronics Corp.
Box 9098
Phoenix, Arizona

50. Kriss Electronics, Inc.
191 Oraton Street
Newark, New Jersey

51. Litton Industries
Electron Tube Division
960 Industrial Road
San Carlos, California

52. Lear Siegler, Inc.
3171 South Bundy Drive
Santa Monica, California

53. LTV Continental Electronics Division
P.O. Box 17146
Dallas, Texas

54. The Machlett Labs., Inc.
1063 Hope Street
Springdale, Connecticut

55. Marconi Radio
Division English Elec. Corporation
750 Third Avenue
New York, New York

56. Maryland Telecommunications, Inc.
York and Video Roads
Cockeysville, Maryland

57. Matsushita Electric Corp. of America
200 Park Avenue
New York, New York

58. Motorola Communications & Electronics, Inc.
4501 Augusta Boulevard
Chicago, Illinois, 60651

59. Mullard, Inc.
125 Park Avenue
New York, New York

60. Mullard Overseas Ltd.
Mullard House
Torrington Place
London, W.C. I, England

61. North American Philips Co., Inc.
100 East 42nd Street
New York, New York

62. Novicor Electronics, Inc.
3000 Industrial Boulevard
Bethel Park, Pennsylvania

63. Oceanographic Engineering Corp.
Box 1560
LaJolla, California

64. Packard-Bell Electronics Corporation
12333 West Olympic Boulevard
Los Angeles, California

65. Philco Corporation
Lansdale Division
Church Road
Lansdale, Pennsylvania

66. Philips Electr. Instrs. Division
Philips Electrs. Phara, Ind. Corp.
750 South Fulton Avenue
Mt. Vernon, New York

67. Photo Research Corp.
837 North Cahuenga Blvd.
Hollywood, California

68. Pierpont Industries, Inc.
77-15 25th Avenue
East Elmhurst, New York

69. Radio Communication Company
1020 East Land Place
Milwaukee, Wisconsin

70. Radio Corp. of America
Broadcast & Comm. Prods. Division
Front and Cooper Streets
Camden, New Jersey

71. Radio Corp. of America
Defense Electronic Products Div.
Front and Cooper Streets
Camden, New Jersey

72. Radio Corp. of America
Electronic Components and Devices
415 South Fifth Street
Harrison, New Jersey

73. Rank Cintel
Worsley Road
London, England

74. Rauland Corporation
4245 North Knox Street
Chicago, Illinois

75. Research Instruments Corporation
16 South 12th Street
Richmond, Virginia

76. Riker Industries, Inc.
875 East Jericho Turnpike
Huntington Station, New York

77. R. M. S. Associates, Inc.
102 East Sanford Boulevard
Mount Vernon, New York

78. Sanyo Seiko Co., Ltd.
634 Mizudo Kiyoshi-Shinden,
Amagasaki
Hyogo Pref., Japan

79. Sarkes Tarzian, Inc.
Semiconductor Division
415 North College
Bloomington, Indiana

80. Siemens America, Inc.
350 Fifth Avenue
New York, New York

81. Sony Corporation of America
Ind. Products Division
580 Fifth Avenue
New York, New York

82. Spectron, Inc.
4216 Ponce De Leon
Coral Gables, Florida

83. Spencer-Kennedy Labs., Inc.
1320 Soldiers Field Road
Boston, Massachusetts

84. State Labs., Inc.
215 Park Avenue South
New York, New York

85. Surface Conduction, Inc.
1501 Boardway
New York, New York

86. Sylvania Electric Products, Inc.
Electronic Tubes Division
Seneca Falls, New York

87. Sylvania Electric Products, Inc.
Home and Comm. Electronics Division
700 Elliott Street
Batavia, New York

88. Sylvania Electric Products, Inc.
Home and Commercial Electronics Division
730 Third Avenue
New York, New York

89. Techniserv Corporation
370 North Halstead Street
Pasadena, California

90. Telectro Industries Corporation
35-16 37th Street
Long Island City, New York

91. Telemet Company
185 Dixon Avenue
Amityville, New York

92. Teletronics, Inc.
7542 Park Avenue
Garden Grove, California

93. Television Utilities Corporation
10-11 50th Avenue
Long Island City, New York

94. Thomas Electronics, Inc.
122 Eighth Street
Passaic, New Jersey

95. Thomson Electric Company
50 Rockefeller Plaza
New York, New York

96. Thor Electronics Corporation
287 Morris Avenue
Elizabeth, New Jersey

97. Tor Labs., Inc.
2051 Pontius Avenue
Los Angeles, California

98. Video Color Corporation
729 Centinela Avenue
Inglewood, California

99. Warnecke Electron Tubes
175 West Oakton Street
Des Plains, Illinois

100. Westbury CATV Corporation
212 South Fulton Avenue
Mount Vernon, New York

101. Westinghouse Electric
Electric Tube Division
Box 284
Elmira, New York

102. Westinghouse Electric Corp.
1501 Franklin Avenue
Mineola, New York

103. The Whittaker Corporation
Gencom Division
12838 Saticoy Street
North Hollywood, California

104. Zenith Radio Corporation
6001 Dickens Avenue
Chicago 39, Illinois

105. Zoomar, Inc.
55 Sea Cliff Avenue
Glen Cove, L.I., New York

C. Summary of Replies

1. Ball Brothers Research Corporation
   Boulder Industrial Park
   Boulder, Colorado 80301

   This company has been designing a flexible TV slow-scan facility to be used in experimental verification of trade-offs in TV systems for space applications. Information was supplied on the Slow Scan Test Facility and on other applicable equipment designed and built by BBRC including their "Digilink" developments.

2. CONRAC
   Division of Giannini Controls Corporation
   Glendora, California

   Although present plans do not include wide field displays, CONRAC has provided a large group of 23" monitors at J.P.L., Pasadena. CONRAC monitors are widely used in existing simulators.

3. General Television Network
   901 Livernois Avenue
   Ferndale 20, Michigan

   In addition to large screen TV projectors that have been used in simulation, GTN is developing a completely transistorized large screen system which should present advantages in reducing both size and weight of equipment in this field. Information was supplied on the "giant view" equipment now available.

4. Hydro Products Division
   Oceanographic Engineering Corporation
   San Diego, California

   Developed for undersea applications, HP's high resolution camera low light level (600 lines at $\approx$ .10 foot/candles) and a 1000 watt Hg vapor light source could prove of value in certain types of simulators. Data was supplied describing some of the equipment that has been built for research and for industrial use.

5. Cooperative responses were also received from the following twenty other firms, British and Japanese as well as domestic. None of these suppliers, however had any contributions to make to the subject of simulation.

1. Admiral Corporation, Government Electronics Division, Chicago, Ill.
2. Collins Radio Co., Dallas, Texas.
3. A.B. Dick Co., Chicago, Ill.
4. English Electric Valve Co. Ltd., Chelmsford, Essex, England.
5. General Electric Co., Defense Electronics Division, Utica, N.Y.
6. Hitachi, Ltd., Tokyo, Japan.
7. ITT Industrial Products Division, San Fernando, California.
8. Jerrold Electronics Corporation, Philadelphia, Pa.
9. Lear Siegler Inc., Electronic Instrumentation Division, Anaheim, Calif.
10. The Machlett Laboratories Inc., Stamford, Conn.
11. Matsushita Electric Corporation of America, New York
12. Motorola Communications & Electronics Inc., Fair Lawn, N.J.
13. The Rank Organization, Welwyn Garden City, Herts, England.
14. Sony Corporation of America, Inglewood, Calif.
15. Surface Conduction Inc., New York

16. Sylvania Electric Products, Bedford, Mass.

17. Thor Electronics Corporation, Elizabeth, N. J.

18. Warnecke Electron Tubes Inc. , Des Plaines, Ill.

19. Whittaker Corporation, Gencom Division, Hollywood, California.

20. Zoomar, Glen Cove , New York.

## V. SIMULATION SURVEY

A. State-of-the-Art Questionnaire

B. Organizations Surveyed

C. Summary of Replies

# SECTION V

## SIMULATION SURVEY

A state-of-the-art questionnaire was prepared for use in a survey of the visual simulation industry. The main purpose of the survey was to compile descriptions of existing design principles or techniques, of a non-proprietary nature, that may be applied or adapted to a virtual image display system in such a way that current designs may be further enhanced in such areas as field of view, eye relief distance, exit pupil size, and other parameters.

This section includes: (A) the state-of-the-art questionnaire; (B) a list of industrial concerns, research institutions, and governmental agencies to which it was sent, and (C) a summary of replies. Every effort was made to adhere closely to the basic content of the replies in the course of editing them for greater brevity.

## A. STATE-OF-THE-ART QUESTIONNAIRE

Dear Sir:

The Farrand Optical Company, under Contract NAS 9-3678, is currently engaged in a study of virtual image, out-the-window display systems for the National Aeronautics and Space Administration. The objective of the program is to further the NASA flight simulation facility program for virtual-image out-the-window displays. This study will result in a statement of work for the design, development and construction of a very wide field of view display system whose configuration will be established at that time in concurrence with NASA.

As part of the study effort, a comprehensive survey is being made of the state-of-the-art of virtual image out-the-window display systems. Significant parameters, some of which follow, are being defined. An evaluation of the trade-offs or compromises that may be, or were, necessary to achieve a set of desired characteristics shall be included:

a) Field of view and format of field

b) Exit pupil and exit volume

c) Eye relief and clearance problems in inserting an image into a simulator cockpit

d) Distortion control

e) Image quality, contrast and resolution

f) Image illumination

g) Insetting methods for various types of input devices such as cathode ray tubes, film, direct projection from models, etc.

It is obvious that many of the parameters under consideration are common to other techniques and approaches used in visual simulation. For this reason, leading organizations (private companies, research institutions, and governmental agencies) engaged in some capacity in the design, development and/or evaluation of visual simulation techniques or devices are being contacted for this survey. You and your organization may be able to help us in this effort. The type of information that will aid us is, in general, embodied in this group of basic questions:

1) If you are, or have been engaged in the design and/or development of visual simulation techniques or devices, what basic techniques are, or were, used?

2) If you are, or have been engaged in the evaluation of visual simulation techniques or devices, what basic techniques are being, or were, evaluated?

3) Which of the parameters mentioned above are considerations in your techniques, devices or evaluation?

4) In your estimation, do any of the system components or techniques you are using represent improvements in the state-of-the-art?

5) If your answer to question 4) is YES, can you elaborate, or are proprietary interests involved?

6) What is the full name by which your technique or device is known? What specific vehicle or situation is it planned for? Is it adaptable to other vehicles or situations?

If it appears, from your answers to the above questions, that personal contact will improve the chances of maximum results from this study program, Farrand will request clearance to visit your facility. It is intended that non-proprietary material resulting from this study will be made available to cooperating organizations.

The Farrand Optical Company is actively engaged in the design and development of virtual image display systems for flight simulator out-the-window displays. Thus, in soliciting your cooperation in this survey, Farrand acknowledges that proprietary interests could conceivably create a conflict at some future date. It is for this reason that the Farrand Optical Company discourages the disclosure at this time of any proprietary methods or techniques which have not been properly protected by your company. However, since the report of this study has every indication of being a limited access document, it would be to your benefit to describe in generalized terms your current advances in the state-of-the-art of visual simulation for inclusion in said report. Again it is emphasized that disclosure of specific engineering principles and designs is not only discouraged but likely to be refused. The intent of this report is to make known to NASA and other interested agencies the current state-of-the-art.

Any suggestions, comments or literature you may offer to aid us in this program will be appreciated.

Very truly yours,

FARRAND OPTICAL CO., Inc.

R.H. Bull
Project Manager

RWT:RHB:sp

FOCI

## B. ORGANIZATIONS SURVEYED

1. ACF Electronics Div.
   ACF Industries, Inc.
   Riverdale, Maryland

2. Aerojet-General Corp.
   9100 E. Flair Dr.
   El Monte, California

3. Aeronutronics
   Div. of Ford Motor Co.
   Newport Beach, Calif.

4. Aircraft Armaments, Inc.
   Cockeysville, Maryland

5. Ames Research Center
   Moffett Field
   Sunnyvale (Mountain View)
   California

6. Aviation Medical Acceleration Lab.
   NADC
   Johnsville, Pa.

7. Bell Aerosystems Co.
   Div. of Bell Aerospace Corp.
   Buffalo, N.Y.

8. Bell Helicopter Co.
   Fort Worth, Texas

9. Boeing Co.
   Verrol Div.
   Morton, Pa.

10. Boeing Co.
    Renton, Washington

11. Boeing Co.
    1103 SW 166th Street
    Seattle, Washington 98166

12. Boeing Co.
    Wichita, Kansas

13. Cornell Aeronautical Laboratory, Inc.
    P.O. Box 235
    Buffalo, New York

14. Curtiss-Wright Co. - Electronics Div.
    35 Market Street
    E. Paterson, N.J.

15. Dalto Electronics Corp.
    38 Oak Street
    Norwood, N.J.

16. Douglas Missile & Space Systems Division
    2730 Ocean Park Boulevard
    Santa Monica, California

17. Drexel Dynamics Corp.
    Maple Avenue
    Horsham, Pa.

18. GAEC
    NADC Airborne Instrument Lab.
    Johnstown, Pa.

19. General Dynamics/Electric Boat
89 Eastern Point Road
Groton, Conn.

20. General Electric Co.
Missile & Space Div.
Spacecraft Dept.
P.O. Box 8555
Philadelphia 1, Pa.

21. General Electric Co.
Technical Products Dept.
Syracuse, N.Y.

22. General Electric (S.T.C.)
Valley Forge, Pa.

23. Goodyear Aerospace Corp.
Akron 15, Ohio

24. Grumman Aircraft Engineering Corporation
Bethpage, N.Y.

25. Honeywell, Inc.
Corporate Offices
2747 Fourth Avenue South
Minneapolis 8, Minnesota

26. Honeywell, Inc.
Simulation Studies Group
1360 Soldiers Field Road
Boston, Massachusetts

27. Hycon Mfg. Co.
700 Royal Oaks Dr.
Box 668
Monrovia, California

28. International Business Machines
Data Systems Div. Development Laboratory
Neighborhood, Road
Kingston, N.Y.

29. Jet Propulsion Laboratory
Calif. Inst. of Technology
Pasadena, Calif.

30. Ling-Temco-Vought, Inc.
PO Box 5907
Dallas, Texas 75222

31. Link Division
General Precision Inc.
Simulation and Control Group
Binghamton, N.Y.

32. Lockheed Missile and Space Co.
Department 465
P.O. Box A504
Sunnyvale, California

33. Marquardt Corp.
Pomona, Div.
2771 N. Garey Avenue
Pomona, California

34. Martin Co.
Baltimore, Maryland

35. Martin Co.
Denver, Colorado

36. The Matrix Corp.
507 18th Street S
Arlington 2, Virginia

FACI

37. McDonnell
Electronic Equip. Div.
P.O. Box 516
St. Louis, Mo. 63166

38. Melpar, Inc.
3000 Arlington Blvd.
Falls Church, Virginia 22046

39. MGD Research and Development Corporation
Subsidiary of Miehle-Goss-Dexter, Incorporated
22-10 State Highway #208
Fair Lawn, N.J. 07410

40. National Cash Register Co.
Electronics Division
Hawthorne, California

41. Norden Division
United Aircraft Corp.
Helen Street
Norwalk, Conn.

42. North American Aviation, Inc.
5701 W. Imperial Highway
Los Angeles, California

43. North American Aviation, Inc.
Columbus Division
4300 E. Fifth Avenue
Columbus 16, Ohio

44. North American Aviation, Inc.
Space & Information Sys. Div.
12214 Lakewood Boulevard
Downey, California

45. Northrup Corp.
Norair Div.
Hawthorne, Calif.

46. Oxford Corp.
5727 Main Street
Buffalo, N.Y. 14221

47. Radio Corp. of America
Defense Electronic Products
Burlington, Mass.

48. Radio Corporation of America
Front & Cooper Sts.
Camden 2, N.J.

49. Reflectone Electronics, Inc.
Stamford, Conn.

50. Rheem Electronics
5250 W. El Segundo Blvd.
Hawthorne, California

51. Rheem Manufacturing Co.
7777 Industry Avenue
Rivera, California

52. Ryan Aeronautical Co.
San Diego, California

53. Sikorsky Aircraft
Stratford, Conn.

54. Sylvania Electronic Systems
Eastern Needham, Mass.

55. University of Illinois
Urbana, Illinois

56. Vought Astronautics Div.
Chance Vought Corp.
Dallas, Texas

C. Summary of Replies

1. Aircraft Armaments, Inc., Cockeysville, Maryland 21030

Although this company has been very active in the simulation field, this activity has not extended significantly into the visual area. The visual portions of simulation systems have been furnished to them under subcontract. They are therefore not in a position to furnish information of the type requested.

2. Ames Research Center, Moffett Field, California 94035

This Center has been engaged in research on aircraft and spacecraft simulation problems using a number of different visual techniques. The research goals have dictated the acquisition of a number of different cue-producing devices which are assembled for a given research project in accordance with the cues most important to that project.

For aircraft use, three basic image generation devices have been used. These devices are basically servoed television cameras viewing aircraft runways. All of these systems present a view angle of approximately fifty degrees horizontally with the conventional 4:3 aspect ratio, 525 scan line, 30 frames per second television picture. When used with a fixed cab or a cab of moderate motion, the image had been presented by means of Schmidt projectors with the screen positioned so as to give the proper view angle with a picture 6-10 feet wide centered about the captain's seat. For presentations of this type, no attempt has thus far been made to collimate the display.

Spacecraft research simulations at the Ames Research Center, in which an out-the-window scene has been used, have thus far been limited to guidance, control, and navigation studies in the midcourse portion of the mission. The Midcourse Navigation Simulator has been the principal facility used for these investigations. The star field is located on a board 40 feet from the cab and contains background stars of subliminal size. In addition, four highly accurately placed collimated navigation stars are used together with a collimated moon landmark for research in navigational instruments and techniques. The collimated stars and landmark allow measurements to be taken to an accuracy of four arc seconds with some freedom of motion of the navigational instruments.

Because of the number of different image generators and display devices and the capability of combining them with different vehicle cockpits and motion generators, the limitations imposed on the out-the-window devices in any research project depend upon the experimental design of that project.

3. Cornell Aeronautical Laboratory, Inc., Buffalo, New York 14221

Cornell reviewed the subject matter and decided that they are not in a position to offer assistance at this time.

4. Curtiss-Wright Corporation, Electronics Division, East Paterson, N.J.

The Electronics Division developed the VISULATOR visual simulation equipment. However, they have not been active in the visual simulator product line for several years and, except for information in a VISULATOR brochure, had no information to submit.

5. Drexel Dynamics Corporation, Horsham, Pennsylvania

Drexel is unable to contribute any new technical information in the field of virtual image, out-the-window displays at this time.

6. General Dynamics, Electric Boat, Groton, Connecticut 06340

For over eight years, General Dynamics/Electric Boat has been directly involved in the design and development of tactical training devices (including submarine, land warfare, and surface ship operations) and scientific displays employing visual simulation techniques. The following is a partial list of General Dynamics/Electric Boat recent or current developments in this field:

a. Armor Leader Tactical Trainer (Device X17AR1)

General Dynamics/Electric Boat developed a system for the Army Participation Group at the U.S. Navy Training Device Center.

The training complex consisted of a 1/20 scale maneuvering area on which radio controlled vehicles, some of which carry self-contained television cameras/transmitters, operate in a simulated tactical arrangement under the control of student armor leaders. Twenty assorted friendly and opposition tanks and personnel carriers can be operated on the terrain at any one time, under the control of students located in balcony control booths. This system has proved very effective in the simulation of the "feeling" of driving a tank. For an expanded version of this training device, General Dynamics/Electric Boat is experimenting with 3-D television systems.

b. Periscope Optical Servo System

The Periscope Simulator was designed to handle 16 targets at ranges 600 feet to infinity, with speeds zero to 35 knots, and with sea state, time of day, shadows, and weather conditions included in the design considerations. This system was able to accomplish realism by utilizing scale model ships, servo activated, projected on a translucent screen using reflected light. Range and closing speed were achieved using an electrically controlled zoom lens.

c. General Dynamics/Electric Boat "EB 3-D" System

The Smithsonian Institution requested General Dynamics/ Electric Boat to develop a system suitable for the demonstration of various atomic theories for their newly constructed Hall of Science. Under contract, Electric Boat developed a 3-D optical system that presents apparent 3-D objects in space. Upon the development of this optical system, referred to as "EB 3-D", the Smithsonian Institution planned three major exhibits for fabrication: the Rutherford Bombardment Chamber, the radioactive atom, and the discovery of the nucleus. Of these, the Rutherford Bombardment Chamber has been fabricated, and the radioactive atom was scheduled to be completed by July 1, 1965.

The "EB 3-D" system is based on an image splitting glass that has a special optical coating on both sides. Each of these displays has a particular requirement for mechanisms to produce the appearance of various sub-atomic particles traveling through space. The system, which will also be in wide use at the 1967 World's Fair (Montreal), is applicable to portraying environmental and physical conditions (space, ocean currents, the aurora borealis, etc.).

d. 3-D Television System

General Dynamics/Electric Boat is currently investigating 3-D television systems for use in wide variety of visual simulation systems. Of particular interest is the application of such a system to the Armor Leader Tactical Trainer.

(The letter from which the foregoing was condensed resulted in a facility visit by the Farrand Optical Company. See General Dynamics/Electric Boat in Section VI: Facility Visits.)

7. General Electric Company, Space Technology Center, Missile and Space Division, Valley Forge, Pennsylvania

The Missile and Space Division of General Electric has conducted experiments utilizing two dimensional TV display presentations. Only state-of-the-art visual display techniques were used. No comparative evaluations were made of visual simulation techniques or devices.

8. Goodyear Aerospace Corporation, Akron 15, Ohio

Goodyear Aerospace Corporation (GAC) is engaged in the design, development, and evaluation of visual simulation techniques for use in training devices and research tools. Simulated vehicles include various aircraft, spacecraft, and land and sea roving craft.

A contract with the U.S. Department of Health, Education, and Welfare was recently completed for an automobile driving simulator test model. A test and evaluation program is presently being conducted by GAC Human Factors scientists, to determine its adequacy for driving behaviour research.

The automobile driving simulator operates in real time. The visual scene is generated by a servo-controlled optical probe moving over a three-dimensional relief model. A closed circuit television system provides the relay link between the generation system and the display. It operates with 675 scan lines and has a system bandwidth of 10 megacycles. The scene is projected onto a large curved screen positioned a few feet in front of a standard size automobile. The 9 ft by 12 ft screen is a rigid structure of exceptionally light weight. The semi-specular characteristics of the screen offer a gain of 22 with an effective exit pupil of 2 ft.

Other visual systems have been produced by GAC which allow true stereoscopic viewing of real time visual data. This has been accomplished without the need for special devices which the operator must wear. (Separate exit pupils are provided for each of an observer's eyes.)

Additionally, GAC has developed means for providing virtual image display systems with widely overlapping fields of view for two-man displays.

No obstructing media which would require special compensation in vehicle components such as size, location, or function are interposed between the men and display. Their approach to this system is considered proprietary; however, they feel it represents a significant advance in the state-of-the-art. The technique is made possible by their ability to fabricate very large shaped mirrors of appropriate optical and physical characteristics. The fabrication process results from corporate research programs in materials technology.

9. <u>Grumman Aircraft Engineering Corporation, Bethpage, Long Island, N.Y.</u>

Grumman has designed and developed some visual display equipments and devices in-house on occasion, but it has been a standing company policy to specify these subsystems and procure them from specialty houses. In this light, their design experience has been limited and knowledge is drawn mainly from what others have done in this field and their evaluation of these efforts.

In answer to the Farrand Optical Company questionnaire:

1. Basic techniques used:

   a. Moving 35mm color slide projection on rear viewing screen; F11F-1 and A6A roll divergence and longitudinal flying qualities simulations.

   b. Point light source reflective rear viewing screen projection; various V/STOL studies, LEM Lunar Landing, Missile Terminal Homing study, Carrier Landing study.

c. Front and rear viewing screen TV projection for LEM Engineering Simulations. Terrain and CSM scenes generated by six degree of freedom scanning systems. Starfield and blinking light CSM generators. TV scene mixing and electronic occulting using color and dichroic filter system.

d. Large screen, direct TV viewing on a CRT monitor (27 inch); MOLAB.

e. Electronic display generation; lissajous patterns and analog function generators driving a CRT.

2. Evaluation of visual simulation techniques:

a. GAEC has more or less continuously evaluated all types of state of the art systems. Evaluation has not been to a deep technical level in most cases.

b. Most recent review was for LEM trainer display procurement.

c. The value of a stereo scanner was evaluated.

d. Color presentation was evaluated.

e. Cinerama evaluated.

f. deFlorez Projector evaluated.

g. Thermoplastic Picture Recorders evaluated (General Electric).

h. Image "squeezing" using anamorphic lenses.

3. Parameters of interest:

    a. All those listed on page I of the Farrand Optical Company questionnaire.

    b. Model scaling and entrance pupil size.

    c. Size and weight of presentation device.

    d. Lighting spectrum bandwidth.

    e. Servo drive compatibility.

    f. Noise

    g. Depth of field/automatic focus.

4. Improvements of state-of-the-art:

    a. Yes

5. Partial Elaboration of (4):

    a. Use of surplus Nike-Ajax radar pedestals as spherical coordinate terrain map scanner transport systems.

    b. "Inside-out moon ball" combined with (a). Uses barrel distortion of optics in the scanner to curve the moon surface "outside-in".

6. Name of technique:

    a. Nike-Ajax scanner transport system (Scanoptic Viewing Head).

    b. Used for LEM Engineering Simulators.

    c. Adaptable to other vehicles.

10. Honeywell, Inc., Military Products Group, California Ordnance Center, West Covina, California 91790

Honeywell feels at the present time that the investigations and work presently underway at Honeywell in the field of visual simulation are proprietary and oriented to specific programs which they are pursuing actively. For that reason they must at this time decline to participate with Farrand and other developers of visual display systems in the study for the National Aeronautics and Space Administration.

11. International Business Machines Corporation, Data Systems Div., Kingston, New York

(The Farrand Optical Company questionnaire was forwarded to the IBM, Owego, New York facility, and culminated in a facility visit. See International Business Machines in Section VI: Facility Visits).

12. Ling-Temco-Vought, Inc., Astronautics Division, Dallas, Texas 75222

LTV have made a Manned Aerospace Flight Simulator. They do not currently employ the use of a virtual image display system; however, they are presently investigating the advantages of using this type of system.

13. Ling-Temco-Vought, Inc., Military Electronics Division, Dallas, Texas 75222

The type of display required for this program is not within the field of endeavor of LTV Military Electronics Division. A plotting-projection display system is in production at their facility.

14. The Marquardt Corporation, Pomona Div., Pomona, California

Marquardt have developed a visual system which offers a virtual image out-the-window display, highly adaptable to simulation applications. A breadboard unit of the system, called the VueMarq, has been fabricated and is in operation at Pomona.

(The basic concept of the VueMarq system was detailed in attachments. See VueMarq in Section II: Abstracts, of this volume, and Section III:

15. The Matrix Corporation, Arlington 2, Virginia

The Matrix Corporation has not been engaged in research in the area of virtual image displays.

(The survey questionnaire was addressed to Courtney and Company. Courtney and Company was acquired by the Matrix Corporation a few years ago and no longer exists as a separate entity.)

16. Melpar, Inc., Falls Church, Virginia 22046

Visual simulation techniques of subject type are not, as yet, a strong area of business for Melpar and the work they have done is proprietary in nature. They are unable, therefore, to furnish information at this time.

17. MGD Research & Development Corporation, Subsidiary of Miehle-Goss-Dexter, Incorporated, Fair Lawn, New Jersey 07410

The deFlorez Visual Display Projector was developed to project a wide angle terrain image picture for flight simulation It is able to provide a projection of a synthetic world to a pilot operating the controls of an aircraft simulator. The cockpit controls provide electrical signals to an analog computer capable of solving the dynamic equations of flight of the aircraft for which it has been programmed. The outputs of the computer are electrical signals corresponding to position and attitude of the aircraft in space. These outputs are relayed to the deFlorez projector which then presents to the pilot a projected display on a screen corresponding to what the pilot would normally see in an actual aircraft. The unprogrammed, wide angle projection is accomplished by a point light source system and is in full color.

Development of this system was carried out under contract for the Training Devices Center for the Navy. Another one of these units is in operation in the Ryan Aeronautical Simulation Laboratory. They are currently building similar systems for North American Aviation and Edwards Air Force Base. It should be pointed out that variations of this projection technique can be designed such as rear projection, or the use of reflective transparencies.

(A summary of specifications for the deFlorez Visual Display Projector was attached. See deFlorez in Section II: Abstracts, of this volume, and Section

18. <u>North American Aviation, Inc., Columbus Division, Columbus 16, Ohio</u>

NAA do not presently design, develop or fabricate simulation equipment for other than internal use. They have, however, been engaged in the development of visual simulation techniques for our internal application. Vidicon TV cameras are utilized with a monitor in an aircraft/spacecraft cockpit and/or a projected view on a screen in front of the pilot/astronaut.

The parameters considered have been: 1) field of view and format of field, 2) image quality, contrast and resolution, 3) image illumination, and 4) insetting the view from one camera onto that from another camera in the projected picture. They do not believe that the rather straight-forward techniques being used are advancing the state of the art.

Efforts in the field of simulation have been for the purpose of developing aircraft and missile systems, rather than the development of simulation capability per se. The abilities of the personnel involved and the particular equipment available have made their efforts to simulate real world situations relatively effective.

19. The Oxford Corporation, Buffalo, New York 14221

The Oxford Corporation developed a flight simulator for the Navy Department which used the virtual-image-out-the-window type of display. The simulator specifically was concerned with the carrier aircraft landing problem. A cockpit was involved with an external scene being presented depicting the sea and sky. An image of a carrier model was imposed on this background by means of a direct optical combining technique. There are no television pick-ups involved in the system. The entire system employs a direct optical technique.

The simulator is presently located at the Carrier Suitability Branch, Naval Air Test Center, Patuxent River, Md.

(See Oxford Corporation in Section II: Abstracts, and Naval Air Test Center in Section VI: Facility Visits, of this volume, and Section III:

20. Radio Corporation of America, Defense Electronic Products, Burlington, Massachusetts

The bulk of RCA's effort in the visual simulation field is described in NTDC report NAVTRADEVCEN 1053-1, entitled "Investigation of 360-Degree Non-programmed Visual Presentation", dated 5 June 1962. (AD 291-468). In retrospect according to RCA the implementation suggested is probably not feasible from an illumination standpoint. However, they still feel that the multi-channel television approach holds the only real promise for wide angle high resolution visual simulation, and continuing improvements in microelectronics and component development constantly improve both the economic and technical feasibility of this approach.

# Section VI

# FACILITY VISITS

## SECTION VI

## FACILITY VISITS

Facility visits were made to selected companies and government agencies when it appeared that personal contact would benefit the objectives of the study program, including opportunities to witness demonstrations of visual simulation displays and trainers.

The displays that were seen and demonstrated are described in the pages that follow in this section. The installations that were visited appear in alphabetical order.

Opinions as expressed in the reports of facility visits with regard to evaluation of simulation devices are solely those of the Farrand research team, unless otherwise stated.

### A. Dimensions Unlimited, Inc., Plainview, New York
June 14, 1965

The primary reasons for visiting Dimensions Unlimited were to discuss the methods and techniques used in producing their three-dimensional photographs, and to estimate whether there is any applicability in areas where Farrand is involved, in particular as use for inputs to simulators.

A Tridyne Camera System used for taking three-dimensional color photographs was described and demonstrated. It consists basically of a rotating stage, upon which a subject is posed, and an automated 8" x 10" view camera. The photographs are accomplished by use of a Tripak assembly of lenticular screen, color film, and diffusing plate. The screen consists of approximately 500 right cylindrical lenses oriented vertically. Each lens has a .4mm pitch and a focal length of 1.4mm.

The system is fully automated and electronically controlled in operation. Exposure is accomplished while both subject and Tripak rotate, the camera lens remaining fixed. Each lenticule splits a picture segment into a multiplicity of elements during exposure. After film processing and realignment of elements with the lenticular screen, the reconstituted photograph is seen as a combination of angularly displaced images, due to object rotation during the exposure cycle, giving a certain measure of true depth.

The three-dimensional photographs that were available for examination at Dimensions Unlimited are of very superior quality compared to the mass-produced "Xographs" that have appeared largely in magazines and as an advertising gimmick. The former photographs, produced by the Tridyne Camera System, have been largely limited to use in studio portrait photography, and receive individual attention during the realignment process.

The choice of the particular lenticular screens used in their system was made only after testing and comparing screens from different manufacturers. The testing consisted mostly of measuring photographic resolution against exposure times. The screens which Dimensions Unlimited use are manufactured in France. They give superior results, judging by the comparison test photos.

They also own patent rights on a technique for making three-dimensional photographs in which the effect is obvious for all viewing angles. This technique has not however entered the developmental stage.

B. Federal Aviation Agency (Atlantic City, N.J.)
April 5, 1965

The purpose of this visit was to discuss the areas of visual simulation studies and experimentation that are being conducted at FAA. Current operations at FAA were summarized and a tour of their facilities was made. Three simulator devices are in use at FAA; a description of these devices follows. Evaluation of the two Dalto devices was based on performance witnessed. The Rheem device was not in operation at the time of this visit.

Installations at Federal Aviation Agency,
Atlantic City, N.J.

1. Doman Approach Landing and Takeoff Simulator (DALTO)

This device, which is designed for night takeoff, breakthrough and landing, presents a true-perspective view of approach and edge lights on a runway. Painted fluorescent markings are used to duplicate light and runway markings on a moving belt approximately 18 inches wide, which simulates the runway. Closed circuit TV picks up the movement of the belt and projects it onto a flat screen approximately 15 feet in front of a trainer cockpit. The trainer controls are linked to the camera to simulate roll, pitch, and yaw. Altitude and lateral movement are restricted to normal approaches to keep the device simple. Weather effects, such as fog or patches of cloud, are simulated by using a movable ground glass in front of the camera.

The display lacks sophistication, compared to later model simulators. Effectiveness of the display is impaired by an obvious need for repair. Resolution is low, and screen contrast is very poor.

2. Dalto Scanalog Trainer Attachment, Visual Simulator

This device uses the flying spot scanner technique for image generation. At the pickup end of the system, a 5-inch diameter transparency of a terrain scene is scanned with a trapezoidal raster. At the display end, a rectangular raster is used. By employing appropriate distortion coefficients on the flying spot scan to alter the aspect of the trapezoid, the display can be made to present a portion of the transparency in a wide variety of sizes, orientations, and perspectives. Rotation is accomplished by physical rotation of the flying spot scanner CRT. This rotation is about an axis just off the viewing area, which represents the "infinity point" in the display.

Light passing through the transparency is collected by a fresnel lens, and directed by means of dichroic mirrors to three photomultipliers. These provide intensity signals for the three color kinescopes which are projected onto a rear screen display.

The Scanalog display system comes with an accessory attachment to display the "strobe" lights used to define the centerline of the approach path to an IFR runway. This consists of a neutral beamsplitter in the optical path between the flying spot CRT and the transparency, a second transparency, and an additional photomultiplier. The auxiliary transparency is opaque except for apertures located to correspond with the position of the strobe lights on the main transparency. A motor-driven occulting mask uncovers the strobe light apertures in repeating sequence at the appropriate rate, and the illumination is in turn presented to the strobe light photomultiplier. This signal is used to key all three color projector kinescopes which produces an intense white light to simulate the strobes.

The Scanalog technique permits display of an area surrounding the runway, about 5 miles diameter in all, and permits maneuvers such as complete fly-around with the runway in sight at all times. This is considered an important advantage over the original Dalto belt system, particularly with regard to training for aircraft carrier landings.

Resolution varies with altitude and orientation of the plane with better resolution appearing at higher simulated altitudes.

In the version demonstrated, the system was modified to include a 24 inch diameter plastic plano-convex lens to collimate the screen image. The square display screen covered at least a 70 degree field across its diagonal. The collimation appeared acceptable for a 40 degree or 50 degree field of view over a limited head motion. At larger fields and head motions of three or four inches, severe "swimming" of the image was apparent. Lateral color was evident at field angles 25 degrees or more off the axis, and was considered only moderately objectionable. Within limited head motion, very little distortion was observed.

The scene being simulated was a night scene of an airport landing strip, including strobe lights. Color register and registration of the strobe lights were imperfect, but the over-all impression was favorable. (See Wright-Patterson AFB in this section; Doty and Gill in Section II: Abstracts, of this volume, and Section III, Volume I.

3. Rheem F-151 Fixed Gunnery Trainer

This trainer originally utilized a closed circuit TV system for pickup and projection of airborne and ground targets on a ten foot radius spherical screen. The system has since been modified by replacing the TV system with an optical display projection system. Very small three-dimensional models are servoed on command from a simulated cockpit of an F-100, oriented so as to locate the trainee's eyepoint on the vertical axis of the sphere. The projector, located on top of the cockpit, projects the target image to a movable reflecting mirror, located at the center of the sphere. The image is projected onto the screen at the appropriate azimuth and elevation.

A separate optical system is used to project a sky and earth horizon on the screen. The area of projection is 280° in azimuth and 120° in elevation.

The modified system gives better performance than the original system, but severe limitations still exist. The screen brightness is approximately three foot-lamberts. The contrast ratio is 5:1. However, it still is difficult, if not impossible, to produce a dark target on a light background.

One requirement for this system, as stated by FAA personnel, is to add a movable point source to represent the flashing red beacon of a distant plane. (See Gartner and Lybrand in Section II: Abstracts, of this volume, and Section III, Volume I.

C. General Dynamics/Electric Boat, Groton, Conn.
August 4, 1965

The purpose of this visit was to view demonstrations of visual displays and to discuss display research currently being conducted by the Research and Development group at Electric Boat. A major portion of the activities of this group has been directed towards the design and development of tactical training devices and scientific displays employing visual simulation techniques. The displays that were demonstrated or discussed are described below.

I. Armor Leader Tactical Trainer (Device XI7ARI)

This system was developed for the Army Participation Group at the U.S. Naval Training Device Center. The training complex consists of a 1/20 scale maneuvering area on which radio controlled vehicles operate in a simulated tactical arrangement under the control of student armor leaders. Up to 20 assorted friendly and opposition tanks and personnel carriers can be operated on the terrain at any one time. The student operators are seated in control rooms at either end of the training room. Two of the 14-inch long, simulated tanks are equipped with self-contained vidicon TV cameras using 1-inch lenses. These give approximately the correct scaled view from the tank.

The TV equipment consists of "GPL Precision 800" components in suitable arrangements. The TV links transmit over channels 2 and 5, while the vehicle control signals are modulated onto carriers below 1 mc.

Training maneuvers can be simulated under day-or-night conditions. Overhead banks of lights provide illumination on the terrain up to ten foot-candles. Overhead lights are also used for aircraft and flares simulation.

This system was not on display at the time of our visit. It is installed at Ft. Knox, Kentucky.

2. Periscope Optical Servo System

This is an all-optical system which simulates the view seen through the periscope of a submarine. Illuminated scale models of ships on rotating bases are projected on a rear view projection screen. Target ranges from 600 feet to infinity are achieved by using an electrically controlled 25:1 zoom lens made by Perkin-Elmer. The system was designed to handle 16 target ships, servo activated at speeds zero to 35 knots, in a display which includes a 360° periscope rotation.

A plastic material simulating waves is attached from the bottom of the screen to the periscope. Below-surface lights convey the impression of movement of the waves. Overhead lights are positioned to simulate the time of day, shadows and weather conditions.

A periscope with scanning prism views the rear of the screen. The field of view through the periscope is approximately 90°. A picture was shown that had been taken through the periscope which demonstrated the realism of the ship model and wave pattern. The view was vignetted, which we were assured was due to the camera system and not the periscope.

3. 3-D TV Display

This is an in-house experimental effort which consists of two 8-inch GPL TV monitors at right angles to one another with a beamsplitter in between. By placing

Polaroid materials in front of each monitor and in front of the observer, 3-D images can be seen. The camera consists of two units mounted side-by-side and pointed at some fixed point in space. One raster is reversed to account for the single channel reflection in the beamsplitter.

The unit was not assembled but a later demonstration was planned. General Dynamics/Electric Boat is investigating 3-D TV systems for use in a wide variety of visual simulation systems. Of particular interest is the application of such a system to the Armor Leader Tactical Trainer.

4. "EB 3-D" System

This is one of several virtual image displays that the Smithsonian Institution commissioned Electric Boat to develop for the demonstration of various atomic theories and experiments for their newly constructed Hall of Science. The system that was demonstrated is the Rutherford Bombardment Chamber, in which the appearance of various sub-atomic particles traveling through space is illustrated.

The display consists of a Rutherford Bombardment Chamber model, with cutaway view, behind a 45° tilted beamsplitter, all mounted in a display case. An out-of-sight system of rotating spirals of sequentially controlled small lamps is imaged within the bombardment chamber. The viewer sees apparent 3-D particles in space, each trailing a glowing comet-like tail, moving in linear paths from one end of the chamber to the other. The effect of the moving particles in the model was very realistic and a beautiful sight.

Electric Boat is building two additional displays, utilizing the same principle, for the Smithsonian Institute: a radioactive atom display, and a display illustrating the discovery of the nucleus. A similar system will also be built for the 1967 World's Fair in Montreal.

D. IBM, Owego, New York, Re: Advanced Display Systems Study
May 6, 1965

IBM have a fairly extensive in-house simulation group which occupies several large rooms in one of their engineering buildings. Facilities comprise a General-Purpose Visual Simulator, a Display Projection and Mockup room, Earth Sighting Simulator, Computer Rooms, and a Gemini Simulator. All but the last were shown and described in detail. These are discussed below:

General Purpose Visual Simulator:

This is the IBM name for an image generation system. It consists of a three-degree-of-freedom TV probe mounted on a large three-degree-of-freedom platform. The platform is a modified Otis T-2A sonic tank radar simulator. It provides translatory motions over a range of 5 by 5 by 8 feet at a rate of 1 inch/sec. The TV probe has an optical field of view of 50° diagonal, and may be positioned with an accuracy of 5 arc minutes to any point in space and as close as 3/16 inch to the model surface. Minimum focal distance is 3/4 inch.

Subject matter for viewing by the probe is arranged on the wall. This consists of a plaster relief model depicting typical lunar features, a relief map of a portion of Korea, a black-and-white transparency of the area between Tucson and Phoenix, Arizona.

The lunar landscape is sharply sidelighted by a column of reflector lamps, and the transparencies are backlighted. Both lunar and Korea scenes viewed through the television system on a Conrac monitor appeared very realistic.

The probe for this image generator was made by Scanoptic, and the MTI image orthicon camera uses a standard 525 line EIA scan structure.

A Telemet video insetter is available at the operator's console, and can be used to mat another video signal (usually a model) into the video line. The second signal is picked up via a vidicon camera equipped with a remotely controlled Angenieux varifocal lens.

Display Projector and Mockup:

A mockup of a generalized two-seater aircraft cabin is set up in a very large room used as a projection theater. (Previously, a Gemini capsule was installed here, but future work is expected to be with aircraft, such as terrain-following displays.) Most of the cabin instruments are themselves simulations, but the controls are operational. These operate via the computer complex to cause the visual display on the projection screen to vary in proper response to control stick motions.

The projector is a black-and-white Eidophor machine, and the signal inputs are provided by the image generation apparatus described above. There is ample space on the projection room floor for the substitution of other simulated space vehicles or airplane cabins.

A screen about 14 x 16 feet allows for a 50° diagonal field as seen from the craft location, which matches the probe field of view.

Computer Complex:

The computer section is housed in two large rooms. The first, used almost exclusively for simulation of vehicle dynamics, contains five PACE analog machines which are used in whatever combination is necessary for the vehicle being simulated.

An IBM 7090 computer is housed in a room adjacent to the analog computer facility. This machine is normally used for producing guidance data to be used in conjunction with simulations. For instance, for orbital flight the 7090 is used to produce all the orbital pre-computations. These results are later used as input for the analog section after interface processing in an IBM 7090 computer housed in the analog room.

The 7090 can also be used directly to generate real-time guidance functions for the analog setup where the simulation requires this feature. Since real-time guidance represents inefficient use of the 7090, it is done only when necessary.

Most of the time the 7090 is used on separate or off-line work.

Earth-Sighting Simulator:

Several highly detailed maps have been made up from composites of aerial photographs of Seattle and other west coast areas. A frame on a three-degree-of-freedom motion base accepts one of these composites and displays it in front of a telescope located in a simulator cabin between ten and twenty feet away. The telescope (a modified Wild transit with 4 rotationally interchangeable eyepieces) has a remotely controlled focus adjustment and two additional degrees of freedom built into its optical path by means of mirrors. Motions of all components are controlled by the computer complex.

This system is used for simulations and studies of sighting from moderately high to orbital altitudes. A film strip permits the insertion of haze when desired, and a separate output allows photography of the scenes being observed by the subject.

Scenes viewed through the telescope appeared extremely detailed and realistic. Resolution was quoted at 4 seconds of arc for the total system.

E. Naval Air Test Center, Patuxent River, Maryland
June 16, 1965

The purpose of the trip was to see the Carrier Landing Flight Simulator built by the Oxford Corporation, and delivered to NATC in 1961. Very little modification was made to the simulator as described in the Oxford report No. 6102 of August 1961. This simulator was the only one built.

The simulator consists of an A-4D aircraft cockpit, windshield and instrument panel, an infinity display optical system, day or night aircraft carrier models with associated illumination, drive mechanisms and electronics.

A primary purpose of the device is to evaluate various landing marking patterns and visual aids placed on the carrier deck. Programmed and non-programmed simulated "landings" are used in the evaluations.

System Details:

A subject in the cockpit looks into the lower off-aperture section of a hemisphere rear-coated Plexiglass "eyepiece" mirror. Another hemispheric Plexiglass mirror is placed at the focal surface of the eyepiece mirror. Part of this focal surface mirror is painted blue to simulate the ocean and horizon. A 14" diameter, front coated glass mirror is mounted above the eyepiece mirror and is intended to form a continuation of the eyepiece mirror surface. (The glass mirror replaced the upper half of the original one piece Plexiglass "eyepiece" mirror.)

Basically then, these mirrors act as one large mirror with a reflecting focal surface. If the pupil is considered a plane at the center of curvature, then a section of the top of the pupil is imaged at the bottom of the same plane. Thus the pilots eye can in effect be transferred to another point in space about 2 feet above his head. An erecting lens system at this upper pupil point then sees the aircraft carrier model directly. The lens consisted of a package about 6" diameter and a foot long. It was linked to the model position so it could be continually refocussed in an attempt to keep the carrier model collimated over the 7 foot movement along its track. This lens system was apparently not coated.

The carrier models were scaled 1 inch to 50 feet, travelled on a 7 foot bed and were illuminated by four white 6 foot long tubular fluorescent lamps. Illumination of the night model landing lights came from the interior of the model. No data was provided by Oxford to NATC on the optical system.

Measurements and Subjective Evaluation

A 3 power diopter scope was used to measure the collimation of the carrier image at three positions.

| Carrier Position | Image Distance | Approximate Pupil Size | | | |
|---|---|---|---|---|---|
| farthest position on track | 0.3 diopters | Horizontal - | 1.5" | Vertical - | 1" |
| center position on track | 0.5 diopters | " | 1.5" | " | 1" |
| nearest position on track (apparently over the deck) | 1.4 diopters | " | 1.0" | " | 0.3" |

The pupil aberrations were apparently great enough to cause a 3 inch horizontal and 1 inch vertical pupil movement with head motion. This had the effect of allowing both eyes to be used in viewing the model at the closer ranges. The 3 dimensional effect, good resolution and unobstrusive color errors contributed to a realistic effect. Since the background was a solid blue, no real bleeding through of images was observed, although the carrier did appear "ghostly". Roughness of the Plexiglass mirror surface was evident as spots in the field of view but this was not obtrusive.

The severe swimming of the pupil and its small size made finding and holding the carrier image very difficult. A head rest and electric controls for pilot seat movement were provided and were necessary. Even slight head movements caused a loss of the image or an annoying amount of "swimming", which made the carrier appear to turn to the right or left. Possibly the pupil stop was made small in order to minimize this image swimming. The horizon image measured +.2 diopters and was also affected by swimming.

Except for the wide horizon in the horizontal field (possibly 120°-150°), the field from the upper pupil was limited to the carrier and the area dead ahead with a maximum diameter of about 25°. (See Oxford Corporation in Section II: Abstracts of this volume, and Section III, Volume I.

F. U.S. Naval Training Device Center, Port Washington, New York
March 26, 1965

The goals of the Virtual Image Study Program were outlined by Farrand representatives. NAVTRADEVCEN supplied the names and addresses of manufacturers and users of visual simulation apparatus heretofore unknown to Farrand and listed several pertinent reports. (Since the meeting, letter questionnaires have been sent to the companies and agencies named by NAVTRADEVCEN and the reports have been ordered.)

Installations at NAVTRADEVCEN

1. Wide Angle Television Projection Design Study

The Wide Angle Television Projection Design Study being prepared for NAVTRADEVCEN by GPL was discussed. A breadboard model of the television pickup system, which utilizes three high definition cameras side by side viewing the target through a 150° common entrance lens, was on hand but not working at the time.

Image generation for the wide angle display is accomplished by means of three Vidicon cameras sharing a single compound lens. The scanning rasters each have a 4 x 3 aspect ratio, which is a standard EIA raster rotated by 90°.

Synchronization and registration have been recognized as a major problem area in this system from its inception. These difficulties are expected to be overcome by the use of common deflection and power supply components for all three camera chains.

2. Miscellaneous Installations

Several other visual simulation devices were at the NAVTRADEVCEN. These were the Helicopter Flight Trainer Research Tool, Device 2FH-2, which utilizes an intense point light source to project a transparency on a screen; (See deFlorez Co., and Butler and Havron, in Section II: Abstracts, in the present volume, and Section III, Volume I.

the Low Visibility Approach and Landing Attachment, Device 2H53, which projects a non-programmed scene from a CRT faceplate onto a rear view projection screen; and a "Cineglobe" 142° wide angle visual display system for projecting motion pictures upon a spherical screen. Only the last-named system was in operation. A 10-foot radius spherical screen subtending $3\pi$ solid angle was in storage, and evidently had been inoperative for a long period of time.

Following the meeting, a consensus of comments and observations regarding the performance of the "Cineglobe" display was made. All agreed that the resolution of the projected image was of sufficient quality for visual observation. The projection screen was made of a fiber glass base with a matte-white surface. The contrast in the image was below average, but it probably could be improved if a beaded screen were used. Off-center observers noted a peripheral flicker in the image which distracted from the effectiveness of the performance. A high degree of realism, similar to that created by the Cinerama process, was experienced by some observers, especially during scenes involving motion.

G. Wright-Patterson Air Force Base, Ohio
April 19-20, 1965

The purpose of this trip was to discuss the work being conducted at WPAFB on visual simulation devices and techniques. A tour of WPAFB facilities where such investigations are being carried on was made under the guidance of Flight Simulation Branch personnel.

Two of their visual simulation devices are of the virtual image type. The ACF virtual image display (the "official" name of this device was not made known to us) was in process of assembly by ACF personnel at the time of our visit. Their simulator system incorporates an orbital planetarium system made by Bell Aerosystems, Inc. Most of the information was derived from personal examination of the equipment and from comments made by WPAFB personnel. A more extensive description of this and other simulation devices and experiments follows.

Installation at WPAFB

1. ACF Virtual Image Display

The ACF simulator is designed to provide training for rendezvous against a star field background. The device uses a composite of optics, television, and computer techniques to achieve this objective. An orbital planetarium, made by Bell Aerosystems, Inc., simulates a star background. This is a four-foot diameter hollow sphere perforated with 463 apertures for stars, 0 to +4 magnitude. The stars are large and vary perceptibly in size. The sphere is externally illuminated by a blue fluorescent light source with porcelain reflectors. An axis of rotation simulates the polar axis. A TV Camera, mounted inside the hollow sphere, is rotated to simulate the other axes. Any one of three fixed masks inside the sphere occults the TV pickup of the star field.

The planetarium pickup system employs a G.E. TV system (Model TE-9C), 735 lines, 8 mc, and Tele-Beam TV projector. The scene is projected onto a rear view screen. The screen image is projected at infinity by a glass lens (approximately 25 inches diameter) made in Japan.

An electronically generated image is prepared by an analog computer and displayed on an oscilloscope. (A doughnut-shaped lissajous image has the appearance of an orbiting space station. Control movements from the simulator cockpit modify the signals from the analog computer for change in perspective of the electronic image). This image is picked up by a TV system similar to the planetarium pickup system, and displayed on another viewing screen. The scenes on the two screens are superimposed through a beamsplitter. The second screen moves with respect to the first, to bring the docking target in from infinity. The movable screen is driven by four screw jacks and a chain drive. The focusing projector is driven by cables from the screen.

A solid model may be used in place of the electronically generated image if the type of docking vehicle is too complex to be synthesized. Another possibility is to add another background scene, such as the earth or moon globe, by resistively adding the new signal to the star signal in the TV amplifier.

The orbital planetarium and electronic image systems were originally made by Bell Aerosystems, Inc., and later integrated by ACF into a hardware system. The display end of the system, including the viewing screens, projectors and optics, is housed in a wood and masonite package which has the outward appearance of a large black box. The star field of view available to the simulator cockpit is approximately $52^{\circ}$ on the diagonal. (It is reported that the price of a system with field of view greater than $60^{\circ}$ would be prohibitive.)

The system was in process of installation at the time of the visit, making it impossible to comment on the quality of performance. The claimed resolution over the field of view is better than one minute of arc, not considering TV degradation (six minutes of arc). (See Section III, Volume I)

# VII. A GUIDE TO THE LITERATURE OF VISUAL SIMULATOR DEVICES

Section VII

# A GUIDE TO THE LITERATURE OF VISUAL SIMULATOR DEVICES

This guide has been prepared as an aid and convenience to engineers and researchers working with visual simulation displays and trainer attachments. It identifies each simulator device or system by name, and lists the manufacturer and simulation techniques employed, when known. In addition, it provides at the end of this section literature references to each item for the benefit of persons desiring to go to the original sources of information.

| Simulator Systems Developed/Proposed | Manufacturer | Technique | References |
|---|---|---|---|
| 1. Landing Display | University of Illinois | Computation of Pictorial Elements | 1 (p42, BI-12); 4 (p45-46) |
| 2. Runway Lighting Attachment for Aircraft Simulators | Rheem Manufacturing Co. | Computation of Pictorial Elements | 1 (p42, BI-12); 4 (p44-45) 24: |
| 3. Mark I Visual System (Vamp) | Link Div. of G.P.I. | Film | 1 (p42, BI-12); 3 (p66-68); 4 (p82-84); 5 (p189-191) 21 |
| 4. Mark II Visual | Link Div. of | Film | 1 (p42, BI-12); 4 (p84-86); 3 (p69); 5 (p190) |
| 5. Bellarama | Bell Aircraft Corporation | Film | 1 (p42, PI-12); 3 (p64-66); 4 (p86-88) |
| 6. Celestial/Terrain Viewing System | Kearfott, Div. of G.P.I. | Film | 1 (p42, BI-12) |
| 7. Contact Flight Trainer, Device 12-L-2 | | Direct Viewing (Model) | 1 (p43, BI-12) |
| 8. Tank Platoon Leader Trainer Device 17-AR-1 | H.A. Wagner Co. | Direct Viewing (Model) | 1 (p43, BI-12); 4 (p79-81); 6; 26 |
| 9. A Periscope for Forward Vision out of High-Speed Aircraft | American Optical Co. | Direct Viewing | 1 (p43, BI-12) |

| | Simulator Systems Developed/Proposed | Manufacturer | Technique | References |
|---|---|---|---|---|
| 10. | Contact Landing Trainer, Device 20-L-1 | U.S. Naval Training Device Center | Optical Display Projection (Diascopic) | 1 (p43, B1-12); 4 (p13-15) 25 |
| 11. | Contact Analogue Landing Trainer, Device 20-L-10A | Reflectone Co. | Optical Display Projection (Diascopic) | 1 (p43, B1-12); 4 (p15-17) 22 |
| 12. | Helicopter Flight Simulation Research Tool, Device 2-FH-2 | Bell Aircraft Co. and deFlorez Co. | Optical Display Projection (Diascopic) | 1 (p43, B1-12); 4 (p17-21); 10; 17; 18; 19 |
| 13. | Modified Visual Flight Attachment for Aircraft Flight Simulation | Rheem Manufacturing Co. | Optical Display Projection (Epidiascopic) | 1 (p43, B1-12); 4 (p37-38) |
| 14. | Projected Optical Viewing of Bellarama Display | Bell Aircraft Corp. | Optical Display Projection (Epidiascopic) | 1 (p43, B1-12); 3 (p72-75); 4 (p40-42) |
| 15. | Torpedo and Rocket Attach Trainer, Device 14B3 | Austin Co. | Optical Display Projection (Epidiascopic) | 1 (p43, B1-12); 4 (p38-40) 16, 27. |
| 16. | Dalto Mark III | Dalto | Closed Circuit Television | 1 (p44, B1-12); 29 (p59-63) |
| 17. | Visulator | Curtiss-Wright | Closed Circuit Television | 1 (p44, B1-12); 2 (p9-10); 4 (p57-59) 29 (p50-57) |

| Simulator Systems Developed/Proposed | Manufacturer | Technique | References |
|---|---|---|---|
| 18. Link Visual System, Mark IV & IVA | Link Div. of G.P.I. | Closed Circuit Television | 1 (p44, B1-12); 2 (p9); 4 (p55-57); 29 (p115-118) |
| 19. Scanalog Visual Attachment | Dalto | Synthetic Image Generation | 1 (p45, B1-12); 11 (p167-168); 29(p63-68); 10(p179-180)(Low Vis. App. Landing Att. for Fl.Tr. 2H53). |
| 20. Night Landing Device | Link Div. of G.P.I. | Synthetic Image Generation | 1 (p45, B1-12); 2 (p8-9); 5 (p192-193); 11 (p167, 174); 29(p109-115) 35 |
| 21. Multi-Channel Memory System (MCM) | Marquardt-Pomona | Synthetic Image Generation | 1 (p45, B1-12); 29 (p122-124) |
| 22. Synthetic Image Data Generation (SIDG) | Goodyear | Synthetic Image Generation | 1 (p45, B1-12); 29 (p85-88) |
| 23. Carrier Landing Trainer, Device 12-BK-5 and 5a | Engineering & Research Corp. (ERCO) and National Scientific Laboratory (NSL) | Closed Circuit Television | 2 (p8); 4 (p49-52); 14; 23 |
| 24. F-151 Fixed Gunnery Trainer | Rheem Mfg. Co. | Closed Circuit Television and Point Light Source | 2 (p9); 4 (p52, 54-55) 20 |
| 25. Simulator Landing Attachment for Night Training | Burton-Rodgers | Point Light Source and Closed Circuit TV | 2 (p10) |

| Simulator Systems Developed/Proposed | Manufacturer | Technique | References |
|---|---|---|---|
| 26. Day/Night Visual Simulation System, SMK-23 (Visualink) | Link, Div. of G.P.I. | Closed Circuit Television | 2 (p10); 5 (p192-194, 195); 11 (p166-167, 173); 29 (p105-109) |
| 27. Electric Boat Contact Analog System | Electric Boat Div., General Dynamics Corp. | Closed Circuit Television | 2 (p10-11) |
| 28. Fish-Eye System | (Suggested by) RCA | Closed Circuit Television | 2 (p96-109, 125-133) |
| 29. Fly's Eye System | (Suggested by) RCA | Closed Circuit Television | 2 (p109-133) |
| 30. Visual Flight Attachment for Aircraft Flight Simulators | Rheem Mfg. Co. | Optical Display Projection (Epidiascopic) | 4 (p35-37) 12 |
| 31. Doman Approach Landing and Take-off Simulator (Dalto) | Dalto Electronics Corp. | Closed Circuit Television | 4 (p52-53) 15<br>2 (p8) |
| 32. Contact Flight Simulator, Device 14-L-2 | Farrand Optical Co., Inc. | Direct Viewing (Model) | 4 (p77-79) 10; 31; 32 |
| 33. Experimental Model, Wide Angle Projection Visual Display System | NASA | Film | 5 (p198-199) |

| Simulator Systems Developed/Proposed | Manufacturer | Technique | References |
|---|---|---|---|
| 34. Out-the-Window Display System for Spacecraft | (Proposed by) Link, Div. of G.P.I. | Film and Direct Viewing (Model) | 5 (p200-205) |
| 35. Trainer Attachment, Visual Simulator SMK 22/F37A-J | Fairchild Stratos Corp., Electronic Systems Div. | Closed Circuit Television | 7 |
| 36. Visual Simulator Attachment for F-104 Flight Simulator | Canadian Aviation Electronics Ltd., Montreal, Canada | Film and Closed Circuit Television | 8; 34 |
| 37. Flight Simulator Device 2-FH-4 | deFlorez Co. | Point Light Source | 13 |
| 38. VueMarq System | Marquardt Corp., Pomona Electronics Division | Closed Circuit Television and Optical Projection | 28 |
| 39. Wide Angle Projection Visual Display System | Jam Handy | Film | 5 (p195) |
| 40. Electronic Airport Display | (Proposed by) Aerojet-General Corp. | Synthetic Image Generation | 29 (p24-33) |
| 41. Virtual Image Projection Display System (I) | (Proposed by) Aerojet-General Corp. | Closed Circuit Television | 29 (p33-37) |

| Simulator Systems Developed/Proposed | Manufacturer | Technique | References |
|---|---|---|---|
| 42. Virtual Image Projection Display System (II) | (Proposed by) Aerojet-General Corp. | Closed Circuit Television | 29 (p37-38) |
| 43. Aerojet Model V-9 Low-Visibility Approach and Landing Simulator Attachment for Flight Trainers | (Proposed by) Aerojet-General Corp. | Synthetic Image Generation | 29 (38-45) |
| 44. Flight Simulator Visual Display Sys. | (Proposed by) Goodyear Aircraft Corp. | Closed Circuit Television | 29 (p70-76) |
| 45. Visual Simulation System, System Ex. No. 1. | (Proposed by) Goodyear Aircraft Corp. | Closed Circuit Television | 29 (p76-80) |
| 46. Visual Simulation System, System Ex. No. 2. | (Proposed by) Goodyear Aircraft Corp. | Closed Circuit Television | 29 (p80-83) |
| 47. Visual Simulation System, System Ex. No. 3. | (Proposed by) Goodyear Aircraft Corp. | Closed Circuit Television | 29 (p83-85) |
| 48. Carrier Landing Flight Simulator | The Oxford Corp. | Direct Viewing (Model) | 30 |
| 49. Visual Flight Simulator (V.F.S.) | General Precision Systems Ltd., Aylesbury, Bucks., England | Closed Circuit TV | 9 |

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