VOLUME II

REPORT OF A STUDY ON A VIRTUAL IMAGE OUT-THE-WINDOW DISPLAY SYSTEM

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[redacted]

ABSTRACT

This report contains background material for Volume I of the study program. Included are abstracts of reports and documents pertinent to a study of visual simulation techniques and devices; bibliographic references; a summary of replies to a television survey; a summary of replies to a survey of the visual simulation industry; a report on facility visits; and a guide to visual simulator literature.

VIRTUAL IMAGE OUT-THE-WINDOW
DISPLAY SYSTEM STUDY

Volume II

APPENDIX

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Section I

INTRODUCTION

Volume I of this report is a technical discussion of a study to further the NASA flight simulation facility program for virtual image, out-the-window display systems. The two phased study program involved a detailed analysis and evaluation of four categorical designs for an infinity image system, including auxiliary studies in the field of high resolution closed circuit television. The most promising design in terms of present capability and future expansion was carried to a point suitable for a definitive design.

The present volume gives the results of a comprehensive survey of the visual simulation and television manufacturers' industries. Included herein are abstracts of documents, reports, and papers pertaining to visual simulation and television techniques and design, as well as related system components; a general bibliography of related reference material; a summary of replies received to a state-of-the-art television survey; a summary of replies to a survey of the visual simulation industry; a report on facility visits; and a guide to visual simulator literature.

Thus this compendium, while essential to the technical discussion carried in Volume I, performs the additional function of serving as a handbook to persons working in the general areas of visual simulation. It is a summary of known attempts at design, manufacture, and evaluation of visual simulation equipment.

Section II

ABSTRACTS

The primary consideration in choosing documents and articles for abstraction was pertinence to the technical portion of this study; that is, to compile pertinent data, state-of-the-art designs, and new ideas, all of which would be evaluated in the parametric studies forming a part of Phase I and Phase 2 of the program.

It soon became obvious that strict adherence to the original idea would not produce much of anything to abstract. The actual amount of literature relating to virtual image, out-the-window display systems that is unclassified or free from proprietary strings is still relatively scarce.

With the horizons of the literature search broadened through necessity, the subjects that were searched and abstracted included: visual simulation devices and techniques, display systems, optical training devices, wide angle optical systems, television design and techniques, feasibility studies, etc. Methods of improving performance of related components (such as in reduction of specular reflections from display surfaces: see Colman, et al) were included, in some instances.

The literature search utilized the resources of the U.S. Patent Office, the Defense Documentation Center, the Office of Technical Services, the Engineering Societies' Library, and the Technical Information Service. The types of literature that were covered in the search included:

A. Research, development, test, and evaluation documents

B. U.S. and foreign patents

C. Periodicals and books

D. Meeting papers and conference proceedings

E. Translations of foreign journals

F. Journal articles.

The abstracts that follow vary in length and in technical content. Generally, this is because added emphasis has been placed on those reports most pertinent to the technical discussion in Volume I. For the same reason, pertinence to the overall objective of the study program, the writer has added his own conclusions to several abstracts. This was done only when such conclusions are obvious. At all times, objectivity has been the keynote of the abstracts.

Author: Allen, C.H., Jr., Doty, A.B., Jr., and McCormick, E.C.

Title: "The Space Flight Simulator for the U.S.A.F. Aerospace Research Pilot School." Paper presented at AIAA/AFLC/ASD Support for Manned Flight Conference, Dayton, Ohio, April 21 - 23, 1965.

SUMMARY: This paper provides technical details on the design, measured performance of the various system elements, and use of the T-27 Space Flight Simulator for training and research at the USAF Aerospace Research Pilot School. A description in detail is provided for each of these areas.

Use of the Simulator

The T-27 Space Flight Simulator will be used for training selected aerospace pilots for flight crews, research pilots and systems managers of the future. It will serve to bring about a physical interpretation and significance of fundamental theories such as vehicle dynamics, launch, ascent, orbit injection, orbital theory, and other concepts. It will also serve as an engineering evaluation tool.

Computation System

The entire system is controlled by a solid-state digital computer with analog accessories. After a change in platform orientation in response to commands, the platform is returned to its original or rest position at rates below the detection threshold of the subjects being trained.

Motion System

The main motions are provided by the moving base on which the cabin portion of the simulator is mounted. These motions are accomplished by means of a hydraulic drive system, selected for its low noise in operation and high power efficiency at low and zero speeds.

In addition to the cabin motions, vibration and buffeting are supplied by means of seat motion.

Visual Simulation

The T-27 Space Flight Simulator utilizes the virtual image visual system designed by the Farrand Optical Company to provide an out-the-window view of the star field, rendezvous vehicle, and earth scene as viewed from an earth orbiting flight.

The celestial sphere and its drives, the illuminator and associated occulting disc, and the optical elements which comprise the star field image generator are described in operation. In general, the star field generator forms the necessary star images, subtracts the image in the earth's shadow, and relays the final result into the rest of the system.

The rendezvous image generator is the only portion of the system which employs television techniques. The TV pickup is accomplished by means of a model and an optical system, and is injected into the display by means of a CRT display. The pickup tube is a 1-1/2 inch vidicon, selected for its low noise in spite of noticeable "stickiness". The TV system employs a 33 mc bandwidth for its 1200 scanning lines. Resolution was not stated.

A Mission Effects Projector, or MEP, for earth scene image generation is also described. The earth scene is made up from a colored transparency, a separate cloud transparency for the horizon, and a mask to simulate the transition from daylight to night. Provisions have been made to add a simulation of the sun at a later date.

The equipment was subjected to extensive tests. This included measurements of the optical system losses, angular size of the field of view through the window, system collimation, system mapping, etc. The authors conclude that the visual simulation, in the opinion of the USAF, is a successful development.

Author: Altes, S.K and Chu, J.H.

Title: Feasibility Study, Wide Angle Television Display. General Electric Company, Technical Products Department, Syracuse, N.Y. Technical Report: NAVTRADEVCEN 15U7-1, 14 November 1956. Contract No. 1928(00). (AD-273 486)

SUMMARY: This report describes the result of a study of known approaches to generation and presentation of a non-programmed wide angle television display. The purpose of this program was to provide information on the means and methods of using television to present a wide angle, non-programmed visual display of a real world environment. The study examined all possible approach techniques, including both feasible and non-feasible approaches.

The authors conclude that high efficiency optical systems used with a cathode ray tube are the most likely solution to the problem. This high efficiency can be achieved either with a highly directional projection screen or by a virtual image system. They state that the wide-angle requirement makes it virtually impossible to obtain high definition at the camera as well as at the display end.

Since this study was made, techniques employed in virtual image projection have achieved the high resolution, wide-angle requirements. In particular, in the section dealing with virtual imaging techniques, the authors describe approaches which have since been evaluated at Farrand. The techniques included in the discussion of virtual image systems include projection at infinity using oil filled lenses; systems using a refractive-reflective compound approach; projection on a directional screen; a mirror virtual image system; Fresnel lenses technique; and systems using anamorphic lenses. The authors suggest that anamorphic systems offer a greater flexibility in design than those using spherical optics. They imply that this approach may be an advantage in designing panoramic displays in which the angle of view is larger in the horizontal than in the vertical direction.

Author: Aronson, M.

Title: "Wide Angle Visual Simulation Requirements and Experience"
Paper presented at AIAA Simulation for Aerospace Flight Conference, Columbus, Ohio, August 26-28, 1963.

SUMMARY: This paper defines and discusses the requirements for acceptable non-programmed wide angle visual displays for use in the training of pilots. It shows how an analysis of requirements for flight near the earth's surface can establish the design parameters for visual simulation. Some visual attachments and research hardware developed by the U.S. Naval Training Device Center (NAVTRADEVCEN), Port Washington, N.Y., to achieve these requirements are described. The compromises and limitations of the equipment are discussed.

Over the years NAVTRADEVCEN has obtained engineering solutions for non-programmed wide angle visual displays in four categories:

1. Optical display projection
2. Computation of pictorial elements
3. Television
4. Direct model viewing

In the evaluation of devices under study at NAVTRADEVCEN, advantages and limitations of each technique were discussed. These can be summarized as follows:

1. Optical display projection (utilizing point light source)

Advantages

a. Color - realistic, within certain limits.

b. Linear perspective - sufficiently correct.

c. Detail - three dimensional objects are presented in proper perspective.

d. Fidelity - good resolutions within certain ranges.

Limitations

a. Size of transparency - large, in terms of engineering practicalities.

b. Fidelity of simulation - contrary to human experience. Due to changing ratio of magnification, clarity varies with light source to display - object distance. The lower the simulated altitude, the poorer the definition.

c. Perspective - using front projection, perspective is distorted because of the location of the projection source above the horizon passing through the observer's eye.

d. Three dimensional objects - lines or contours on "backside" of solid, transparent object will be projected and superimposed over "front side" projection.

e. Small flight angles (5° down or less) - limit on visibility range, ten times the altitude.

2. Computation of pictorial elements

Advantages

a. Wide angle - large, limited by number of panels used.

b. Resolution - at time, 525 line TV on 16" X 16" panel.

c. Light level - 1/2 foot lambert.

Limitations

a. Image display - limited to patterns whose shape and shadows can be expressed mathematically.

b. Color reproduction - limited.

c. Visual information content - limited by computer storage capacity.

3. Television

Advantages

a. Full color reproduction possible.

b. Versatility - by use of transparency or other display object, various scenes can be changed at will.

c. Insertion - multiple scenes can be mixed on screen.

d. Perspective - electronically computed relationships provide accurate cues.

e. Resolution - limited by TV state-of-art.

f. Light amplification - low light level available in image generating system does not prohibit bright projected picture.

Limitations

a. Resolution - decreases proportional to angular coverage.

b. End registration with multiple projectors.

c. Brightness - low level represents low visibility only.

4. Direct model viewing

Advantages

a. Observed realism - excellent, particularly with respect to other techniques.

b. Image quality - approximately equal to that of unaided vision.

c. Field of view - large, particularly with respect to most other techniques.

Limitations

a. Head movement - limited by optical considerations.

b. Ambient lighting conditions - limits viewing to darkened compartment

NAVTRADEVCEN has feasibility studies underway on some of these problems. A television project at General Precision Laboratory under contract N61339-695 attempts to solve the resolution problem by using three high definition cameras side-by-side viewing the target through a common entrance lens. The resulting coverage is 150°. Improved edge registration of the projectors is by high stability and quality sweep circuits. The brightness problem is acute only when projecting on a screen of ten feet radius or larger. At the time of this paper, the project had not yet presented a solution.

With respect to field of view requirements, experiments show that airplane pilots can do remarkably well with limited vision. For adequate distance to a reference point at an angular rate formation, 25-30 degrees is sufficient to give full cockpit vision performance. The edge of the display screen should not be within the angular field of view needed by the pilot or a false external reference clue is provided.

Of solutions produced from 1947 - 1962, more emphasis has been placed upon the television technique than the others. For this period, no mention is made of virtual image simulation techniques.

Appended to this paper is a list of 39 references and a bibliography comprised of 14 items.

Author: Baldwin, M.W. Jr.

Title: "The Subjective Sharpness of Simulated Television Images", Proceedings of the I.R.E., Vol. 28, Oct. 1940, p. 458-68.

SUMMARY: This study employs a method for determining the subjective sharpness of television images by comparison with defocussed projected film. Subjects were required to compare resolutions as the film focussing was adjusted for equal sharpness of the TV and film images. When the images were judged equally sharp by the median of the observer group, the size of the figure of confusion of the motion picture was taken as a measure of resolution of the compared television image.

Sharpness in the subjective sense is found to increase more and more slowly as the resolution (an objective measure) is increased. Television images in the range of 150 to 600 line scan structure were covered, and it was determined that the 600 line structure was already well into the area of "diminishing returns" with respect to resolution, although still far from the ultimate boundary of sharpness discrimination.

Measurements were also made of "sharpness" versus aspect ratio, for figures of confusion having aspects in the range 2/5 to 5/2. For high sharpness pictures, the difference noted over this range was very small, while for low sharpness pictures there was a slight preference for horizontal as opposed to vertical resolution.

Author: Bjelland, H.L.

Title: Data Display Study. National Cash Register Co., Hawthorne, California, Quarterly Report No. 3, 1 June - 1 Sept. 63, Contract No. DA 36-039-SC-90855 (AD-425 941)

SUMMARY: Investigation covered in this phase of the contract was directed toward the use of photochromic techniques for information display. The concept appears to be to control the density of photochromic material by means of ultraviolet or other light produced by a CRT. The photochromic is then used as a light valve in conjunction with a separate source for producing an image for projection.

The discussion of visits to 18 agencies and organizations presents some useful views on several aspects of the television art.

Author: Brouillette, J.W., et al

Title: Large-Area Display Panel, Eighth Quarterly Report, 1 March through 31 May 1964 on Contract DA36-039-sc-90755 to General Electric Co., Syracuse, N.Y. (AD-443043)

SUMMARY: This project is directed toward achieving large area high resolution display that can be viewed comfortably under conditions of high ambient illumination.

The selected approach consists of obtaining an image on thermoplastic medium by writing with an electron beam, and displaying this image by means of a TIRP (Totally Internal Reflecting Prism) optical system. The light source will be a 1600 watt xenon arc lamp, and it is expected that nearly 100 watts will be incident on the aperture when the system is run at full power. Resolution of the system should approach the desired goal of 3000 lines.

No definitive conclusions are reached in this report, but the techniques employed are in the direction of producing high resolution high brightness displays, and they seem to be conceptually sound.

Author: Buddenhagen, T.F. and Wolpin, M.P.

Title: A Study of Visual Simulation Techniques for Astronautical Flight Training. Avionics Division, Bell Aerosystems Co., Division of Bell Aerospace Corp. WADD Technical Report 60-756, March 1961. Contract No. AF 33(616)-7028, Project No. 6114, Task No. 60863.
(AD-260 093)

SUMMARY: This report presents the results of a study of the engineering requirements for visual simulation in astronautical flight training, and presents and evaluates the techniques and design concepts which are applicable to such simulation. It includes a compilation of applicable techniques, the determination of the probable visual environment of space, and an investigation of a method which predicts the perceptual fidelity achieved by the various simulation techniques. The report is divided into sections which discuss visual simulation requirements, basic techniques, image display and generation, and conclusions and recommendations. Appendices deal with particular problems: theater configuration, the visual environment in space, fidelity of simulation, and special techniques and equipment. Organizations that were visited in preparation of the study are listed.

A number of topics that are discussed appear worthy of investigation. These include:

1. The subject of window design. The authors state that the problem of providing for wide angle view can be minimized if more than one window is considered. The windows will be located close to the pilot who will be expected to move his head from side to side to extend his field of view. It appears that extra wide angle direct viewing facilities, such as those available from a bubble canopy, will not be provided. Windows will be relatively small and widely spaced, so the total view may be simulated by several individual display systems with

their lines of demarcation outside the trainees field of view.

2. Basic techniques considered for application to the visual simulation of space flight. These are:

a) film

b) combination of film and television

c) fully optical

d) point light source

e) fully optical with image intensification

f) television

g) electroluminescence.

Only fully optical and television techniques were considered feasible for the simulation of astronautical flight.

3. The section dealing with image generation discusses how the image may be displayed by the use of several separate model systems: a celestial model system, an orbital model system, close approach model systems, and a landing model system. Principal requirements of the celestial model system are:

a) Star images of suitable quantity, quality, and accuracy must be provided to achieve realism and to facilitate their use for direction finding.

b) The celestial image must be capable of being occulted.

c) The model system must be capable of generating the view in all directions with a minimum of display or control restrictions.

d) Moon and planet images must be accurately varied as to size and location in the star field.

e) The sun image must also be capable of being accurately varied as a function of time and vehicle location.

A technique is presented for projecting the earth globe. This utilizes a point light source projection technique. A spherical transparency, representing the earth, rotates about the light source. The resulting image is directed to a translucent rear projection screen, which is a segment of the surface of a large sphere.

Consideration is given to the design of a camera lens. A conventional lens, having its entrance pupil within the objective, requires considerable clearance of the entrance pupil to avoid physical interference with the model. The authors then go on to describe a lens with an external pupil, which has a viewing point in front of the objective, permitting a close approach to the model. Thus, proper perspective can be obtained while permitting the incorporation of rotatable prisms to vary the orientation of the line-of-sight without moving the camera. A lens of this type called the "Angular Coordinate Camera Lens" has been designed for television simulators. The authors then discuss a proposed optical arrangement. The discussion includes descriptions of an azimuth motion prism arrangement and a multi-view camera lens system which provides three window views simultaneously.

Analyses presented in this report have been limited exclusively to the problems involved in the simulation of wide-angle viewing through vehicle portholes or windows. As used, "wide-angle" refers to fields-of-view of approximately 60° to 80°.

Only one mention is made of a wide-angle system which is an exception to this last statement. In the appendix dealing with special techniques and equipment, the authors discuss a wide-angle anamorphic lens for motion picture pickup, giving a 130° field. The view is distorted about 40%, but this distortion is removed in the projection system by suitable choice of projector location and screen shape. A major drawback of this type of lens for use in a simulator application is the location of the entrance pupil point within the glass, limiting the closeness of approach to a model.

The basic types of television camera tubes suitable for use in visual simulation are described. The flying spot scanner technique of generating a television signal, television display techniques, television resolution rating techniques, color television techniques, and television image enhancement techniques are all discussed.

Author: Calucci, E.J. et al

Title: "Solid-State Light Valve Study" Technical Documentary Report No. RADC-TDR-64-192 dated June 1964. (AD-602666)

SUMMARY: To circumvent the limitations imposed by cathode ray tubes, light valve techniques have been envisioned for data display applications. This study was undertaken to determine the feasibility of using a solid-state crystal exhibiting an electro-optic effect, as the heart of a light valve projection display system. The electro-optic effect considered employs polarization phenomena. The crystal is mounted in a vacuum tube, and is scanned by an electron beam. The concept is due to Dr. Hans Jaffee, and is covered in his 1952 patent number 2,616,962.

Conclusions are that a solid-state light valve is feasible for large screen display applications. Materials suggested are from the 42M(Vd) tetragonal class, and KD_2P is mentioned in particular since it possesses a lower half-wave retardation voltage and an inherent charge storage which makes the optical image appear brighter. Optical resolution is a problem because of electron beam spot size and fringing electrostatic fields within the crystal.

Author: Carel, W.L. and Zilgalvis, A.

Title: Analysis Of Pictorial Displays, JANAIR Joint Army-Navy Aircraft Instrumentation Research. First Quarterly Report, September 1964 No. 2732.01/19 Contract NONR 4468 (00) (AD-606705)

SUMMARY: The objective of this study is an analysis of the capabilities of pictorial cockpit displays. It includes a study and definition of the associated sensor and data processing requirements.

The desired output of the program is the specification of pictorial display systems which will be useful in specific types of missions. In the course of the work a large family of displays and television systems are considered. This report contains good discussions of conventional cathode ray tubes, storage display tubes, color cathode ray tubes and several video sensors.

Author: Carey, P.M.

Title: "Pilot's-Eye View Is Projected on Screen in Visual-Simulation Flight Trainer", Canadian Electronics Engineering, Vol. 7, Feb. 1963, p. 31-35, 46.

SUMMARY: A visual simulator built by Canadian Aviation Electronics for the F-104 Flight Simulator is designed to give the pilot visual training in landings, take-offs, and tactical exercises. A non-programmed view projected on a screen in front of the pilot depicts what he would see from the aircraft in actual flight.

The technique used by CAE was explained. The visual system is built up around an analog model of the ground. An actual aerial photographic slide transparency of an area of ground stores the basic information containing the ground terrain. The slide is projected on to a spherical "model" screen, the image on the screen being a direct analog of the terrain to a certain scale. The terrain image is then transformed by a lens into a perspective image on the photocathode of a TV camera tube. The plane of the photocathode is inclined at an angle to the ground plane, this angle contributing to the amount of perspective distortion. The lens is located at all times by aircraft motions such that it analogs the pilot's eye.

The TV video is cabled to a projector behind the cockpit. This projects the perspective display on to a screen in front of the pilot.

One assumption made in using this technique is that the earth is plane. This means that buildings are not displayed in true perspective.

The TV camera lens operates at about f/12 - f/14. The focal length of the lens is approximately 10 millimeters and the depth of focus about 3 in. - 12 ft. within the resolution limitations of the vidicon. Field of view is 60 degrees.

The linear magnification of the TV image from vidicon face to pilot's display is 250X. The TV projector uses Schmidt optics and a 5-inch kinescope tube giving about 5 foot lamberts brightness. The perspective scaling is such that the pilot's display subtends the same angle at the pilot's eye as the real scene would from a real aircraft.

Author: Carey, P.M.

Title: "Simulating the Moving Perspective View From an Aircraft", SMPTE, Vol. 73, No. 10, October 1964, p. 854-857.

SUMMARY: This article discusses a system which has been developed to provide the same visual cues to a pilot in a flight trainer that a pilot flying an actual airplane would encounter. In order to create the sensation of flying, the system continuously computes a perspective view of simulated terrain. This is accomplished by projecting a magnified image of a photographic terrain slide onto a screen. This represents the area of terrain over which the simulated flight takes place.

The screen is at an angle from the perpendicular to a scanning TV camera lens. Thus the camera lens sees a terrain scene in perspective. The perspective image relayed by the TV link is formed on the photocathode of a TV camera tube. The video signal which now contains the perspective distortion is fed to a TV projector, which reproduces the picture on a screen in front of the pilot.

Simulated motions of the aircraft are managed by controlled movements of the TV camera (roll, pitch, and attitude) and the terrain slide (aircraft heading). Servo information defining these parameters is generated by the flight computer and forms the input control signals to the visual system.

Author: Choi, O., Gray, S., Herold, P., and Murray, P.

Title: Applied Research on High Resolution Camera Tube. Interim Engineering Report No. 3, Contract No. AF 33(657)-7939. RCA Electron & Tube Division, Lancaster, Pennsylvania.
(AD-292 650)

SUMMARY: This work is a continuation in development of a camera tube of the Image Orthicon type. One object is the development of a target structure consistent with a high sensitivity camera tube capable of 1500 television lines per inch at 50% sine wave response over a 2 x 2 inch format. Improvements were obtained by the use of smooth cathodes.

While most of the report expounds the details of making improved image orthicons it does seem that the authors have succeeded in obtaining results somewhat superior to those obtained in present image orthicon, and may eventually achieve the resolution being sought.

Author: Clay, B.R., Kidd, M.C., Whistler, R., and Wendt, H.W.

Title: Investigation of 360-Degree Nonprogrammed Visual Presentation. Radio Corporation of America, Defense Electronic Products, Aerospace Communications and Controls Division, Burlington, Mass. Technical Report: NAVTRADEVCEN 1053-1, 10 March 1962, Contract No. N61339-1053.

SUMMARY: A study was undertaken to determine whether a 360° panoramic television system of good performance could be designed, utilizing recent advances in electronics, optics, and data recording in judicious combination. The objective was to so design the system that it would meet the requirements of a visual simulation attachment for vehicle training devices.

Following a survey of past accomplishments in the field of visual simulation, a study was made of potential system components and techniques. Two basic systems were synthesized that appeared to hold high probability of successfully fulfilling the requirements of the 360° system. In each of these systems, a television pickup scans a terrain model in response to computer-processed control actions of the trainee. The scan is optically rotated 360° in azimuth. The video-information is transmitted to a display system mounted directly above the head of the student. The scene on the display screen is formed as a real image on the focal surface of an ellipsoidal mirror that surrounds the observer. The scene is thus made to appear at infinity.

The two proposed television systems differ from each other in the number of channels, and in the pickup and display devices that are used.

The first system, called a "fish-eye" system, employs a relatively small number of parallel channels (in the system described in the study, five channels); the second, or "fly's-eye" system, utilizes one channel for each elevation resolution element-a total of 3025 channels. The "fish-eye" lens, then, is a wide angle optical system; whereas the

"fly's-eye" lens gets its name from the large number of small lenticulated elements which make up the optical system. Each system utilizes fiber optics to transmit the image from the pick-up optical system to the focal plane of the projection lens. Each system also incorporates optical derotators.

As a result of the work performed during the study, the authors claim that the 360° television system appears to be within reach. Recommending that development be continued, they give highest priority to the development of the "fly's-eye" lens system.

Author: Colman, K.W., Courtney, D., Freeman, J.B., and Bernstein, R.

Title: The Control of Specular Reflections from Bright Tube Radar Displays. Courtney and Co., 1711 Walnut St., Philadelphia, 3, Pa., Report No. 23, Project K, 15 November 1958. Contract No. Nonr-2346(00). (AD-209 279)

SUMMARY: This report is the result of a study to determine methods for coping with reflections from display surfaces and for minimizing the effects of specular reflections on operator performance. A search was undertaken to determine whether applicable techniques for eliminating reflections might already be available. A theoretical solution to the problem was proposed. Based on this theory, a prototype of the Reflection Attenuator (RAT) was built and tested.

This technique consists of combining a circular polarizer with a curved implosion screen to form a reflection attenuator. The device is positioned between the observer and the display device; i.e., bright tube radar display. The circular polarizer is used to eliminate reflections from the tube face, and the implosion screen is curved to eliminate first surface reflections from the glass and the circular polarizing filter. The first surface reflections are absorbed by a light absorbing surface or a light trap.

Comparative physical measurements made with the RAT prototype model showed a reduction of reflections on the order of 97% when the RAT was used. Some of the proposed features to improve performance are an adjustable angle of incidence for the implosion screen for various ambient lighting conditions and viewing angles, and lamination of the circular polarizer into the implosion screen to improve strength and optical properties.

Author: Cope, A.D. and Bruce, W.F.

Title: "Low-Energy-Electron Scattering from Photoconductors Applied to a Camera Tube" RCA Review - Vol. XXVI, No. 2, June 1965, pp. 242-261.

SUMMARY: The paper describes developments in vidicon tube targets which give high performance in the Isocon mode of scanning. Tubes incorporating these improved targets were found to have illumination thresholds two orders of magnitude lower than those of conventional vidicons, signal-to-noise ratios comparable with the image orthicon, and a dynamic range ten times that of the image orthicon.

The isocon method of scanning differs from orthicon scanning in that the scattered electrons rather than specularly reflected electrons are used in readout of the target. A demountable photoconductive isocon was constructed in which the photocathode and storage target of the orthicon were replaced by various different photoconductive targets. The electron-optic structure was modified so that operation could be achieved in either the orthicon or the isocon mode.

Resolution is high because of the photoconductive target, and at low illumination the lower noise of the isocon mode results in higher resolving power than is obtainable with the orthicon.

Author: deFlorez Co., Inc., Englewood Cliffs, N.J.

Title: Study of Point Light Source Projection System Components. Technical Report: NAVTRADEVCEN 1628-1, March 1959. Contract Nonr 1628(00). (AD-233 882)

SUMMARY: This report is the first in a series designed to indicate the usefulness of the point light source in presenting the visual displays required for various training devices. The point source projection system utilizes a very small intense light source to project a display-object onto a screen, with appropriate drives and controls to move the light source and display-object relative to one another and with an appropriate supporting structure. Thus a continually moving, wide angle visual display is presented to an observer who is actually stationary in space. This display is presented with appropriate perspective, size, and position relative to the observer, thus simulating the visual world as viewed from any desired position and viewing angle in space. The display is completely non-programmed.

The study has been directed to the three basic components of the system: the point source of light, the display-object, and the screen, and to the inter-relationships of these components as they affect the net end product of the system, the visual display-image as seen by the observer. The current state-of-the-art of point light source projection techniques is covered, and areas are indicated where further development would contribute most to the usefulness of this technique and training devices. Technical considerations in the design of devices using point light source techniques are discussed. Derivation of important relationships as well as other useful technical information are furnished in appendices.

The report points out the advantages of the point source projection technique

which make it attractive in training programs requiring visual displays. These features are pointed out as being desirable:

1. Presentation of the visual display is non-programmed. The trainee is free to maneuver at will within the range of the trainer.

2. The visual display covers a very wide angle. Displays up to 160° in azimuth are off-the-shelf items. More sophisticated point source projectors can provide displays up to 200° in azimuth. A claim is made for full 360° displays.

3. The visual display is sufficiently correct in perspective to be convincing, regardless of the relative viewing position of the observer.

4. The display can be presented in color.

5. The components involved in the point source projection technique are relatively inexpensive, compared with other visual technique systems.

6. If necessary, three dimensional objects can be presented in this display in proper perspective.

This report also admits to certain deficiencies in the point source projection technique. These are listed as follows:

1. The maximum distance visible in any direction is limited due to the total reflection of light which occurs when rays are incident at acute angles on a transparent medium denser than air. With flat transparent display-objects of commonly available materials, the observer's simulated visibility is limited to a distance equal to approximately 10 times his simulated viewing altitude.

2. Clarity of the display-image varies inversely with simulated altitude. This results in a reversal of conditions experienced in real life, since in real life resolution improves with approach to ground.

3. There is a moderate distortion of perspective because of the displacement between the observers eye and the projection source. This results in distortion of position, and its derivatives, size, velocity, and acceleration.

4. Because of limitations on scale resulting from diffraction effects and extended source effects, large display objects are required to present extensive training areas.

Author: The deFlorez Company, Inc., Englewood Cliffs, New Jersey

Titles:

The Application of Point Light Source Techniques to a "Break-Out" Landing Attachment to a Twin-Engine Instrument Trainer. Technical Report: NAVTRADEVCEN 1628-2, March 1959. (AD-227 558)

The Application of Point Source Projection Techniques to Helicopter Low-Altitude Navigation Training. Technical Report: NAVTRADEVCEN 1628-3, March 1959. (AD-235 880)

The Application of Point Source Projection Techniques to Low-Altitude High-Speed Navigation Training. Technical Report: NAVTRADEVCEN 1628-4, April 1959. (AD-235 881)

Methods of Presenting Moving Objects in Point Light Source Visual Displays. Technical Report: NAVTRADEVCEN 1628-5, June 1959. (AD-233 912)

The Application of Point Source Projection Techniques to Air-to-Air Gunnery Training. Technical Report: NAVTRADEVCEN 1628-6, March 1959. (AD-235 882)

The Application of Point Source Projection Techniques to Air-to-Surface Attack Training. Technical Report: NAVTRADEVCEN 1628-7, June 1959. (AD-235 074)

The Application of Point Source Projection Techniques to Air-to-Surface Observation Training. Technical Report: NAVTRADEVCEN 1628-8, June 1959. (AD-233 913)

The Application of Point Source Projection Techniques to Surface Vessel Operation Training. Technical Report: NAVTRADEVCEN 1628-9, June 1959. (AD-233 914)

The Application of Point Source Projection Techniques to Ground Operation Training. Technical Report: NAVTRADEVCEN 1628-10, June 1959. (AD-233 915)

Evaluation of Experimental Light Sources and Transparencies for the Helicopter Hovering Flight Simulation Device 2FH2. Technical Report: NAVTRADEVCEN 1628-11, February 1959. (AD-235 883)

Preliminary Design Data, Basic Motion Device and Screen Structure. Technical Report: NAVTRADEVCEN 1628-12.

Preliminary Design Data, Item IC Basic Motion Device Electrical System. Technical Report: NAVTRADEVCEN 1628-13.

Preliminary Design Data, Item IC Inter-Coordination Techniques of Basic Motion Development. Technical Report: NAVTRADEVCEN 1628-14.

Final Test Report of Device 2-FH-4, Item II. Technical Report: NAVTRADEVCEN 1628-15.

The Development, Application, and Study of the Point Light Source Technique. Technical Report: NAVTRADEVCEN 1628-16, Sept. 1963. (AD-435 547)

Contract for all Reports: Contract No. Nonr 1628(00)

SUMMARY: The first report in this series (Study of Point Light Source Projection System Components. Technical Report: NAVTRADEVCEN 1628-1, March 1959. AD-233 882), abstracted separately, presents the current (1959) state-of-the-art of point light source projection techniques and indicates areas where further development would contribute most to the usefulness of this technique in training devices.

Each of the reports, NAVTRADEVCEN 1628-2 through 1628-10, discusses the applicability of the point light source system to a specific training problem. Insofar as the point light source technique is applicable to that problem, a typical design for a suitable trainer is presented and evaluated.

Report NAVTRADEVCEN 1628-11 compares two light sources and two trans-

parencies as used on the specific training device. The relative merits of these components are discussed and the importance of the various parameters to this training task are evaluated.

Reports NAVTRADEVCEN 1628-12 through 1628-14 cover the preliminary design data.

Report NAVTRADEVCEN 1628-15 covers the final test report.

Report NAVTRADEVCEN 1628-16 covers the final engineering operation and maintenance report for the complete device and includes a complete discussion of the principles involved in the device and its application to the point light source technique.

Components are discussed and the importance of various parameters to this training task are evaluated.

Author: DeHaan, E.F., et al

Title: The "Plumbicon", a new television camera tube, Philips Technical Review, Vol. 25, No. 6/7, pp. 133-151, 1963/4.

SUMMARY: A new type of television pickup tube and its method of operation are described.

By the use of a "sandwich" of photoconducting materials as a light detector in a tube of construction similar to that of a vidicon, greatly improved performance is obtained. The plumbicon exhibits greater sensitivity, greater dynamic range and less noise than the vidicon, and has much less lag.

The target consists of a layer of intrinsic (undoped) lead oxide interposed between layers of P-doped lead oxide and N-type tin oxide. In operation this makes the target sandwich act as a back-biased diode, which has low and uniform leakage (dark current). Incident photons react with the relatively thick intrinsic layer, liberating charges which can be efficiently collected because of the high field strength present in this region.

The paper considers in detail those properties and effects contributing to sensitivity, spectral response, resolution, speed of response, various sources of lag, constance of tube properties with life, and tube uniformity.

Author: Doty, A.F., Jr. and Gill, A.T.

Title: "Visual Simulator of Aerospace Flight".
Paper presented at AIAA Simulation for Aerospace Flight Conference, Columbus, Ohio, Aug. 26-28, 1963.

SUMMARY: This paper discusses a program which has been in effect at Wright Patterson Air Force Base since 1952. First studies in visual simulation space flight in 1957 led directly to a vigorous contractual and in-house research and development program which started formally late in 1958. The authors discuss a major part of the art of visual simulation as it applies to space flight. Specifically, this paper covers the more important ideas and technology which have come out of recent in-house efforts, contractual work with Bell Aerosystems, and travel and consultation work done in support of both efforts.

The contractual research and development efforts of Bell Aerosystems were mainly in the areas of image generation problems, particularly high resolution television and high frequency television insetting. In-house effort was concentrated mainly on image forming for display. Such areas as high brightness, cathode ray tube projectors, high gain screens, and hemispherical mirrors were studied.

Descriptions were given of some operational visual simulators. The visual simulation device for the space flight simulator for Edwards Air Force Base, being constructed by Link Division of General Precision, Inc., with Farrand Optical Co. as a major subcontractor, is described in some detail. So is the SMK-23 Day-Night Visual Landing Trainer, being built by Link. Another Link product, the All-Electronic Night Landing Device, is similarly treated.

Another type of visual simulation device, one which uses a flying spot scanner to

read information from a transparency, is described. One of the two known visual simulation devices presently in use which uses this technique is the landing trainer built by the Dalto Corporation of Norwood, New Jersey. This process does not use a television camera or lenses in the basic image forming process. The authors conclude that the fully computerized or flying spot scanner devices offer unique advantages in simulating the re-entry and landing portion of a flight. This is because these two classes of devices can cover the large initial values of altitude and range to go, which will then shorten to values of a few feet at final touchdown.

While evaluation programs were being conducted, an experimental apparatus was set up to generate a virtual image of a training scene. In effect, the device utilized the basic image generating technique employed in the Farrand Optical Co. infinity image systems. The device was given a preliminary subjective evaluation, using transparencies, television, etc. to produce the training scene. Subject's opinions were all highly commendable to the operation of the device.

Author: Fairchild Stratos Corporation, Electronic Systems Division, Wyandanch, New York

Title: Trainer Attachment, Visual Simulator SMK 22/F37A-T
Technical Report No. ASD-TDR-63-335, October 1963.
Contract No. AF33(600)-42063, Project No. 6166, Task No. 616601
(AD-425 682)

SUMMARY: This report describes a visual simulator which provides a dynamic simulation of the pattern of a runway and approach lights. Pilots are trained in the transition from instruments to visual flight, and gain experience in making decisions based on the visual cues.

The pilot's view from the cockpit of an aircraft is simulated by a television camera located in front of him and above the instrument panel. The television camera is synchronized with the roll, pitch, yaw, vertical, and lateral motions of the aircraft. Forward motion of the aircraft is produced by moving the simulated runway, mounted on a continuous conveyor belt synchronized with the airspeed of the flight trainer, beneath the camera. Belt speed and camera motion combine with the lighting display to simulate the effect of flying over a runway at night. The pilot views the display on a closed circuit TV monitor mounted in front of him in a simulated cockpit.

The system has some inherent drawbacks which would disqualify it for use as a wide-angle visual display. The 27" TV tube provides the pilot with a cone of vision of only 30°. At closer distances the image is degraded to a point where the individual raster lines can be seen. Additionally, a parallax problem exists which makes the "proper" location of the display with respect to one person incorrect for any other.

Author: Farrand Optical Company, Inc., New York

Title: Operating Manual (Maintenance) for Contact Flight Simulator, Device 14-L-2. NAVEXOS P-374, 12 January 1945. Contract N5ori-82.

SUMMARY: This report provides a description of, and operating instructions for, the Contact Flight Simulator, Device 14-L-2. The device is designed for broad general-purpose use in connection with the combat training and briefing of pilots and others concerned with the strategical and tactical use of aircraft as an offensive weapon. It provides a means of simulating pilot-controlled contact flight for the specific purpose of briefing pilots over three-dimensional models of enemy territory which is to be subjected to an attack.

The major components of the device are a movable chassis, periscope, and related components; an aerodynamic computer; and a servo system.

Manipulation of the trainer controls result in an illusion of actual contact flight over actual terrain at corresponding real altitude and attitude of the plane. A three dimensional model of the terrain under consideration, made to scale, is suspended in an inverted position from the ceiling. The scene is viewed through the periscope and is oriented properly, with respect to the trainee, by all-optical means.

Author: Farrand Optical Company, Inc., New York

Title: Optical Viewing Devices for Aircraft. WADC Technical Report 52-254, January 1953, Contract No. AF33(616)-144, R.D.O. No. 696-67

SUMMARY: The results of a survey of the literature pertinent to optical viewing devices for aircraft are presented. It is shown that the extent of vision provided for the pilot in current aircraft is inadequate, especially in fighter aircraft, that the provision of adequate window areas in supersonic aircraft is incompatible with efficacious aerodynamic design, and that providing an effective optical periscope appears to be the most reasonable solution to the problem.

Experiments in the use of optical periscopes for pilot's vision in aircraft are described. Some of the more obvious problems which will arise in the design of a useful periscope are reviewed and discussed. Descriptions of some alternative instrumental arrangements are given.

Summaries of fields of knowledge pertinent to the design of optical viewing devices for aircraft are included in the study. Subjects that are discussed include: wide angle optical systems, large aperture optical systems, aberrations, optical scanning systems, human vision, etc.

Conclusions as to the significance of the informational material collected are drawn, and recommendations as to the next phase of the investigation are presented. Specifically, construction of one or more model instruments based upon the results of the design studies is advised. Flight testing of the model instruments is recommended for the purpose of revealing all possible new problems which were not apparent from the study, and for providing an effective evaluation of the efficacy of the characteristics which resulted.

Author: Farrand Optical Company, Inc., New York

Title: Report of Concept Study: Wide Angle Viewers for Tanks
ER-351, 30 November 1957. Contract No. DAI-30-069-507-ORD-(P)-1645 (Phase I) for Frankford Arsenal, and Dept. of the Army Project No. 5T13-02-062, Ordnance Project No. TT2-689.

SUMMARY: This report is a study of wide-angle viewing systems for tanks. The various possible solutions to such a system are classified and analyzed, and ten possible solutions, each representative of a different basic form of optical system, are described and illustrated. The relative advantages and disadvantages of each of these solutions with respect to the significant parameters of a tank viewing system are evaluated.

Lack of really definite information on the requirements for a tank viewing system made it impossible to arrive at a choice of an optimum system among those presented.

Recommendations are made for the construction of several instruments of different types, in order that a field test program may be undertaken to determine, on an objective experimental basis, which of the solutions is optimum.

Author: Fox, P.L.

Title: Design Study for Trainer, Visual Flight Attachment for Aircraft Flight Simulators. Rheem Manufacturing Co., WADC Technical Report 57-137, Part I, March 1957. Contract No. AF 33 (600)-32579, Project 6166.
(AD-216 438)

SUMMARY: This report discusses the design of a comprehensive visual display system to be attached to, and used in conjunction with, a fixed air-spaced electronic flight simulator. The essential requirements for a visual presentation system, which were used as a basis for the determination of the visual simulation problem, are as follows:

1. The Visual Flight Attachment is intended to present to the pilot of a flight simulator the visual effects of takeoff, traffic pattern navigation, landing, and ground roll.

2. The flight simulator cockpit will be located within a spherical shell which serves as a screen, and positioned so that the view point of the pilot is near the spacial center of the screen.

3. The projection system, utilizing an illuminated, opaque relief map of the ground scene as the object for the optical system, will project a full-color, control-responsive image on the inside surface of the spherical shell.

4. The ground scene will extend generally from horizon to horizon, and will extend slightly above the horizon to include objects that form the skyline when seen from a point as low as 10 feet above the ground.

5. All the characteristics of actual flight will be duplicated on the cockpit instruments and controls, and in the environment as displayed on the screen.

The recommended design system concept utilizes a unique reflected-light projection system to create a realistically-sized terrain image on the inside of the spherical shell which surrounds the flight simulator cockpit. Its operation is based upon a panoramic-type rotary-sweep lens system which generates a very wide-angle field using relatively narrow-angle optical techniques. The lens axis is pointed downward at some angle from the horizontal and made to revolve about a vertical axis. A panoramic image is swept onto the screen each time the lens passes by. As speed of revolution is increased, the persistance of vision will blend the successive images into a continuous band or horizontal field.

The terrain image extends from horizon-to-horizon and 360° in azimuth. The instantaneous field of view of the optical viewing and projection lenses, which comprise the telecentric lens system, are 45° each. A central image field will be generated by a stationary telecentric lens system of 90° field width . It is expected that the image formed by the central field will be poor both in resolution and brightness.

Special design details are given of the optical system object lens, image plane erector prism, and a parallax correction device. This latter is designed to work in conjunction with the projector lens.

The optical system was subjected to a detailed mathematical analysis by Farrand Optical Co. The results of that analysis were reported in a later report. (Fox, P.L. Design Study for Trainer, Visual Flight Attachment for Aircraft Flight Simulators, WADC technical report 57-137, Part II, Sept. 1958, Contract No. AF 33(600)-32579. AD-233 189)

Author: Fox, P. L.

Title: "Design Study for Trainer, Visual Flight Attachment for Aircraft Flight Simulator", Rheem Manufacturing Company, Electronics Division, Downey, California; WADC Technical Report No. 57-137, Part II, Sept. 1958, Contract No. AF33(600)-32579. (AD-233 189)

SUMMARY: This report documents the work which followed the efforts described in WADC technical report #57-137, Part I, Astia Document #AD-216 438. Part I describes a visual flight attachment to a ground based electronic flight simulator. The attachment is intended to provide a substantial part of the visual effects that a pilot would encounter in actual flight maneuvers, such as landing, take-off, and traffic pattern navigation. The report is a result of an intensive search for a solution to the many difficult optical, geometrical, and mechanical problems involved in providing a display of sufficient scope and realism to make the trainer a positive and significant tool in the accomplishment of its intended function.

A continuing study of these problems has resulted in further clarification of the functional requirements and has led to the development of advanced techniques which permit certain modifications in the system concept. These modifications are the substance of part II, which, in effect, is a supplement to the original report.

At the completion of the study documented in part II, and as a result of discussions between Rheem and Air Force personnel, it was concluded that a cluster lens objective system with an optical image relay system (lenses, mirrors, prisms) was the most feasible attack on the problem of providing a wide angle panoramic view. The cluster lens system involves a technique of dividing the field into several smaller fields and projecting each in juxtraposition through separate optical channels, much as in the manner of Cinerama. Ordinary narrow angle optical

components are used throughout, but the system is mechanically very complex.

A sub-contract was concluded with an optical design firm to prepare designs for a complete optical system. After several months of design effort the results of the optical design analysis revealed that the particular system under study could not be refined sufficiently to bring the various distortions and aberrations within acceptable limits. To obtain acceptable results it would have been necessary to start a new system design. At that point, the effort was abandoned by the Air Force, the reason being the limited expectations of success and because of high cost.

One other approach to the optical system had been considered, that of a 200° wide angle centered optical system. A preliminary study of this system was conducted under sub-contract to Rheem Manufacturing Co. by Farrand Optical Co., the results of which are recorded in FOCI ER-356. In substance, the FOCI report states that such a system is feasible having properties as follows: 200° field of view, 1/4 inch to 3/8 inch diameter entrance pupil measured normal to the principal rays, and resolving power of ten minutes of arc or better in the critical portion of the field from 15° to 45° below the horizon.

The above conclusions were based on a mathematical ray trace analysis of the objective lens.

Author: Fox, P.L. (Assigned to Rheem Manufacturing Co., Inc., Downey, California)

Title: Synthetic Projection, U.S. Patent No. 3,114,979, December 24, 1963, Patent Office, Washington, D.C.

SUMMARY: This invention relates to a visual display device, and to an image storage means for such a device. An essential feature of the invention is a set of plates that bear a plurality of lens elements on one of their sides, and a matching number of sensitized image storage elements on the opposite side. These elements are exposed to a scene, much as in the case of film in a camera, and then developed, thus retaining the data to which they were exposed. A multiplicity of these plates are stored in a cabinet which is part of the equipment of a flight training apparatus. The plates are positioned sequentially under a projection device. When illuminated from behind, each image storage element yields rays which tend to return to their original orientation in space relative to the plates. There they reconstitute an image which is projected onto the inside surface of a spherical viewing screen. This image is viewed by a person occupying, and operating the controls of, a training device. The display is completely unprogrammed, so that simulated positions within the operating range of the device may be selected at random, providing an aspect of the scene unique to the randomly selected position.

Author: General Electric Military Communications Department

Title: Large Area Electronic Display Panel Report No. 8, 1 Mar. - 31 May 1964 (AD-443043)

SUMMARY: The project described by this report apparently uses thermoplastic recording and a total internal reflection prism for readout. A 1600 watt Xenon arc lamp is operated at high power to provide illumination. Recording is expected to be done with 3,000 line resolution and readout at 60 lines per millimeter resolution. Both of these are considered feasible values. This report is one of several on thermoplastic and photoplastic recording and readout work, at least some of which should be applicable to high-resolution, high-brightness television systems.

Author: General Electric Company, Syracuse, New York

Title: Matrix Control Display Device
Second Interim Development Report, 15 Sept. - 15 Dec. 1963
(AD-426716)

SUMMARY: This report describes development of a large screen matrix control display device using in-air surface deformation recording and the total internal reflection prism (TIRP) projection technique. The TIRP projection system for the optical readout of surface deformation on a thermoplastic medium appears to be an alternate to the Schlieren system usually used. The total internal reflection prism technique in combination with a thermoplastic recording or photoplastic recording medium might form the basis for an improved television output device. The main advantage of thermoplastic or photoplastic recording is that projection can take place with an external light source. Secondly, in those portions of the scene which are to appear dark, energy need not be absorbed by the film.

Author: General Electric Company, Syracuse, New York

Title: Final Development Report for Matrix Controlled Display Device dated 1 August 1964, this report covers the period 1 July 63 to 1 August 64 Contract NObsr-8933 4. (AD-603545)

SUMMARY: A matrix controlled display device utilizing in-air surface deformation recording and display techniques to provide a large, bright projection display has been developed.

Matrix electrodes at different spacings and widths were investigated to determine the cell dimensions for an optimum display. The final matrix fabricated for the experimental model has 32 lines and 32 columns at the optimum electrode spacing (2 mils) and width (1 mil) resulting in 500 cells per inch at the thermoplastic medium. The TIRP projection system implemented easily resolves these cells to provide 16 elements per inch at the display screen.

The transfer of parallel row information to a single line requires 100 microseconds. Therefore a display with 2000 lines and 2000 columns can be written as a charge pattern in 0.2 seconds. Conversion of the charge pattern to a surface deformation recording by I^2R heating requires 0.3 second per frame. Since frame erasure requires 1.2 seconds, the update time for a 2000 x 2000 element display is 1.7 seconds.

Image storage time is in excess of several months. In addition, short time storage of less than a second has been achieved. Although individual storage is feasible, individual erasure of a cell has not been achieved.

Author: Glenn, W.E.

Title: "Thermoplastic Recording: A Progress Report", Journal of the SMPTE, Vol. 74, Aug. 1965, p. 663 - 665

SUMMARY: Descriptions and performance data are given for current thermoplastic recorders including 16 mm tape and a continuous loop machine. Recording in color, and a 1029 line raster, 2000 line resolution wideband system are described. Systems for electrical readout of thermoplastic recordings are also presented.

The 16 mm system is capable of 2000 line horizontal resolution, with film running at nine inches per second. An image is provided for monitoring purposes. Although recording must be done in vacuum, evacuation time is only about one minute.

Since the thermoplastic film can be erased and reused, a practical loop recorder can be built. The loop has a life of a few thousand cycles with intermittent transport operation, and a much greater life when continuous motion is employed. Life limitation is due solely to mechanical damage to the film base.

Color recording requires modulation at a subcarrier of 18 mc which produces diffraction effects in two directions.

High frequency capability has been demonstrated by recording an 850 mc sine wave. The resultant dot pattern indicates significant modulation capability at this frequency, with a charge density of about 10^6 electrons per recorded bit.

Author: Goetze, G.W. and Boerio, A.H.

Title: "Secondary Electron Conduction (SEC) for Signal Amplification and Storage in Camera Tubes" Proceedings of the IEEE, September 1964, pp. 1007-1012.

SUMMARY: An image tube is described which combines the desirable features of an image intensifier with those of the vidicon.

The SEC vidicon has a photocathode separated from the electron-beam scanned "target" both physically and by a potential of about 10,000 volts. The section between photocathode and target thus acts as an image intensifier, except that the recipient of the accelerated electron image is the target rather than a phosphor. Conduction through the target is by energetic free electrons traveling in the interparticle layer, rather than by conduction band electrons. (With increasing voltage on the target the gain is increased due to the contribution of electrons in the conduction band.)

Resolution achieved to date has been 1000 TV lines/inch, but this figure is expected to be raised ultimately to 3500. Since the tube operates by direct readout, noise is minimal. Good pictures have been obtained with faceplate illuminations of 10^{-4} to 10^{-3} foot-candles. The tube has excellent dynamic range and extremely good integration capability.

2.50

Author: Goldsmith, A.N.

Title: "Theater TV - A General Analysis", Journal of the Society of Motion Picture Engineers, Vol. 50, No. 2, Feb. 1948, p. 95 - 121

SUMMARY: A summarization of the state-of-the-art of motion picture theater television is given. The analysis is a descriptive report, stressing such areas as theater and screen design, location of projection equipment, sound-reproduction methods, cost factors, programming problems, etc.

The technical discussion was held to a minimum. The author discusses, in general terms, picture size and viewing conditions, picture brightness and whiteness, and picture resolution.

The author also describes two of the main techniques for reproducing TV programs on theater screens. The first of these is a CRT projection system, usually using Schmidt optics or some high-speed projection - lens system. According to the second method, the incoming program is reproduced on a bright CRT, but the image is projected, not on the theater screen, but on motion picture film and recording camera. It is rapidly processed and then projected according to the usual theater techniques.

Author: Gray, Robert, et al

Title: Secure Color Video Techniques and Annotated Bibliography, Vols. I and II Technical Report No. RADC-TDR-64-339, February 1965, Communications Techniques Branch, Rome Air Development Center, New York (AD-462528, -462529)

SUMMARY: Volume I "examines and compares the merits of many analog matrixing techniques for color television". It is quite thorough, and not restricted to systems compatible with existing monochrome television standards.

Volume II contains an extensive annotated bibliography which covers monochrome as well as color techniques and systems. Subject headings include:

General References

Color Cameras

Color Television Systems

Color Video Displays

Perception

Bandwidth Compression

Storage

Author: Grodsky, M.A., Moore, H.G. and Flaherty, T.M.

Title: "Crew Reliability During Simulated Space Flight." Paper presented AIAA/AFLC/ASD Support For Manned Space Flight Conference, Dayton, Ohio, April 21-23, 1965.

SUMMARY: This paper describes a simulation experiment which was perfomed for the purpose of estimating crew reliability for extended space flight missions. The mission selected for simulation was the lunar landing mission since this mission was well conceptualized and had a variety of tasks which the pilot could perform.

An integrated mission simulation technique was utilized which, with the exception of the earth ascent phase of the lunar mission, simulated the mission and system as completely as possible in terms of equipment, mission phases, crew tasks, etc. In addition, the simulation was conducted in real time so that such factors as the time sequencing of tasks, duty cycles, etc., were considered.

The simulation equipment consistsed of a command module simulator, a lunar excursion module, (LEM), a mission control and data collection facility, and an analog facility. Only the crew compartment portion of the LEM was actually simulated.

A 24 foot diameter spherical screen was mounted in front of the LEM module so as to fill the out-the-window field of view ($\pm 90^{\circ}$ azimuth, +18 to -90° elevation). Two projector systems provide the displays on the screen. An out-of-sight star-horizon projector projects a star field and an outline of the moon on the spherical screen. The whole scene moves as the pilot controls the vehicle's simulated roll, pitch and yaw motions via the analog computer. A rendezvous projector, located on the nose of the LEM, projects a blinking light and an outline of the command module on the screen during rendezvous phase. At close range, when the command module itself is visible, the projected light

becomes a steady outline which grows in size as the range decreases to maintain the proper apparent vehicle size.

At the start of the docking phase, the screen separates in half, along its line of intersection with the LEM plane of symmetry, to permit rapid retraction out of the crew's field of view. To perform the docking maneuver between the LEM and command module, a translator (representing the command module) was used with the LEM gimbal to perform actual physical docking with 6-degrees-of-freedom at a distance of 12 feet.

The hover-descent phase in the real Apollo mission will be controlled by the pilot using his out-the-window view of the terrain. The cost of simulating such a view was not considered justified. However, a CRT display was added to the panel to show the downrange and crossrange position of the LEM relative to the landing site.

The data presented in this paper show that performance degradation of the pilots during the seven-day simulation experiment occurred only in some of the mid-course correction switching phases. All other performance was statistically within pre-mission baselines.

Author: Grosso, P.F.

Title: Development of Phosphor Screens for High Resolution Display Devices. Technical Documentary Report No. AL-TDR-64-94, dated May 1964 under Contract No. AF33(657)-10632 by CBS Laboratories. (AD-600724)

SUMMARY: Suitable suspensions were developed for electrophoretically depositing P-15, P-16, and P-24 screens. Four inch diameter screens with limiting resolution of 80 line pairs/mm (2000 TV lines/inch) have been produced. No mention is made of brightness achieved at this or other line densities.

Further work is recommended to improve the uniformity of phosphor screens.

Author: Gruner, H.

Title: "Super-Wide Angle Projection Mapping Instrumentation", Photogrammetric Engineering, Vol. 30, Sept. 1964, p. 745-749.

SUMMARY: A 120° field coverage lens, designed by Dr. L. Bertele, is described. The lens has application to small scale mapping; i.e., to publishing scales of 1:20,000 and smaller. Basically, a symmetrical lens of the quadruplet category with six elements was derived which, when manufactured to extraordinary tight tolerances, met the requirements of field coverage, high resolution and near zero distortion at a given finite magnification ratio. Its notable optical performance is achieved by new methods of centering and calibration. The lens system can be compensated for any given magnification ratio, including infinity application, by a method of internal reciprocal air spacing.

The illuminator is a reflective condensing system produced by replication from a master ellipsoid.

Author: Harshbarger, J.

Title: "Television Displays for Visual Simulator Training". Paper presented at AIAA/AFLC/ASD Support for Manned Flight Conference, Dayton, Ohio, April 21-23, 1965.

SUMMARY: This paper was a brief analysis of the parameters involved in television systems, and several of the trade-offs among them. Interesting observations reported in this paper include the following:

The 7WP4 projection television tube seems capable of much higher resolution than has heretofore been obtained. Ultimate capability of 1000 TV lines seems indicated.

In spite of the importance of low picture noise in producing a realistic simulation, information on this subject is not available.

At high line density (1000 lines and more) it appears that the traditional Kell factors need to be revised upward because of the change in scanning pitch.

No part of the paper was directed toward the infinity image type of displays.

Author: Harshbarger, J.H. and Gill, A.J.

Title: Development of Techniques for Evaluation of Visual Simulation Equipment. Systems Research Laboratories, Inc., Dayton, Ohio 45432, AMRL-TDR-64-49, August, 1964. Contract No. AF 33(657)-8299. (AD-607 680)

SUMMARY: In Phase I of this report, a study of large area image display by projection television was undertaken for the purpose of evolving techniques of suitable image generation for astronautical flight simulation training. An objective method for the evaluation of projected images was developed as part of the program. A portion of the projected image is viewed by a second television system, and the video from this second system is examined with a line-selector oscilloscope for objective determination of modulation, resolution, etc. A closed-circuit television system display from an F-151 Fixed Gunnery Trainer was evaluated. In Phase II of this work, the projector in the F-151 television system was converted from 525-line EIA standards to a high resolution 1029-line system. The performance of the 7WP4 projection tube exceeded the predictions limiting horizontal resolution was found to be 650 to 700 lines with a well defined vertical raster. Recommendations of the authors are that a basic study of CRT characteristics for display devices is warranted.

The method of determining resolution with a separate TV system seems to be novel and useful. No effort was expended in trying to improve the design of the 7WP4, but merely to measure what it can do.

Author: Hellings, G. and Emms, E.T.

Title: "A Visual System for Flight Simulators", British Communications and Electronics, Volume 7, May 1960, p. 334-337

SUMMARY: This article describes a method utilized by Link Division of General Precision, Inc. to simulate a terrain and runway environment for pilot training in the take-off phase and the approach and landing phase of a flight.

The technique used employs a TV camera "eye" to view a relatively moving model landscape. The picture transmitted by the GPS camera unit and its associated equipment is in the form of a standard video signal, and can be displayed by a monitor tube or projection system.

One form the model takes is that of a terrain manufactured on an endless belt principle. The camera optical unit is placed near the bottom of the belt and by the use of a small mirror or prism "looks up" its length. This principle is applicable only where the model size is relatively modest. The camera is mounted on a trolley moving on rails perpendicular to the belt surface.

In one model, the scale factor of 1:2,000 implied that the depth of field of the camera and its optical system (the probe) must range from 0.36" to 12.5 feet. This necessitated a very small aperture optical system. A high-sensitivity image orthicon tube was used in the camera to obtain a satisfactory picture. Since the entrance pupil of the optical system approaches to within 0.090 inch of the model terrain surface at touchdown, a special optical sight was developed to permit this. The design of the sight was not discussed.

Author: Hemstreet, H.S. (Assigned to Link Aviation, Inc., Binghamton, N.Y.)

Title: Grounded Aviation Trainer for Rotary Wing Aircraft, U.S. Patent No. 2, 885, 792, May 12, 1959, Patent Office, Washington, D.C.

SUMMARY: This invention describes an apparatus for creating a visual image of the scene viewed by the pilot of an actual aircraft for use in training students in the operation of an aircraft.

The apparatus projects a scene, such as an aircraft carrier deck or an airfield runway, upon a translucent screen. A simulated helicopter hovers above the screen. By maneuvering the simulated aircraft controls, the pilot causes the scene on the screen to change in perspective, representing the view the operator of an actual helicopter would observe as his craft went forward, backward, sidewise, turned, pitched, banked, or gained or lost altitude.

Another light source, shining through a blued lens, projects a simulated blue sky on the screen immediately above a horizon line.

2.60

Author: Hemstreet, H.S. (Assigned to General Precision, Inc., Delaware)

Title: Method and Apparatus for Producing Visual Display, U.S. Patent No. 2, 975, 670, March 21, 1961, Patent Office, Washington, D.C.

SUMMARY: This invention describes a technique and apparatus for producing visual displays. In a preferred embodiment of the invention, motion pictures made from an aircraft during an actual flight are projected for observation by a pilot in a stationary grounded trainer. The images from the motion picture film are distorted or altered in apparent perspective in accordance with deviations of the simulated course "flown" by the grounded trainer from the course along which the pictures were taken. Optical distorting means (a rotatable prism and a variable power anamorphoser) are used to modify an image projected from a film to provide a perspectively correct image which, when viewed from a position corresponding to the location of the camera when the film was exposed, simulates the same scene as it would appear when viewed from a different position.

Author: Hemstreet, H.S. (Assigned to General Precision, Inc., Wilmington, Del.)

Title: Method and Means for Correcting Parallax, U.S. Patent No. 3,071,875, January 8, 1963. Patent Office Washington, D.C.

SUMMARY: This invention describes a method for correcting errors due to parallax in projected displays of simulated scenes for flight simulators. The method is described in connection with a closed circuit television system, although it is applicable to other techniques used with display systems, some of which do not employ projectors.

In the embodiment chosen, the flight simulator system consists of a model terrain, a servoed television camera and projector, a viewing screen, and a simulator cockpit. The optical axis of the pick-up lens used within the television camera is displaced laterally from the face of the television camera tube. The amount of displacement is chosen so that the horizon of the object being picked up will be imaged on the center of the television tube in spite of the fact that the camera tube has been tilted. The image formed in the camera is then projected onto a viewing screen in front of the simulator cockpit. The television projector, mounted on top of the cockpit, is slightly tilted in order to provide clearance for the projected image. Since the face of the kinescope and the face of the screen are placed in parallel, the image on the screen presents a warped perspective as viewed from most viewing points or viewpoints in space.

A viewpoint is selected so that a horizontal line will pass between the viewpoint and the projected image of the horizon on the screen. The distance of the viewpoint from the screen, measured along the horizontal line, is such that the angle subtended at the observers eye by any two points on the projected image is equal to the

angle subtended at the pick-up lens by corresponding points in the physical object. The image is free of parallax for this particular viewing point.

The principles involved may be adapted to any non-projection optical display system in which the position of the viewpoint relative to the image is different from the position of the camera relative to the object.

Author: Hemstreet, H.S. and Woodson, R.A. (Assigned to General Precision, Inc. Delaware)

Title: Means for Producing Visual Display in Grounded Aircraft Trainers, U.S. Patent No. 2,938,279, May 31, 1960, Patent Office, Washington, D.C.

SUMMARY: This invention relates to a visual simulation apparatus for projecting photographic images of topographic features onto a viewing screen. The image magnification is varied in simulation of altitude changes in response to simulated flight maneuvers to produce a more realistic simulation of contact flight by visual reference. Claims are made that it is possible, by the present invention, to simulate a complete flight from take-off through climb to a designated cruising altitude, and let down to landing at a distant air field.

A student pilot sits in a flight trainer cockpit facing an inclined projection screen. The image has controlled keystone distortion which is produced by projecting an undistorted photographic transparency at an angle onto the inclined screen. The lower portion of the formed image, which is closest to the point of observation, is so magnified that it subtends a larger angle at the eye than the upper or more remote portion of the image. The image on the screen has no perspective distortion when viewed from the pilot's position.

The factor of vertical perspective may be added by employing a three dimensional transparent object in lieu of a simple two dimensional transparent film. An image will be projected onto the screen which will include shadowgraph features conveying a sense of a third dimension, or vertical perspective corresponding to the relative heights and shapes of the three dimensional transparent models. Such three dimensional transparencies may be used, for example, for simulating the maneuvers of hovering at a low altitude in a helicopter.

Author: Herud, E.

Title: Final Engineering Report on Study of Television Multiple Insertion Techniques, by Allen B. DuMont Laboratories, Inc. for U.S. Naval Training Device Center, Contract No. N61339-90, Technical Report: NAVTRADEVCEN 90-1. (AD-291 762)

SUMMARY: This report is a brief, and not too technical, description of several matting and wiping systems for use with television. There is a good technical comparison of several alternative matting schemes on pages 103 to 108. Much of the report is taken up with the description of a system that apparently was built as part of this contract.

Brief mention and description is also made of two interesting matting systems used in commercial television. These are Vitascan (which is a flying-spot technique) and Cinecon (which uses a 24-sided rotating prism).

The author concludes, among other things, that the limitations of the pick-up and display devices used in television are attained long before those involved in a multiple insertion system.

Author: Huang, T.S.

Title: "The Subjective Effect of Two-Dimensional Pictorial Noise", <u>IEEE Transactio</u> <u>on Information Theory</u>, January 65, Vol. IT-II, No. I, pp. 43-53.

SUMMARY: A study was made of the subjective effects of the class of independent additi rectangular low-pass Gaussian noises. The pictures were digitized, noise of a predete type added, and the pictures reconstituted for presentation to the test subjects. No work was done in real time, or with motion subjects. The human observer was considered m as a "black box", whose input/output function was to be determined.

Isopreference surfaces were determined in the 3-space defined by horizontal vertical noise bandwidths and RMS noise amplitude. For the small number of observers the agreement among subjects was rather good. They were more in agreement as to the of noise power changes than on bandwidth changes. The isopreference surface shows a maximum of objectionability for noise bandwidth of about 0.2 cycle per minute of arc, falling off at higher and lower frequencies. Noise with vertical streaks is more objec able than that with horizontal streaks, although details of the isopreference surfaces v found to vary considerably among the three pictures used.

Author: Hutchinson, C.H.

Title: Final Report - Automobile Driving Simulator Feasibility Study. Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y. CAL Report No. YM-1244-V-6, 18 November 1958. Contract No. SAph 69692.

SUMMARY: This report discusses system requirements for the visual display of a vehicle simulator. Four optical techniques are evaluated in terms of their ability to solve field of view, brightness, contrast, resolution, color, perspective requirements, etc. The techniques that were discussed are: closed circuit television, direct optical viewing, point light source projection, and motion picture film.

Motion pictures ranked higher than the other methods for most characteristics, the notable exceptions being unprogrammed situations, perspective, and traffic intelligence. Televised and direct optical systems are roughly equal on an overall basis, while point light source is ranked lowest for automotive application. With regard to development potential, it appeared that television will progress more rapidly than the other techniques primarily because of the tremendous amount of commercial interest and investment. Thus, it was concluded that a visual display simulator utilizing a television link between a model terrain and the data display offers greater potential value than any other method.

Author: Ingalls, A.G.

Title: "The Making of a 'Fish Eye' Camera", Scientific American, Dec. 1953, p. 110-113 and Jan. 1954, p. 90-95.

SUMMARY: These two articles describe the making and performance of a simple, single-element hemispherical lens. The lens, sometimes dubbed a Sintar lens, in appearance resembles a protruding fish's eye. It has a true field of view of 180°. Because of its peculiar, one-element design and construction, the Sintar lens is strongly afflicted with three forms of optical aberrations: barrel distortion, curvature of field, and lateral chromatism.

The lens design can be modified to reduce the lateral chromatism while retaining the curved image field and/or distortion characteristics over the field of view. The magnitude of those aberrations that are tolerable are dictated by the lens application.

Author: Johnson, H.T.

Title: "Simulation and Training Facilities", Astronautics and Aerospace Engineering, Volume I, February, 1963, page 82-86

SUMMARY: The probable training and simulation facilities for manned space flight projects- Gemini, Apollo, LEM, and others as yet unapproved - is described. The requirements for providing good out-the-window displays for these trainers is discussed.

The number and type of displays for the various flight trainers had not been decided upon as of the date of publication of this article. The probable displays were:

1. Gemini - starfield, rendezvous and docking, and earth with cloud cover display.
2. Apollo - Gemini inputs plus earth and moon from a wide range of distances, and moon from close orbit.
3. LEM - celestial display and a display of the moon ranging from close orbits to selected landing sites.

The author mentions some of the display system techniques under study: new methods of producing virtual images (which, by nature, have extremely high resolution), high resolution closed circuit television systems, beamsplitter techniques for combining various scenes easily, and methods of generating scenes electronically which eliminate the need for models.

Miscellaneous training devices were described. The Apollo three-dimensional lunar-trajectory simulator, in the early proposal stage in 1963, will show in true scale, except for spacecraft size, the relative dynamics of the earth, moon, and spacecraft system. The earth-moon system will rotate about its total center of gravity, which will be placed at the center of a building approximately 70 feet in diameter. A one-foot diameter earth model will rotate about its own axis. Collimated light falling on the earth model represents the dayside of the earth as seen from space, while an internal light shining past a hemispherical movable shade represents the sun's illumination of the moon.

To an observer, seated inside a spacecraft model, the device would represent an "inside-out" display. The earth and the moon would be seen in the same geometric aspect as would be seen by the occupants of an Apollo spacecraft en route to the moon.

The NASA Ames Research Center midcourse navigation simulator, in a developmental stage in 1963, consists of an Apollo command-module spacecraft mock-up located in a hemispherical domed room of 50 foot radius. Simulated stars will be fixed in the surface of the dome to provide the extremely high accuracy necessary for the practice of sextant operations during the mid-course navigation phase.

Author: Kinkade, R.G., Synder, H.L. and Greening, C.P.

Title: "Simulation of a Star Field," Human Factors, Vol. 5, June 1963, pp. 335-338

SUMMARY: This article describes the results of an investigation of certain variables affecting the perceived realism of a projected star field. The variables which were investigated were star size, star intensity, sky luminance, and heterogeneity of star field. The results of tests involving 12 observers indicate that maximum realism is obtained from a star field which has the following characteristics:

1. Sky (background) luminance quite low, in the order of the outer space sky (10^{-5} candelas per square meter).
2. Individual stars subtend one minute, or less, of visual angle, appearing as point sources.
3. Simulated stars are fairly bright, appearing as first to third magnitude, average.

One important overall characteristic of these conditions is that of virtually infinite contrast between the simulated star and its background.

Author: Klemperer, W. B. (Assigned to Douglas Aircraft Company, Inc. Santa Monica, Calif.)

Title: Visual Simulator for Flight Training Device, U.S. Patent No. 2,979,832, April 18, 1961, Patent Office, Washington, D.C.

SUMMARY: This invention describes a visual simulation apparatus which utilizes models and closed circuit television to present a non-programmed scene of a landscape, as seen through a cockpit windshield, to a student pilot. The invention particularly relates to the training in those phases of flight operations which concern the beginning and termination of flight such as the take-off, the landing, and the approach to a landing field.

The invention provides a scaled-down model of a typical landscape area; for example, an airport with runways and buildings, and the area on the approaches to the airport. A television camera is directed at the model landscape to provide, through a projector, a visual reproduction of the airport on a screen corresponding to the panorama which would be seen from the plane. The camera is carried on a mount capable of being moved in six degrees of freedom.

The picture taken by the camera is transmitted through a closed wire circuit to a projector and projected on a screen which is viewed by the pilot. The screen provides a two-dimensional picture in such a manner that a three-dimensional illusion is conveyed. During the landing maneuver, the pilot operates his controls in accordance with his impressions of what he sees on the picture presented on the screen. These controls regulate a flight simulator computer so that it will compute and integrate the various components of linear accelerations, velocities, and positions as well as angular accelerations, velocities, and attitudes which the simulated airplane would successively undergo, attain, or hold. These par-

ameters are fed into a six-component servo system so designed that it moves the television camera optical system continuously into the scaled-down positions and directions over the model landscape which a real airplane would assume during a real approach over a similar real landscape. Thus, the flight pattern presented by the camera to the pilot is adjusted in accordance with the pilot's operation of the controls.

Author: Kraus, C.J., et al

Title: Display Improvement Program (ECPX 0027)
Final Report dated November 1, 1960 on Contract AF30(635)-1404 to IBM, Kingston, New York
(AD-253400 - Vol. 1
AD-253401 - Vol. 2)

SUMMARY: The program reported on represents an exhaustive study of possible displays and display improvements for the SAGE-I system. The work has been subdivided into the following basic tasks:

Correction of Immediate Problems
Psychology Studies
Phenomena Investigation
Applications Study
Audible Presentations
Display Feasibility Models

Of these, only the second and the last have any application in the field of television displays.

The phenomena investigation presents a good overview of the techniques and principles available for use in displaying computer-generated information. The conclusion was reached that the combination of electroluminescence and photoconductivity indicated the greatest potential for this and therefore these techniques were investigated in detail. However, no definitive results were presented.

A display panel and a high brightness CRT were produced under this contract, but more work is recommended if practicable display panels are to be fabricated.

Author: Laird, J.P., Jr.

Title: Optical Projector and System, U.S. Patent No. 2,482, 115, Sept. 20, 1949, Patent Office, Washington, D.C.

SUMMARY: This patent describes an apparatus, optical system, and method for projecting an optical image that creates in the observer an illusion that the object being viewed is at or near infinity. In one form of the apparatus that is described, the optical system consists of a concave spherical mirror and a beamsplitter located between the mirror and its focal surface. The object, a portion of a spherical surface, is made to coincide with the displaced focal surface. Thus the object surface appears at infinity to an observer located in front of the spherical mirror.

The author postulates a use for his invention as a visual training device. The object is shown as being a hemisphere located in a convenient arrangement in a trainer cockpit. The pilot sees the hemisphere as a virtual image at infinity through the windshield. An alternate form of object is provided with a three-dimensional surface, similar to a relief map. Portions of the image appearing at infinity appear to be flat or two-dimensional, while portions of the image appearing in relatively close proximity appear to have depth or to be three-dimensional. When the observer's eyes are moved from the normal point of observation, at the center of curvature of the mirror, there is no appreciable distortion of the image. There is proper apparent relative movement between near and distant object points in any part of the image that is three-dimensional.

Since the object sphere can be rotated relative to the other features of the simulator cockpit, it is possible to present to the observer an image of a changing panorama. This changing scene could consist of sky, clouds, land, and water that would be observed under actual flight conditions.

Author: Lankford, E.

Title: Experimental Investigation of Optical Presentation of Three-Dimensional Display. LTV Astronautics Division, Dallas, Texas 75222. Report No. 00.567, 6 January 1965. Contract Nonr-4439(00). (AD-610 150)

SUMMARY: This report summarizes work accomplished in performance of a program to design and develop a 3-D display utilizing lenses and mirrors to produce 3-D images, and to investigate the various parameters that contribute to producing this image. The inputs to the experimental system were point light images generated by cathode ray tubes. Various approaches of image combining such as time-sharing and light-sharing were investigated.

Feasibility of the 3-D display concept was verified in the performance of this contract. Both time-sharing and light-sharing of multiple image presentations are possible means of reproducing images in three dimensions, the choice of method being predicated on the specific application. Image generation techniques were discussed, such as the use of models, methods of illusions, servo driven inputs, and CRT displays. The utilization of three dimensional presentation is restricted only by the quality of data received for presentation, quality of the optic-electro-mechanical system, and functional space.

It was recommended that a continuation of this study should include: (a) A more thorough investigation to obtain quantitative information of visibility thresholds and fusion frequencies below durations of 5 microseconds toward the lower limit, and (b) An effort to develop uses of CRT techniques to present 3-D information in real time with time and light sharing techniques.

Author: LaRussa, J.

Title: "The Infinity Image System in Visual Simulation". AIAA, and NASA, Manned Space Flight Meeting, 3rd, Houston, Texas, November 4-6, 1964, Technical Papers, AIAA Publication CP-10, New York, American Institute of Aeronautics and Astronautics, 1964, p. 263-270.

SUMMARY: This paper discusses the infinity image system, all-mirror type of visual simulators designed and built by the Farrand Optical Company. In the Farrand approach, an aerial image is created in close proximity to a spherical mirror eyepiece, and then projected to infinity. A first design approach resulted in a virtual image display which provided a 90° horizontal by 75° vertical field of view, with a 4-1/2 inch diameter exit pupil. This system was capable of a full 360° panoramic view by picking off azimuth head motions and rotating the projection assembly within a 360° spherical mirror.

As many as four image generation inputs have been designed into a Farrand virtual image display system. These can be summarized as follows:

1. Star field generation. This employs an eight-ball type of gimballing system supporting a hollow sphere on whose surface reflective balls are imbedded to simulate approximately 1,000 stars. When illuminated by a light source, the reflecting balls are optically projected to form an aerial image, which is in turn re-imaged at infinity. The resulting star images represent true point source stars, even under magnification.

2. Mission Effects Projector (MEP). The MEP is another Farrand development comprising a non-programmed continuous color film strip projector capable of presenting an earth orbital view including moving cloud cover and sunrise and sunset simulations. The MEP consists of two film cassettes, allowing for orbital views presented at different scales.

3. Rendezvous and docking (R & D), and landing and ascent (L & A) generations. To simulate a target vehicle approaching the observer with the celestial sphere retained at in-

finity focus, the object, generally the face of a CRT, is driven accurately inside of focus in the display system. L & A simulations are provided by means of a model, an optical probe, a television camera and closed circuit TV system which provides an image on the face of the CRT input. The same CRT can be used for both displays, since they are never required simultaneously.

4. Solar simulation. A separate light source, representing the sun, is optically projected to infinity, in a manner similar to that used with the previously described inputs.

The Mercury Visual Simulator, developed by Farrand for NASA, represents the first multiple input virtual image system. Two inputs were utilized. The next simulator designed and built by Farrand was the Edwards T-27 Visual Space Flight Simulator. It had three inputs: celestial sphere, MEP, and R & D. This simulator presents a 110° horizontal by 84° vertical field of view through an exit pupil whose diameter is 12 inches.

The system for the rendezvous and docking window of the Apollo Mission Simulator represents a four input system comprising a CRT for R & D, a celestial sphere input, an MEP, and a solar simulator.

In addition, a multiple input display system has been created where several input generations are combined into one single output of optimum perceptual fidelity. This approach has been used on the Gemini simulators which combine two TV inputs in a single input leg.

Author: Leibowitz H.W. and Sulzer, R.L.

Title: An Evaluation of Three-Dimensional Displays. Armed Forces -
- NRC Committee on Vision, Working Group 6, January 1965.
Contract No. NONR 2300 (05).
(AD-457 849)

SUMMARY: This document evaluates three-dimensional visual displays of the volumetric and stereoscopic type; that is, devices that are viewed with two eyes and produce depth impressions principally because of retinal disparity.

A review of such devices revealed no commanding reasons for their adoption in complex man-machine data processing systems. Claimed advantages are specific to particular system tasks, and no general set of requirements was found. Methods presently in use for presenting multidimensional information on 2-D surfaces is generally satisfactory, and far less expensive than that proposed by various 3-D schemes.

It was recommended that new systems use coding and other 2-D methods of presenting depth information unless and until unique and relevant requirements for 3-D methods are established. Nevertheless, requirements studies should be conducted, since there are many proposed applications of the displays that are novel and may turn out to be instances of valid requirements for 3-D displays.

Author: Lopresti, L. P. and Dunmire, G.F.

Title: "TV Missile Target Acquisition and Terminal Guidance Simulation". Paper presented at AIAA Simulation for Aerospace Flight Conference, Columbus, Ohio, Aug. 26-28, 1963.

SUMMARY: This paper describes two simulators designed and built specifically for the investigation of target acquisition capability and guidance accuracy of TV missile systems. The first device described, the Mid-Course Simulator, simulates a missile equipped with a forward-looking TV camera, whose display is viewed on a TV monitor. Motion pictures were taken from an airplane flying a missile trajectory that is to be simulated. The processed film is placed in a projector and the simulator's TV camera focused directly on the film. The view of the simulator monitor is essentially the same as if the TV camera were looking directly at the terrain.

The second simulator which was described, called a Terminal Flight Simulator, consists of a mechanical-optical device that projects a target area on a screen which in turn is viewed by a closed circuit TV system. The manner in which perspective is obtained, without a focusing problem at close range, is by projecting transparencies on an inclined screen utilizing the point light source projection technique. The Terminal Flight Simulator provides a TV presentation of the terrain seen by a missile during the terminal phase of this trajectory from standoff until impact. The operator has six degrees of freedom at his command by using the controls of the simulator.

2.80

Author: Lybrand, W.A., Havron, M.D., Gartner, W.B., Scarr, H.A., and Hackman, R.C.

Title: Simulation of Extra-Cockpit Visual Cues in Contact Flight Transition Trainers. Operator Laboratory, Air Force Personnel and Training Research Center, Air Research and Development Command, Randolph Air Force Base, Texas: Technical Report AFPTRC-TR-58-11, February 1958. Contract No. AF 41(657)-69, Task No. 57052, Project No. 7716. (AD-152 123)

SUMMARY: The primary objective of this study was to provide information needed to make recommendations regarding the visual cues which should be presented in prototype visual attachments to flight simulators. A secondary objective of research was to utilize information which was collected during the study to provide consultative support during initial development of prototype devices.

The work in the study was limited to visual simulation of the "real world"; symbolic or analogue simulation, such as is provided by instruments within the cockpit, was not included. In addition, the study focused on non-programmed visual simulation.

Four visual simulation techniques were discussed which are limited to meeting the above requirements. Those techniques which represent development levels of the state-of-the-art (as of date of report) are: closed circuit television, strip film, point light source, and reflected light (direct) projection.

Variations in techniques are indicated, as well as specific applications of the techniques which have been used in training devices. It was beyond the scope of the study to conduct a comprehensive evaluation of the capabilities and limitations of each visual simulation technique.

The study revealed a serious lack of reliable, emperically derived information regarding the nature and functioning of extra-cockpit visual cues. Recommendations are made which specify critical aspects of visual simulation requiring additional research.

The information presented in this report is outdated. This study has been followed by several other studies which not only discuss additional techniques, but also evaluate same. Nowhere in this study is mention made of a virtual image technique.

Author: Lybrand, W.A., Havron, M.D., Gartner, W.B., Scarr, H.A., and Hackman, R.C.

Title: Simulation of Extra-Cockpit Visual Cues in Contact Flight Transition Trainers. Appendix I - Bibliography. Operator Laboratory, Air Force Personnel and Training Research Center, Air Research and Development Command, Randolph Air Force Base, Texas: Technical Report AFPTRC-TR-58-11, Appendix I, February 1958. Contract No. AF 41(657)-69, Task No. 57052, Project No. 7716. (AD-152 124)

SUMMARY: This appendix contains a listing of those references which were reviewed during the conduct of research on Contract #AF 41(657)-69. Articles and studies which were reviewed in detail are presented in a formal abstract format developed for this literature review. Publications examined, but not formally abstracted, during the conduct of the research are also listed.

Types of literature that were searched included military and non-military, classified as well as un-classified, literature. Seven literature sources were used by the research team members in their search for applicable publications. The criteria which dictated the nature of the literature search is discussed.

Author: Machine Design

Title: "Zoom-Lens TV Displays the Target in Rendezvous Simulator", Machine Design, Volume 35, Sept. 12, 1963, p. 14

SUMMARY: This article describes a computer-driven TV-type simulator in operation at General Dynamics/Astronautics. In the simulated spacecraft, the "window" is a TV monitor. The telecast camera, with a 5,000:1 range zoom lens, photographs a model of a target vehicle or model earth. As instruments in the simulator show the target getting closer, computers determine the rate at which the target image increases in size, from a tiny pin point of light on the TV screen, until it appears to be only a few feet away.

Author: The Marquardt Corporation, Pomona, California

Title: The VueMarq. Excerpted sections of a Marquardt Corporation report. Undated.

SUMMARY: This report describes the VueMarq concept for gathering information from a spherical volume of approximately 3π steradians and forming it on a flat image surface for detection or recording. The flat image can be projected at infinity for visual observation as an exact duplicate of the original scene.

In its simplest form, the principle embodies the use of two mirrors that have conic sections of revolution with reciprocal eccentricities. The mirrors share a common focus and a common axis, and have an optical stop that passes only the rays reflected through the common focus. A ray approaching the mirrors at a given angle to the common axis makes the same angle to the axis after reflection from both mirrors, but rotated 180° about the axis from its original direction. Such an arrangement provides a distortion-free optical system.

The VueMarq technique uses a hyperbolic camera and elliptical viewer combination. The optical probe for the camera consists of a VueMarq hyperbolic element and associated field flattener optics. The simulated eyepoint is at the internal focus of the hyperboloid. Light rays from points on a model aimed at this point will be reflected through the aperture stop located at the external focus of the hyperboloid. The rays passing through the stop are reflected from the field flattener to form a primary image. This, in turn, is enlarged by a relay lens to just fill the active face of a vidicon tube.

The video output of the vidicon is fed to a projection kinescope. The kinescope image is relayed by a projection lens and folding mirror to form a secondary image

on a diffusing screen surface aligned with the focal surface of an ellipsoidal mirror. Field shaping to fit the diffusion screen is accomplished by the shaping of the object plane (kinescope surface) and the longitudinal magnification function of the relay lens. The light from each image point on the diffusion screen spreads and is reflected off the ellipse in a collimated bundle. The central rays of all image bundles intersect at the ellipse focus which is the center of the exit volume. To an observer at the contained focus of the ellipse, the image appears at infinity.

An existant VueMarq feasibility model has a camera field of view of 345° azimuth by 120° elevation. The field of view of the viewer was set at 180° azimuth and 30° above and below the horizon to achieve an exit volume 6 inches in diameter.

A set of data was evolved in a ray trace of the elliptical mirror. The aberrations present are tangential and sagittal coma versus exit pupil position, which results in an angular deviation of rays as a function of incidence position in the exit pupil. The effect on the observer is an apparent shift of the image from infinity towards the observer, and a change in angular position of the image as a function of the observer's eye height. It is claimed that these effects are so small as to be unnoticed except for large and rapid motion of the observer within the exit pupil.

Author: McGraw, E.R., Jr.

Title: Projection Screens for Data Presentation. Rome Air Development Center, Griffiss AFB, New York, Technical Report RADC - TR - 61 - 199, Project 5578, Task 55191, October 1961. (AD-266 612)

SUMMARY: The basic objective of this report is to present sufficient theory and practical information to enable a clear understanding of the problems involved concerning large area (3 ft. x 4 ft. and larger) projection displays. Various screen types are described and measurement data is presented. Nearly every type of screen, as well as the technical aspects of principal importance, are treated. Within the broad categories of reflection (front projection) and transmission (rear projection) screens, numerous techniques for producing controlled optical characteristics are described. Recently developed techniques indicate a degree of predictable control which was previously unattainable.

Author: Miller, W. S.

Title: Projection System for High Ambient Light Conditions. Electro-Optical Systems, Inc., Pasadena, California. EOS Report 160-Final, 15 December 1959. (AD-233 905)

SUMMARY: This report discusses the development of a projection system capable of operating under high-ambient light conditions. The system uses a specular lenticulated screen in conjunction with suitable light traps to prevent extraneous projector flare and random light from reaching the screen and reducing the contrast. The basic optical requirements for the design of a specular lenticulated screen surface were studied. This was followed by extensive trials of various fabrication methods.

Performance figures were evaluated on a final assembled screen model. The facet angular field of view, at a distance from the screen of 15 feet, was approximately 110° horizontally by 40° vertically.

Author: Molnar, A.R. and Lybrand, W.D.

Title: Basic Development Accomplished on Wide-Angle, Non-Programmed, Visual Presentations. Volume I. Carmody Corporation, Buffalo, N.Y. Technical Report: NAVTRADEVCEN 404, April, 1959. Contract N61339-404. (AD-227-192)

SUMMARY: This report provides a summary of the efforts undertaken in the development of wide-angle, non-programmed visual presentations. Basic research and development design concepts which have been employed to meet training requirements are discussed. These are:

1. Optical Display Projection
2. Computation of Pictorial Elements
3. Television
4. Direct Model Viewing
5. Film

The basic design approaches, systems, and components developed within each concept are described. Advantages and limitations of each approach, within the current (1959) state-of-the-art, are identified and discussed in terms of intermediate functional design criteria.

It was concluded by the authors that none of the design concepts could be considered fully developed to its theoretical potential. Additionally, no single design concept was singled out as being superior to all others on all design criteria.

Author: Molnar, A.R. and Lybrand, W.A.

Title: Basic Development Accomplished on Wide-Angle, Non-Programmed, Visual Presentations. Volume II - Appendix. Carmody Corporation, Buffalo, N.Y. Technical Report: NAVTRADEVCEN 404, April 1959. Contract N61339-404 (AD-227 193)

SUMMARY: Volume I of this study was a discussion and evaluation of various techniques used in visual presentations. Volume II consists of abstracts of documents which are applicable to the study; i.e., discussions, designs, and evaluations of devices and techniques related to wide-angle, visual presentations. The sources that were searched yielded training device handbooks, government documents, patents, feasibility studies, R & D proposals, etc.

Also included in the appendix are the results of a state-of-the-art survey of equipment manufacturers.

Author: Naidich, H.H.

Title: "Optically Projecting Data on a Cathode-Ray Tube Face", Optoelectronic Devices and Circuits, Samuel Weber, editor, McGraw Hill Publishing Co., New York, 1964, p. 194-195.

SUMMARY: This article discusses a method of superimposing maps and grids on a radar display while avoiding parallax. The method used is the map projection technique. Using a conventional incandescent light source, the map or grid is projected directly on the CRT, whose phosphor face makes a reflecting screen. The projector is placed at the top of the display console; its optical axis forms a sharp angle with the screen. To compensate for optical distortion of the map, caused by the oblique angle, a severe predistortion is introduced into the map slide. The projected map appears on the same plane as the cathode ray formation on the curved phosphor surface. Reflections from the surface of the CRT outer surface are not apparent to the observer in his normal viewing position, unless the reflecting surfaces become dirty. This method of map presentation is claimed to be highly accurate.

Author: Naish, J.M.

Title: Simulation of Visual Flight, With Particular Reference to the Study of Flight Instruments. Royal Aircraft Establishment (Farnborough), England. Technical Note No. I.A.P. 1099, August 1959. (AD-232 600)

SUMMARY: The pilots forward view in flight is discussed with an aim to formulating the requirements for a visual background, to be used in the study of flight instruments. The appearance of the external world is simulated by extending the known principle of an edge-viewed ground pattern, using a novel television technique, with the addition of a simulated sky.

Details of construction are given and values presented for the chosen field of view, scale, and viewing distance. Picture quality for the moving scene is discussed in relation to the essential characteristics, which are texture, resolution, engineering accuracy, perspective geometry, contrast, depth of focus, and horizon characteristics.

The ground pattern is formed by projection from a transparency, representing the chosen terrain, which is free to move in translation and rotation within the area covered. A TV camera looks across the ground pattern from a point of variable height. The resulting picture is presented on a projector screen before a simulator cockpit, permitting head freedom and binocular viewing. Night and day conditions may be simulated, but vertical ground features are not included.

In laboratory use, the external world is presented to a pilot on a screen placed in front of the cockpit of a flight instrument simulator. He is thus able to "fly"

himself throughout the area covered by the transparency.

The performance of the system is poor, in terms of the state-of-the-art. The picture resolution at the edges of a 30° field of view is 6 minutes of arc.

Author: Nassiff, S.H. and Martikan, F.O.

Title: "Integrated Operating Mode of the Apollo Mission Simulator". Paper presented at AIAA/AFLC/ASD Support for Manned Space Flight Conference, Dayton, Ohio, April 21-23, 1965.

SUMMARY: This paper discusses how the required integration of the Apollo Mission Simulator (AMS) into the Mission Control Center (MCC), for combined training of the Apollo flight and ground crews, affected the simulation design philosophy for the AMS. The purpose of integrating the two operating modes is so that flight and ground crews will be adequately prepared to cope with prepared and unexpected mission events that could occur during an actual flight.

The AMS simulates all mission phases, including the following: launch-boost, earth orbit, translunar, lunar orbit, transearth, reentry, and landing. In the AMS, the astronaut performs the same tasks required in the actual spacecraft for realistic flight training. Navigational observations are made by the astronaut using the simulated optics in the visual system, and then fed into the simulated Apollo guidance computer which also includes the statistical filtering scheme for processing the data. Spaceborne optics simulation requires that the visual sextant and telescope scenes, as well as the simulated optics equipment, be rendered with approximately the same accuracy as the optical system is expected to achieve in the actual system.

The AMS out-the-window visual display simulates the location and magnitude of the navigational stars to a high degree of accuracy, and presents realistic views of the earth and moon and rendezvous vehicles. Each of the four spacecraft windows and the simulated telescope have their own infinity-window optical system which corrects for parallax.

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Author: Operations Research Group, General Dynamics/Pomona

Title: A Catalog of Large Display Systems, Devices, and Techniques. Final Report, Project No. 106-75R, May 1962. Contract No. ARDS-426. (OTS No. PB 181 403)

SUMMARY: This report presents the results of a survey of possible sources of display systems. In an attempt to compile a catalog of large display developments, the report identifies development and manufacturing sources of large display systems, devices, and techniques, which may be applicable for the display of a dynamic air traffic control system. A description is provided of 40 display items reported by 34 companies engaged in applicable R & D. The survey specifically excluded proprietary information.

The main body of the report deals with optical projection systems and electroluminescent - photoluminescent panel systems. In addition, descriptions are given in the appendices of nine three-dimensional dynamic display techniques, and nine solid state module techniques which may be applicable to large status data displays. Included in the catalog is an alphabetical index of companies, addresses, and reported display items. A bibliography was compiled of technical literature of recent years related to large displays.

None of the devices and techniques relate directly to an infinity image display. However, a number of techniques are described which are novel, and appear worthy of investigation. Some of the more interesting techniques, are described below:

1. Stereo Projection System. This display device, at the time of writing (1962), was a proposed system of International Telephone and Telegraph Corp. It utilizes a stereo projection and viewing system which projects models or slides to an optical screen by a projection lens

and a beamsplitter. No visual aids need be worn. The claim is that enlarged images and high brightness is available from low brightness source CRT's.

2. Charactron Projection Display System. This proposed display system, a product of General Dynamics Corp., utilizes a so-called "charactron" tube to render a dark trace tube. The image is then projected by a Schlieren optical technique or an elliptical mirror and xenon lamp technique. The brightness for this proposed system is 30 ft. lamberts on an 8 x 8 ft. screen with a resolution of 4,000 lines.

3. Three-Dimensional Real Image Display System. This system, a product of the Marks Polarized Corp., is in the conceptual development stage. It is the purpose of this system to create solid three-dimensional images in space which retain their integrity when viewed from any spectator position. A detailed description of this system can be found in U.S. Patent No. 2,777,011 issued Jan. 8, 1957.

4. General Electric New Three-Dimensional Display. The three-dimensional display is accomplished by rotating a spherical spiral screen about the fulcrum of a beam of light, and projecting the light beam to the proper azimuth and elevation angle on a screen by means of an optical system. Targets observed as moving point of light on the screen are presented in scale, yet in true 3-D perspective.

5. A New Technique in 3-D Display. This unit utilizes a translucent rotating screen, storage facility for data, cathode ray tube for image forming, and scanner to feed information to the CRT. The three-dimensional picture is produced by the rotation of the image of a time sequenced two-dimensional display, using the flexibility of a CRT as the

transducer of the electrical signal to light. ITT Federal Laboratories is developing this system on an R & D contract.

6. 3-D/2-D Image Generator. Another proposed system of ITT Federal Laboratories. This system utilizes a specially prepared model that is illuminated by a divergent beam of light from a light source through a beamsplitter or half a mirror. The beam of light may be used to illuminate a second model. The models are fabricated with a lenticular surface. All the light rays intercepted by the model are returned to the half mirror on their own axis, and reflected to lenses for projection. A mirror positions the image on a spherical or plain screen as a function of the course generator.

Author: The Oxford Corporation, Buffalo, New York

Title: Phase I Engineering Report, Carrier Landing Flight Simulator. Report No. 6102, 1 August 1961. BuWeps Contract NOw 60-0721-c.

SUMMARY: This report discusses the development of a full color, wide field of view simulator of the scene viewed by a pilot in making a carrier approach. The work under phase I of the contract was aimed at the fabrication and demonstration of a full size, programmed flight mockup of the basic optical system in order to establish its characteristics. It also covers a study of the computer and controls required to incorporate a complete non-programmed flight simulation into the system.

The primary components of the system are two spherical reflectors which share a common axis of revolution. The smaller reflector is convex and is aligned to coincide with the focal surface of the larger mirror. A continuously variable focal length lens is placed at a position off-axis and in front of the mirror system. The exit pupil of the system is located below, and approximately in line with this lens, at an equal distance from the axis of revolution. The aperture stop of the system, and the effective position of the eye, is slightly in front of the focusing lens.

A carrier model, built with a left to right reversal and supported in an inverted position, is located in line with the focusing lens. The system is then controlled so that as the model approaches the eye position, the prime focus of the lens is kept on a nominal position on the flight deck. The result is that the image of the carrier is located at infinity.

The upper surface of the large concave mirror re-images the carrier model on the reflective face of the convex mirror, which is located at the prime focal surface of the first mirror. In turn, the lower surface of the concave mirror re-collimates the carrier model image. This results in the images which the pilot sees being virtual images located at infinity behind the lower surface of the large mirror.

The coating on the convex surface of the smaller mirror can be made semi-reflective. A background scene applied to the opposite surface of the same mirror, as well as the carrier model image reflected from the metalized surface, will be visible to the viewer. Since the two images will tend to "bleed" through each other if they are of the same intensity, in practice the background is normally darker than the surface of the carrier model. The brighter image will tend to dominate.

The field of view is given as 180° azimuth by approximately 30° in elevation.

The second phase of work under the contract provides for the fabrication of a flight simulator which would allow a pilot to control the aircraft during the approach.

Author: Perkin-Elmer Corporation

Title: Investigation of Techniques for Modulating and Scanning a Laser Beam to Form a Visual Display, Final Report, RADC-TDR-64-365, January, 1965. Display Techniques Branch, Rome Air Development Center, New York; Contract No AF30(602)-3122.
(AD-612725)

SUMMARY: The advent of the continuous wave visible laser has introduced the first real competition to the electron beam scanning devices which form the backbone of television systems. The characteristics of the laser which are of major importance are its capability of being focussed to a very small spot size of high intrinsic brightness and the high degree of collimation (or ray parallelism) which can be achieved in a beam of small cross-section. The latter feature permits the light to be angularly deflected and intensity modulated in a manner analogous to that of an electron beam in a cathode ray tube.

Various techniques which might be used to modulate and deflect a laser beam in response to an input video signal so as to form a projected visual display containing 10^6 resolved information bits at 30 frames per second are considered in this report.

Electro-optical modulation techniques are evaluated in general and the Pockel cell using potassium dihydrogen phosphate is considered in detail. Test results indicate that a three-pass KDP modulator should be capable of providing the required modulation, but that further engineering of the video drive circuitry would be necessary to optimize its performance.

Several fast scanning techniques are investigated theoretically and one type device using a prism of barium titanate electro-optically active crystalline material was also evaluated experimentally. Tests indicate that this technique should be capable of providing high resolution displays (at least 1000 lines) but the optical quality and sample size of presently available crystalline materials are not adequate to meet the present requirements. The

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potential advantages of newly developed materials such as potassium tantalateniobate (KTM) are cited and continuation of this investigation using this new material is recommended.

Brief consideration of photometric and synchronization aspects of laser display systems indicates no particular problem areas to be resolved in development of actual hardware systems.

It is also mentioned as being possible, but not so obvious, that a laser can be used to advantage in image pickup.

Author: Pfeiffer, M.G., Clark, W.C., and Danaher, J.W.

Title: The Pilot's Visual Task: A study of Visual Display Requirements
Courtney and Company, Philadelphia, Pa. Technical Report: NAVTRADEVCEN 783-1, March 1963. Contract No. N61339-783. (AD-407 440)

SUMMARY: An analysis was made of the perceptual characteristics of the pilot's visual world while performing various flight tasks. These were compared with the perceptual characteristics made available by typical non-programmed visual displays attached to flight trainers. An experiment was then conducted in the F-100 simulator equipped with the 151 visual attachment to determine training effects. It was determined that, even among experienced subjects, the performance significantly improved, both with regard to the detection of in-flight emergencies and the maintenance of aerodynamic stability.

The external visual display of the 151 visual attachment, made by Rheem Manufacturing Co., consisted of a large hemisphere surrounding the F-100 simulator onto which a display could be projected. A TV system was used for projecting target aircraft onto the screen, and a refractive optical system was used for projecting a horizon. Additional apparatus consisted of two slide projectors which were used to project target aircraft on the hemisphere. This permitted the simultaneous presentation of two intruder aircraft: TV targets (bogies) with the television system, and projector targets (bogies) with the slide projector system.

The addition of the external visual horizon to the 151 display had no overall effect on emergency detection behavior. However, some subjects complained

that the horizon was difficult to see, contrast between the sky and ground being very poor.

One other visual attachment was observed, but not utilized in direct experimentation, during the course of the study. This was the Dalto visual attachment to the P3A. trainer. The Dalto simulation process involves a closed circuit TV pickup of a simulated runway landing. The landing lights consist of objects which reflect light. The display is a projected image on a flat screen facing the pilot.

The Dalto display has severe drawbacks which limit its effectiveness, some of which are:

The only way to make the landing lights more visible is to use larger objects to reflect light. This size-intensity problem means that the Dalto runway lights are not sufficiently blurred into a bar-shape at a distance - compared to the real situation - and, on the other hand, are too blurred at close distances to be like point light sources.

The visual angle between an object and the horizon increases from 0° when the object is distant, to 90° when the pilot is directly over it. The Dalto visual display, not being equipped with a horizon, fails to provide training in the use of this cue, but actually does not require it for the part-task for which it was designed.

The projected image does not elicit a very realistic experience of depth.

Recommendations were made for improving the Dalto display. These include:

"Grain of wheat" lamps or other devices with a similar effect were advised in place of the reflective objects. This would result in making the simulated runway lights actual sources of illumination and therefore permit the closer ones to appear brighter and more distinct than the ones further away. Thus, the relative brightness of the runway lights could be used as a cue for depth as well as resolution of detail.

The edges of the projection screen provide spurious cues for the proper position of the horizon. It was advised that the field of view be widened more in line with that provided by the 151 non-programmed visual display.

Author: Polanyi, M.L. and Osterberg, H. (Assigned to American Optical Co., Southbridge, Mass.)

Title: Wide Aperture Optical Projection Lens System, U.S. Patent No. 2,683,394, July 13, 1954, Patent Office, Washington, D.C.

SUMMARY: This invention describes a wide aperture, image-forming optical system combining reflecting and refracting elements in such an arrangement as to have high optical efficiency. A folded system is shown which consists of two reflecting annuli and a Schmidt-type corrector. In addition, a convergent refractive element is axially located in a central clear aperture provided in the corrector plate.

The object--in the example cited, a CRT faceplate--is located near the focal plane of the optical system. The rays reflected from the two annuli are corrected for spherical aberration in passing through the corrector plate before being focused on a viewing screen. The central cone of rays from each object point pass through the two orifices and are intercepted by the convergent lens in such a manner as to be focused on the viewing screen. The lens is of a magnifying power equal to that provided by the reflector elements and correcting plate. When properly aligned, two images of equal size will coincide on the viewing screen. The combined image will have a greater brilliance on the viewing screen than that of the image formed by the reflecting surfaces alone.

Author: Ratliff, Major F.R.

Title: "Soviet Training Concepts and the Utilization of Simulators". Paper presented at AIAA/AFLC/ASD Support for Manned Flight Conference, Dayton, Ohio, April 21-23, 1965.

SUMMARY: The paper as presented was an unclassified version of a more complete classified paper which discusses Soviet cosmonaut selection criteria. With one exception, a significant omission was the lack of reference to visual devices in Soviet training. Whether this is due to the lack of such devices or to the unclassified status of the paper was not ascertained at the conference.

Prior to the revolution, Russia was considered to have had one of the better educational systems in Western Europe. About one third of the population was literate. The educational system was reorganized with the revolution, but in 1931 classical methods and subject matter were reinstituted, with emphasis on discipline and directed study.

From the early fifties onward, the development of complex systems, and particularly the manned spaceflight program imposed skill requirements that could not be acquired through normal instruction and on-the-job training methods. Simulators were individually developed during the middle and late thirties, but many were eventually proven worthless. It has only been in the postwar period that serious simulator development has taken place based on research and theory.

Cosmonaut training is based on "habit formation", physical conditioning, and "heightened consciousness". In terms of equipment, several models of the Vostok cabin were apparently built to serve different training purposes. Some features mentioned are

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dynamic mounting for motion simulation, instruments which changed their readings according to programmed flight conditions, and an outside environment which simulated as nearly as possible the visual stimuli to be experienced in orbit. The "locator", a globe-like instrument for projecting the landing area of the spacecraft from a given point in orbit, displayed realistic time phased data.

The Soviets have recently been greatly interested in teaching machines based on cybernetic principles. The devices built range from simple machines for individual use to fully computerized programs, integrated with simulation concepts, for the training of groups or crews. The Russians are heavily involved in sleep-training techniques, and in foreign language instruction they claim that students acquire a vocabulary of up to 30 words per night. At the other extreme, the "bigness" of training programs is exemplified by the Navy trainer which permits a crew of students to perform tasks encountered during an "underway watch" under extremely varying conditions.

The ultimate goal in Soviet training seems to be the application of programmed instructional techniques, including computer based technology, to all future training. They warn against mass production of current training models until more experience in their use has been gained to testify to their worth.

Author: Raytheon Company, Equipment Division, Systems Requirements Department, Waltham, Mass.

Title: Feasibility Study of Data Presentation Configurations for Real Time Flight Test Display. Technical Documentary Report No. 63-31, July 1963. Contract No. AF 04(611)-8510, AFSC Project No. 6903, AFSC Task No. 690305.7.
(AD-413 065)

SUMMARY: This report presents the results of an investigation of display techniques and configurations applicable to the monitoring and control of future flight test programs. The major objective of this study was to recommend an initial design configuration of a display device for ground-based monitoring of advanced manned vehicles likely to be flight tested by the AFFTC in the future.

Information presentation techniques were discussed. These included such subjects as console displays, large screen projection displays, three dimensional displays, and others. A display evaluation of techniques was made. Of the several display techniques capable of dynamic variable format presentation, high resolution scan-converted TV is the one which most nearly meets the requirements for versatility, and at the same time offers exceptional performance at reasonable cost.

The subject matter discussed herein does not readily lend itself to a wide-angle display system study. Most of the techniques utilized are for relatively small displays. However, a number of interesting techniques for television presentation are generalized.

Author: RCA Astro-Electronics Division, Princeton, N.J.

Title: Applied Research on Photo-Tape. Technical Documentary Report, Oct. 1962, Project 6263, Task 626302, Contract No. AF33(616)-6365 (AD-224 835U, formerly AD-334 178S)

SUMMARY: This is an interim report summarizing phototape development as of 31 May 1962. The program continued under Contract AF 33(657)-8843.

The report describes the advantages of the phototape system over conventional photography for use in satellites and in heavy radiation environments. Better quantum efficiency than for the Vidicon is claimed, although prospects for further improvement in efficiency seem slight, except for a very high unexplained peak in a narrow spectral band in $ZnIn_2S_4$.

Ball bearings and other mechanical components and lubricants were tested for use in vacuum in the phototape system, and found satisfactory.

Limiting resolution of about 100 TV lines/mm was observed in a one inch storage device, but this is limited by the presence of a collector mesh. An objective of the follow-on contract will be to achieve 200 TV lines/mm resolution.

Author: RCA, Princeton

Title: Wide Angle High Definition Television Systems
Contract N6onr-23605 to RCA, Princeton, New Jersey
(AD-6247)

SUMMARY: The stated purpose of this contract was to study the possibilities of attaining large angle of view (at least 60°) in a high resolution television system for use in a training simulator.

A Schmidt projection system and special CRT were designed and built. The projector alone has an N_e ranging from 1500 lines on-axis to 150 lines at 30° off-axis. It covers a 60° total field angle and has an efficiency of 6%. The CRT has a maximum light output of about 80 candles, and an N_e of from 375 to 410, depending on drive and light output. Although a camera was not designed in the course of this study, an overall N_e figure for a system employing the CRT and Schmidt optics was projected to be about 185.

In addition to the work described above, this report contains an excellent discussion of the criteria needed for defining optical systems in objective terms. This leans heavily on the work of Schade of RCA, who was one of the contributors to this report. The coverage of certain limitations and design factors in camera and CRT design is also quite thorough.

Author: Reed, G. A. (Assigned to The Oxford Corporation, Williamsville, N.Y.)

Title: Viewing Device Having Optical Arrangement Producing Virtual Image at Infinity, U.S. Patent No. 3, 190, 171, June 22, 1965, Patent Office, Washington, D.C.

SUMMARY: This invention describes a viewing device for projecting a model target, such as an aircraft carrier model, at infinity. In a preferred embodiment of the invention, a pilot is trained in making a carrier approach.

The prototype of the trainer is described in "Phase I Engineering Report, Carrier Landing Flight Simulator" (see The Oxford Corporation).

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Author: Reininger, W. G., et al

Title: Photoelectric Storage Interim Report No. 3, 1 December 62 to 28 February 63, on Contract AF33(657)8715 to Westinghouse Electric Corp., Baltimore, Md. (AD-403718)

SUMMARY: This is a continuation of the TVIST phototape camera storage tube begun under Contract AF33(616)6666. Research is directed toward obtaining higher sensitivity and resolution, and better uniformity.

Target limiting resolution of 3800 TV lines per inch has been achieved. With a slow scan system this figure is improved to 5000 TV lines per inch.

A camera tube is being made in the configuration of a 4-1/2 inch image orthicon, and tested with a 7500 line raster.

Limiting resolution values of several lenses were measured using special "diminishing line resolution patterns" developed under this contract.

Author: Rugari, A.D.

Title: In-Cavity LASER Modulation Study Report RADC-TDR-64-129, Project DS-63-9, Display Techniques Branch, Rome ADC, Griffiss AFB, New York, May 1964 (AD-601 660)

SUMMARY: A study was made to investigate the effect of introducing controllable losses into the LASER cavity in the form of misalignment of the cavity reflectors. Modulation was to be accomplished over the range 30 cps to 30 Mc with an index of 0.5 or greater.

A theoretical analysis shows that the proposed modulation technique (use of a KDP electro-optic prism in the resonating path of a CW gas LASER) should result in good modulation with low power loss. However, the practical difficulties associated with maintaining high transmission through the crystal present serious problems. Absorption is only a few tenths of one percent, but inherent birefringence or strain appears to be a major problem.

The subject is receiving continuing attention from this group.

Author: Rutman, A., et al

Title: Electronic Camera Systems Study and Investigation First Quarterly Progress Report, 8 June thru 30 September 1964 on Contract DA28-043 AMC-00117(E) to DuMont Laboratories, Clifton, New Jersey.
(AD-453848)

SUMMARY: The purpose of this study was to evaluate techniques and devices suitable for use in Army Airborne Reconnaissance. As a result of this study a system is to be delineated which will record, in strip photographic form, a real-time video output demonstrating a resolution of 3000 TV lines at 25% response.

A configuration was chosen which consists of a concentric objective lens, a fiber optical geometric converter, and an Image Orthicon operated with circular scan.

A line-to-circle fiber optical converter was fabricated, and a special image orthicon was procured for this work. Preliminary results indicated that maintaining the circular scan within the limits of the fiber optic annulus does not impose impractical electrical tolerances. However, resolution of only 2000 lines and 25% modulation have been obtained.

Author: R. Rutherford, Jr. and P. Grosso

Title: Development of Phosphor Screens for High Resolution Display Devices. Interim Engineering Report #1. CBS Laboratories, Stamford, Conn. (AD-418 207)

SUMMARY: This report describes the first six months of the project for cataphoretically depositing high quality phosphor screens for cathode ray tubes.

Resolutions exceeding 80 line pairs per millimeter have been deposited on glass using intermediate zinc coatings which were subsequently removed.

This work seems to be directed mainly at obtaining extremely high resolution on rather small size tubes. At present resolution of the display tube is not a problem in spherical faceplate display tubes, and the type of screen described does not seem to be directed toward projection tube applications.

Author: Sachtleben, L.T.

Title: High Resolution Display Media Final Report on Contract AF30(602)-2238 to RCA, Camden, N.J. Report RADC-TDR-62-233 dated 7 May 62 (AD-277746)

SUMMARY: An extensive non-mathematical introductory discussion is given of factors involved in image quality using the modern criteria evolved by Schade.

The properties of commercial translucent projection screen materials, including fiber optics techniques, was studied. Conclusions from this part of the study indicate that fiber optics materials may be expected to perform as well as or better than the best commercial screens in all important respects.

Studies of electroluminescent image intensifier panels and photochromic display media indicate that at present (1962) these techniques are insufficiently developed for high resolution display purposes.

Results are presented of research into the problems of providing a large viewing angle while preserving high resolution in a fiber optic display structure. For this, each cladded fiber is terminated in a separate optical diffusing element. The fiber optics screen work is elaborated on in a "report on contract extension" included as a part of this report.

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Author: Schade, O. H.

Title: "Electro-Optical Characteristics of Television Systems," RCA Review - 1948

SUMMARY: (Part I, March 1948, pp. 5-37):

The optical and electro-optical conversion processes in television systems are examined by broad analytical methods. $\overline{N}$, the "balanced line number", is defined as the geometric mean between horizontal and vertical resolution. Tests conducted with many observers showed that up to $\overline{N}$ = 800, slight increases in sharpness on fine detailed stationary subjects could be detected, but little preference was indicated beyond $\overline{N}$ = 500 for motion scenes, persons, and other normal TV subjects. These tests were made at $\mathcal{S} = 4$, where $\mathcal{S} \triangleq$ viewing distance/picture height. Electrical bandwidth in terms of N cutoff and frame time, for standard blanking percentages is given by:

$$f = \frac{0.85\ (N_{co})^2}{T_f}$$

Curves of "Detail Response of the Eye" as determined under several different conditions are included as Figure 8.

The paper concludes with a brief theoretical analysis of the effects of noise on the television picture.

(Part II, June 48, pp. 245 - 286)

A review of aperture and sampling theory, with emphasis on the effects of different aperture shapes and sizes.

Critical Flicker Frequency as a function of brightness level is also discussed, including various sources of flicker, such as interline and detail flicker.

(Part III, September 48, pp.490 - 530)

Electro-optical characteristics of camera systems are considered in very general terms, with heavy emphasis on camera lens analysis and evaluation using aperture techniques.

(Part IV, December 48, pp. 653 - 686)

A discussion of photographic systems with regard to image transfer characteristic (gamma) and graininess. Aperture correction in television systems is examined, but the effect of aperture correction on noise content and subjective picture quality is not considered.

The conclusions section sums up the series of articles, and acknowledges the importance of three basic characteristics of the imaging process: signal-to-fluctuation ratio, transfer characteristic shape, and detail contrast response. A unified system of specification and measurement procedures is demonstrated, and correlated with the corresponding subjective impressions (graininess, tone scale, and sharpness) "by analyzing the characteristics of vision."

Calculations show that a television system with a balanced resolution of 410 lines is technically capable of attaining an image equivalent of 35mm commercial motion pictures.

Author: Schade, O.H.

Title: "Image Gradation, Graininess and Sharpness in Television and Motion Picture Systems." Journal of the SMPTE, Part I: "Image Structure and Transfer Characteristics", Vol. 56, Feb. 51, pp. 137-77. Part II: "The Grain Structure of Motion Picture Images - an Analysis of Deviations and Fluctuations of Sample Number," Vol. 58, Mar. 52, pp. 181-222. Part III: "The Grain Structure of Television Images", Vol. 61, Aug. 53, pp. 97-164. Part IV: "Image Analysis in Photographic and Television Systems (Definition and Sharpness), "Vol. 64, Nov. 55, pp. 593-617.

SUMMARY: Part I: "Image Structure and Transfer Characteristics."

The physical quality of motion picture and television images is determined by the transfer characteristics, signal-to-fluctuation ratio, and flux-response of the system. Noise analysis based on sampling theory is introduced and the sine wave response characteristics of typical apertures is developed. Thus a system of rating image-forming devices and systems is developed which permits objective comparison on a sound theoretical basis.

Part II: "The Grain Structure of Motion Picture Images - An Analysis of Deviations and Fluctuations of the Sample Number."

Part II treats aperture-response theory as applied to the evaluation of relative deviation in motion-picture processes. Methods are developed for computing the frequency spectrum of a projected image as modified by successive aperture response and nonlinear transfer effects. The "effective sampling area" of various components in photographic or television systems is determined from their response to sine wave signals and specified by an equivalent measure N_e. The accuracy of this method is compared with direct evaluation from dimensions and geometrical properties.

Part III: "The Grain Structure of Television Images".

An exhaustive discussion and analysis of the raster scanning process, principles, and the effect of aperture size and shape. A set of photographs illustrates the effect of "side-bands" obtained in raster scanning.

A curve of "sine-wave response of the eye" for moderate brightness levels (4-10 ft. lamberts) is shown on p. 123. The source of this curve is not mentioned.

Several types of noise are discussed as well as the relations between noise and aperture compensation.

The sine-wave characteristics of television camera tubes and kinescopes are described in good detail on pages 137-9, indicating that kinescopes are uniformly superior to camera tubes in performance.

Vertical resolution is shown to depend only on aperture shape and line number, whereas horizontal resolution is a function of aperture and bandwidth.

Aperture correction increases the noise level by a factor which is larger for peaked-channel noise than for flat-channel noise. The visual perception of fine detail and granularity is limited at low luminance by random fluctuations in the visual process, and at medium and high luminance values by the aperture response of the eye's optical system.

One of the conclusions is that the graininess of theater-television images will compare favorably with that of 35 mm motion pictures.

Part IV: "Image Analysis in Photographic and Television Systems".

Part A treats the theory of image analysis (aperture theory) and analyzes by convolution the effects of various types of apertures in cascade. The meaning of N_e, defined in Part II, is reviewed. (N_e is the equivalent rectangular passband of the squared energy response. For the circularly symmetric aperture, N_e occurs at the 50% point on the squared response curve.) Scanning by multiple apertures and aperture correction are also considered, together with methods for improving edge transition response. However, no technique can restore parts of the spectrum which have been lost in a preceeding integrating process.

Part B is an analysis of several types of systems, beginning with the assumptions of "perfect" lenses, point-images, television systems, and coherent light. Modifications for practical optical and television systems are later considered, with a table of equivalent passbands for EIA 525 line television systems under several conditions of components and operation.

Author: Schade, O.H., et al

Title: Applied Research on Camera Tubes Technical Documentary Report No. AL-TDR 64-171 dated 8 July 1964 under Contract AF33(657)-7939 to RCA, Lancaster, Pa. (AD-602425)

SUMMARY: Tubes with 2" x 2" vidicon photoconductive targets were constructed, and typically achieve signal-to-noise ratios of 40 db with 2000 TV line resolution at the 50% response level. The contract objective was 3000 lines at 50%. (These resolutions are achieved at frame rates of one to ten per second.)

A total of 36 tubes was constructed during the contract period, of both vidicon and orthicon types. Results obtained on all samples are tabulated with comments.

(This work is being continued under Contract AF33(615)-2109 with the aim of increasing tube sensitivity.)

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-II, No. I, 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.

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.

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Author: Undersea Technology

Title: "Submarines Guided by TV Display", Undersea Technology, 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.

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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.

FOCI

III. BIBLIOGRAPHY

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.

III. BIBLIOGRAPHY

A. Simulation Techniques and Simulators

1. Arnold Engineering Development Center, Tennessee. Fifth Annual Symposium on Space Environment Simulation. Air Force Systems Command, U.S. Air Force and ARO, Inc., Contract Operator, Arnold Air Force Station, Tenn., (AD-441 312)

2. "Battle Simulator Aids Navy Planning", Missiles and Rockets, June 7, 1965, pp. 41-42.

3. Berliner Zeitung. The Universe on a Picture Screen. Berliner Zeitung (German) April 5, 1963. FTD-TT-64-78/1. (AD-602 688)

4. Buddenhagen, T.F. et al. Development of Visual Simulation Techniques for Astronautical Flight Training, Bell Aerospace Corp., Buffalo, N.Y., Contract No. AF33(616)-7802, Rep. No. AMRL-TDR-63-54, Vol. I. (AD-412 641)

5. Collins, L.L. and Freund, R.B. Celestial Background Simulation Techniques. Northrop Space Laboratories, 1111 East Broadway, Hawthorne, Calif., 1962. (AD-282 788)

6. Connelly, M.E. "A Demonstration Hybrid Computer for Real-Time Flight Simulation". Paper presented at AIAA/AFLC/ASD Support for Manned Flight Conference, Dayton, Ohio, April 21-23, 1965.

7. Cooper, G.E. The Use of Piloted Flight Simulators in Take-Off and Landing Research. North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development, Paris, France, Report 430, January 1963. (AD-426 285)

8. Cording, C.R. and Prodan, J. "A Two Man Space Station System Simulation". Paper presented at Manned Space Flight Conference, Houston, Texas, 1964.

9. Cutler, A.E. and Shelley, M.L. Improvements In or Relating to Ground-Based Flight Simulators, British Patent No. 896, 404, May 16, 1962, The Patent Office, London, England.

10. Cutler, A.E. and Shelley, M.L. Improvements In or Relating to Ground-Based Flight Simulators, British Patent No. 896, 405, May 16, 1962, The Patent Office, London, England.

11. Emery, J.H. and Dougherty, D.J. Contact Analog Simulator Evaluations: Climbout, Low Cruise and Descent Maneuvers. Joint Army-Navy Aircraft Instrumentation Research (JANAIR), Technical Report D228-421-017, May 1964. Contract Nonr 1670(00).
(AD-603 744)

12. Gerhardt, L. and Johnson, A.B. Development of Visual Simulation Techniques for Astronautical Flight Training. Bell Aerospace Corp., Buffalo, N.Y., Contract No. AF33(616)-7802, Report No. AMRL-TDR-63-54, Vol. II.
(AD-427 318)

13. Hemstreet, H.S. Means for Altering Apparent Perspective of Images, U.S. Patent No. 2,975,671, March 21, 1961, Patent Office, Washington, D.C.

14. Hemstreet, H.S. Perspective Alteration Means, U.S. Patent No. 3,015,988, January 9, 1962, Patent Office, Washington, D.C.

15. Kennedy, E.J., et al. Guide for Group Display Chains for the 1962-1965 Time Period. USAF, Electronic Systems Division, no date.

16. Lamont, J.N. Annotated Bibliography on Flight Simulators. Defense Research Board, Directorate of Biosciences Research, Human Resources Research Section, Ottawa, Canada, HR Report No. 68, August 1960.
(AD-247 044)

17. Lebedev, Y.N. and Pakhomou, I.I. "Optical Simulation of Relative Motion of Objects in Space", Optical and Optical Electronic Instruments, No. 110, Moscow Oborongiz, 1962. English translation by Translation Division, Foreign Technology Division, WPAFB, Ohio, pp. 71-80, April 6, 1965.
(AD-618 649)

18. Livingston, W.A., Jr. Outer-Space Environment Models For Use With Space Vehicle Simulators. Cornell Aeronautical Laboratory, Inc., Buffalo 21, N.Y. Technical Documentary Report No. MRL-TDR-62-40, May 1962, Contract No. AF33(616)-6858, Project No. 6114, Task No. 611411.
(AD-283 284)

19. Luton, W.B. Space Flight Environmental Simulator, U.S. Patent No. 3,083,473, April 2, 1963, Patent Office, Washington, D.C. Assigned to Ling-Temco-Vought Inc., Dallas, Texas

20. McNulty, C.F. Simulation Techniques for Spacecrew Training, State-of-the-Art Review. Behavioral Sciences Laboratory, 6570th Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, Project No. 6114, Technical Documentary Report No. MRL-TDR-62-32, April 1962. (AD-283 343)

21. Meissinger, H.F. and Belsky, F.J. "Visual Display Simulation of Lunar Landing Under Remote Control by a Human Operator", Space Rendezvous, Rescue and Recovery. Proceedings: Advances in the Astronautical Sciences, Vol. 16, Part 2, edited by Norman V. Petersen, Western Periodicals Co., North Hollywood, Calif., 1963, pp. 54-76.

22. Muckler, F.A., et al. Psychological Variables in the Design of Flight Simulators for Training. Aviation Psychology Laboratory, University of Illinois, January 1959. WADC Technical Report 56-369, Contract No. AF33(616)-2725. (AD-97 130)

23. Neuberger, T.P. "Optical Techniques of Visual Simulation for Space Travel", S.P.I.E. Journal, Volume 3, December 1964 - January 1965, pp. 52-56.

24. Neuberger, T.P. "Visual Simulation for Rendezvous Training". Paper presented at AAS Symposium on Space Rendezvous, Rescue and Recovery, Edwards Air Force Base, California, September 10-12, 1963.

25. North American Aviation, Inc. Flight Simulator Study of Human Performance During Low-Altitude, High-Speed Flight. Columbus, Ohio, November 1963. TRECOM Technical Report 63-52, Contract DA44-177-TL-803, Project 1D131201D159. (AD-429 114)

26. Prodan, J. "Rendezvous Simulation", Space Rendezvous, Rescue and Recovery. Proceedings: Advances in the Astronautical Sciences, Vol. 16, Part 2, edited by Norman V. Petersen, Western Periodicals Co., North Hollywood, California, 1963, pp. 167-172.

27. Rogers, P.C, Jr. Space Rendezvous, Rescue and Recovery: A Report Bibliography. Defense Documentation Ctr., Cameron Station, Alexandria, Virginia, Aug. 1963. (AD-410 085)

28. Shelley, M.L. Improvements In or Relating to Ground-Based Aircraft Flight Simulators, British Patent No. 896,403, May 16, 1962, The Patent Office, London, England.

29. Shepard, A.B., Jr. "Training by Simulation", The Smithsonian Institution, Edwin A. Link Lecture Series, Smithsonian Publication No. 4597, Jan. 1965.

30. Smith, G.H. and DeRocher, W.L., Jr. A Full-Scale Six-Degree-of-Freedom, Orbital Closure and Docking Simulator, Martin Co., Denver, Colorado, Report No. M-63-134, July 1963.
(AD-457 631)

31. "3-D Display", Space/Aeronautics, September 1962, pp. 60-67.

32. Van Ornum, D.G. Study of Radiation From Vortex Stabilized Arcs. Plasmadyne Corp., Santa Ana, Calif., Technical Documentary Report No. AEDC-TDR-64-165, August 1964, Contract No. AF40(600)-1033, AFSC Program Area 850E, Project 7778, Task 777801.
(AD-603 519)

33. Westbrook, C.B. Background of Piloted Simulator Development. Air Force Flight Dynamics Laboratory, Research and Technology Division, Report No. FDCC TM 64-28, August 1964.
(AD-457 592)

B. Display Devices and Systems

34. Armed Services Technical Information Agency, Display Systems: An ASTIA Report Bibliography. Arlington Hall Station, Arlington 12, Va., November 1961.
(AD-265.432)

35. Ayres, W.A., Projecting Device. U.S. Patent No. 2,304,434, Dec. 8,1942, Patent Office, Washington, D.C. Assigned to IBM, New York, N.Y.

36. Balding, G.H., Electronic Visual Cue Generator. U.S. Patent No. 3,093,822, Assigned to Kaiser Industries Corp., Oakland, California.

37. Baxter, J.R. and Workman, J.D. Review of Projected Displays of Flight Information and Recommendations for Further Development. Dept. of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, Melbourne, Australia, Human Engineering Report 2, August 1962.
(AD-608 843)

38. Blam, C.B., et al. Tracking Performance as Affected by the Position of the Attitude Display. Bell Helicopter Co., Fort Worth, Texas, Report No. D228-421-010, March 1962. Army-Navy Instrumentation Program, Contract Nonr 1670(00).
(AD-273 967)

39. Bolie, V.W. Simulated Perspective Display, 2,988,821.

40. Brouillette, Dr. J.W., Large Area Electronic Display Panel. Report No. 6, Contract DA36-039-sc-90755, DA Task No. 1G6-22001-A-055-03, USA Electr. Res. & Development Lab., Ft. Monmouth, N.J., Mil Com. Dept. & Electronics Lab., General Elec., Syracuse, N.Y.
(AD-431 960)

41. Brouillette, Dr. J.W. et al, Large Area Electronic Display Panel, Report No. 9, Contract DA36-039-sc-90755, DA Task No. 1G6-22001-A-055-03, GE, MCD, Command Sys. Div., Syracuse, N.Y. U.S. Army Electronics Labs., Ft. Monmouth, N.J.
(AD-451 545)

42. Brouillette, Dr. J.W. et al, Large Area Electronic Display Panel Rep. No. 8, Contract DA36-039-sc-90755, DA Task No. 1G6-22001-A-055-03, GE MCD, Command Systems Div., Syracuse, N.Y.
(AD-443 043)

43. Brouillette, Dr. J.W. et al, Large-Area Electronic Display Panel, Report No. 7, U.S. Army Electronics Research & Development Lab. GE, MCD, Syracuse, N.Y., Contract DA36-039-sc-90755, DA Task No. 1G6-22001-A-055-03.
(AD-442 084)

44. Browne, F.P., Multiple Display Plotting System, U.S. Patent No. 3, 026,633, March 27, 1962, Patent Office, Washington, D.C. Assigned to ACF Industries, Inc., N.Y., N.Y.

45. Buddecke, C.L. Electrostatic Recording and Translation of Images

46. Callahan, J.C. "Two Simulation Facilities for Project Gemini". Paper presented at AIAA/NASA Third Manned Space Flight Meeting, Houston, Texas, November 4-6, 1964.

47. Carel, W.L. Analysis of Pictorial Displays. Hughes Aircraft Co., R & D Division, Culver City, California, JANAIR Report No. 2732.01/25, March 1965, Contract Nonr 4468(00).
(AD-613 274)

48. Daily, C.R. "High Efficiency Rear-Projection Screens", Journal of the SMPTE, Vol. 65, Sept. 1956, pp. 470-477.

49. "Digital Computer - TV Displays Gaining Favor for Operations C & C Use", Missiles and Rockets, October 5, 1964, pp. 38-42.

50. International Business Machine Corp., Kingston, N.Y. Display Improvement Program (ECPX 0027) (Final Report Vol. II), 11/1/60, Contract No. AF30 (635)-1404, IBM Corp., Federal Systems Div., Kingston, N.Y.
(AD-253 401)

51. Dugan, J.M. et al. Design Studies for Globular Displays, Battelle Memorial Institute, 1959. RADC-TR-59-65.
(AD-214 597)

52. Carel, W.L. & Zilgalvis, A. JANAIR - Analysis of Pictorial Displays, 1st Quarterly Report - Sept. 1964, Research & Development, Div., Hughes Aircraft Co., Culver City, Calif., Contract No. Nonr 4468(00), Report No. 2732.01/19.
(AD-606 705)

53. Claesson, Prof. Stig., Dept. of Physical Chem. U of Uppsala, Uppsala, Sweden. Flash Photolysis Study of the Reactions Between Photoexcited Fluorescein (and Similar Dyes) and Selected Substrates which are on the one Hand Electron Donors and on the Other hand Electron Acceptors, U.S. Dept. of Army, European Research Office Contract No. DA-91-591-EUC-2828, O1 360461-B.
(AD-602 227)

54. Crumley, Lloyd et al, Display Problems in Aerospace Surveillance Sys. HRB-Singer, Inc., State College, Pa. AF19(604)-7368, Prepared for Operational Applications Lab., Deputy for Tech., Electronic Systems Div. AF Systems Command, Research sponsored by Astrosurveillance Sciences Lab., Electronics Research Directorate, AF Cambridge Res. Labs. Office of Aerospace Res. (USAF), L.G. Hanscom Field, Bedford, Mass.
(AD-263 543)

55. Dugan, J.M., Design Studies for Globular Displays. RADC-TR-59-65, Battelle Memorial Inst., USAF Rome Air Development Center.
(AD-214 597)

56. Edson, A.W. et al, Large-Area Electronic Display Panel, Report No. 5, Contract DA36-039-sc-90755, DA Task No. 1G6-22001-A-055-03, U.S. Army Electr. Res. & Dev. Labs, Ft. Monmouth, N.J., Mil. Com. Dept. & Electronics Lab., General Electric.
(AD-422 000)

57. Emery, J.H. and Dougherty, D.J. Contact Analog Simulator Evaluations: Vertical Display With Horizontal Map Display, Bell Helicopter Co., Fort Worth, Texas, Technical Report No. D228-421-020, October 1964. Contract Nonr 1670(00).
(AD-612 465)

58. Epstein, D.W. Multiple Image Projector, U.S. Patent No. 2,590,240, March 25, 1952, Patent Office, Washington, D.C. Assigned to RCA.

59. DeLateur, L.A. & Munger, M.R. Data Presentation for Positional Representation of Space Vehicles (Phase II), Lockheed Missiles & Space Corp. Sunnyvale, Calif. RADC-TDR-63-109 (Vol. II).
(AD-408 358)

60. Fox, R.K. Consideration of State-of-the-Art of Display Equipment for use in a Teas Simulation Research Facility, PRC R-193, Research sponsored by Electronics Research Directorate, AF Cambridge Res. Labs., Office of Aerospace Res., US Air Force, Bedford, Mass.
(AD-269 680)

61. Gardner, J.F., et al. Inquiry Into Methods Used to Obtain Military Information Requirements. Systems Design Lab Planning Office, Electronic Systems Division, Air Force Systems Command, USAF, L.G. Hanscom Field, Bedford, Mass., Tech. Doc. Report No. ESD-TDR-62-302, May 1962. (AD-298 254)

62. George, B.K., and King, D.E. N., CVD Research Proj. RP3-51 High Resolution Screens, First Progress Report, General Electric Co. Ltd., Hirst Research Centre, Wembley, England Rep. #14,487C, 1 Nov. 1963. (AD-426 563)

63. Gold, T. and Workman, J.D. "Research in the Application of Windshield Projection Displays to the All-Weather Landing Task" Paper presented at 1st AIAA Annual Meeting, Washington, D.C., June 29-July 2, 1964.

64. Gregg, D.P. Scanning with Light-Conducting Rod , 3,112,360.

65. Grosso, P.F. Development of Phosphor Screens for High Resolution Display Devices, CBS Laboratoreis, Stamford, Conn. Contract No. AF33(657)-10632, Rep. No. AL-TDR-64-94, Proj. No. 4156, Task No. 415605. (AD-600 724)

66. " 'Head-Up' Flight Information Display and Visual Flight Simulator", Aircraft Engineering, Vol. 33, January 1961, pp. 22.

67. Hersch, W., 3 - D Display for Air Traffic Control, EMI Electronics Ltd., Hayes Middlesex, A64-19335.

68. Kraus, C.J., Display Improvement Program, Contract No. AF30(635)-1404, IBM Corp., Federal Systems Div., Kingston, N.Y.

69. Lethin, J.E. ASDE Bright-Display Study, Final Report, Prepared for FAA, SR & DS, by Airborne Instru. Lab., Deer Park, L.I., N.Y. Contract No. FA-WA-4149, Proj. No. 104-524 D. (AD-423 537)

70. Lieb, A. Arrangement for the Transmission and Reproduction of Images. 3,110,763, EL-PC Light Amplifier.

71. Loebner, E.E., Storage Light Intensifier Display Panel, David Sarnoff Res. Ctr., RCA Lab. Princeton. Contract No. DA-039-sc-71194, Dept. of Army Proj. No. 3-99-13-022, Signal Corps Proj. No. 112B. (AD-107 158)

72. Mailhot, J.R. Abstract Visual Display System, U.S. Patent No. 3,081,557, March 19, 1963, Patent Office, Washington, D.C. Assigned to General Precision, Inc.

73. Matrix Controlled Display Device, Prepared for Navy Dept., Bur. of Ships, Electronics Div., Contract NObsr 89334, Proj. SR-080301, Task 9475, GE, Electronics Lab., MCD, Syracuse, New York.
(AD-426 716)

74. Matrix Controlled Display Device Phase II, Electronics Lab., Syracuse, N.Y. General Elec., Contract No. NObsr-89334, Proj. SR-080301, Task 615 100.

75. Mayo, B.J., Apparatus for Generating Picture Signals, 3,106,605.

76. Miller, I. Literature Search on Air Traffic Control and the Electronic Equipment Needs of Aviation. Autonetics, Div. of North American Aviation Inc., EM-6428, 2 February 1961.
(AD-251 475)

77. Murray, J.G. et al Compositions of Matter and Uses of Said Compositions in a Projection System, 3,125,634.

78. McKenzie, E.L. et al Reflex-Reflecting Wall Structure, U.S. Patent No. 3,034,406. Assigned to Minnesota Mining Mfg. Co., St. Paul, Minn.

79. Noxon, P.A. "Microvision-A Universal All-Weather Landing, Station Keeping and Navigation System", Journal, American Helicopter Society, Vol. 10, January 1965, pp. 13-18.

80. Reininger, W.G. et al. Photoelectric Information Storage, Westinghouse Elec. Corp., Baltimore, Maryland for Wright Air Dev. Div., Contract No. AF33(657)8715.
(AD-403 718)

81. Rogers, J.G. et al Shared Spectrum Display Enhancement. Decision Sciences Laboratory, Electronic Systems Division, Air Force Systems Command, United States Air Force, L.G. Hanscom Field, Bedford, Mass., Technical Documentary Report No. ESD-TDR-64-673, January 1965. Contract No. AF19(628)-3882.
(AD-611 187)

82. Rutherford, R. Jr. & Speigel, K. Research & Investigation on Phosphor Screens for High Resolution Display Devices, Tech. Doc. Rep. No. ASD-TDR-62-1097, Electr..Tech. Lab., AS Div., USAF, Wright-Patterson AF Base, Ohio, Proj. No. 4156, Task No. 415605, Prepared under Contract No. AF33(616)8509 by CBS Labs., a Div. of CBS, Inc. Stamford, Conn.
(AD-401 348)

83. Sachtleben, L.T., High Resolution Display Media, Applied Research, Defense Electronic Prods. Radio Corp. of America, Contract AF-30(602) 2238, Prepared for Rome Dev. Ctr., Air Force Systems Command, USAF, Griffiss Air Force Base, N.Y.
(AD-277 746)

84. Schade, O.H., Sr. Vertical Aperture Correction

85. Slack, F.F. and Sandberg, A.A. Tracking and Display of Earth Satellites. AFCRC-TR-59-370, December 1959, Project 4649, Task 46495.
(AD-234 552)

86. Snodgrass, R.P. "Head-Up Display", Sperry Engineering Review, Vol. 17, Fall 1964, pp. 10-19.

87. Stein, W. Data Display Study, Quarterly Report No. 7. The National Cash Register Co., Electronics Div., Hawthorne, California, Technical Publication No. 3619. Contract No. DA-36-039-sc-90855.
(AD-457 165)

C. Training Devices other than Simulators

88. Adams, J.A. and Hufford, L.E. Effects of Programmed Perceptual Training on the Learning of Contact Landing Skills. U.S. Naval Training Device Center, Port Washington, N.Y. Technical Report: NAVTRADEVCEN 297-3, 28 April 1961. Contract N61339-297. (AD-264 377)

89. Adams, J.A. and McAbee, W.H. A Program for a Functional Evaluation of the GAM-83 Melpar Trainer. Air Proving Ground Center, Eglin Air Force Base, Florida, APGC-TN-61-41, Project 321BZ4, October 1961. (AD-268 220)

90. Carey, P.M. "Progress of Research Study Into Visual Simulation", International Convention on Military Electronics, 8th, Washington, D.C., Sept. 14-16, 1964, Conference Proceedings edited by B.J. Goldfarb, North Hollywood, Western Periodicals Co., 1964, pp. 123-126.

91. Gabriel, R.F. et al. Using a Generalized Contact Flight Simulator to Improve Visual Timesharing. Douglas Aircraft Co., Inc., Aircraft Div., Long Beach, California, Technical Report: NAVTRADEVCEN 1428-1, April 1965, Contract No. N61339-1428. (AD-619 047)

92. Heilig, M.L. Sensorama Simulator, U.S. Patent No. 3,050,870, Aug. 28, 1962, Patent Office, Washington, D.C.

93. Hutter, W.H. Pilot Trainer, U.S. Patent No. 2,352,101, June 20, 1944, Patent Office, Washington, D.C.

94. Marvin, R.A. et al. Flight Training and Evaluating Equipment, U.S. Patent No. 3,076,271, Feb. 5, 1963, Patent Office, Washington, D.C. Assigned to Communications Patents, Ltd.

95. Smith, R.L. et al Cathode Ray Tube Display for Grounded Aircraft Trainer, U.S. Patent No. 2,890,528, June 16, 1959, Patent Office, Washington, D.C.

96. Zimmerman, A. "Accidents Are His Business", Electronics, January 25, 1965, pp. 102-104.

D. Television, Systems and Components

97. Bedford, A.V. Vertical Aperture Compensation for Cathode Ray Apparatus, 2,757,236.

98. Beesley, J. and Widdowson, A.E. C.V.D. Research Project RP3-51 High Resolution Screens. The M-O Valve Company Ltd., Research Laboratories, Report No. 14,689C, 29 October 1964. Contract No. CP/96341/44. (AD-457 391)

99. F.J. Bingley et al. Research & Development on Photoconductive Photo-Tape, Air Force Systems Command, Aero S.D., Wright-Patterson Air Force Base, Ohio - Project No. 6263, Task No. 626302, Prepared under Contract No. AF33(657)-11485, S.A. No. 2 (64-1748) by Astro-Electronics Div. of RCA, Princeton, N.J. (AD-609 768)

100. Birt, D.R. Transistor Circuit for Applying Sawtooth Cur. to an Inductance. December 25, 1962, Assigned to North American Phillips Co., U.S. Patent No. 3,070,727.

101. Cope, A.D. et al Wide Angle High Definition TV System, Contract N6onr-23605, RCA Laboratories Div., Princeton, N.J. for Office of Naval Research Special Devices Center, Port Washington, N.Y. (AD 6247)

102. E.M. Creamer, Jr. et al Television Receivers, 3,041,496.

103. Clark, M.A. et al Two Way Television Over Telephone Lines, 2,922,843

104. Crowe, K.R. Summary Report for Research & Development to Improve the Resolution of Latron Direct View Storage Tubes, ITT Ind. Labs., Fort Wayne, Indiana 46803, Navy Bur. of Ships Electronics Div. NObsr-87264, SR 00803, Task 9497. (AD-426 172)

105. Damon, P.P. Interim Development Report for Research & Development of Two-Color Direct View Storage Tube with Selective Erasure. Hughes Aircraft Co., Vac. Tube Prods. Div., 2020 Oceanside Blvd., Oceanside, California, Contract No. NObsr-89452, SR 00 80301, Task 9459, Navy Dept. Bur. of Ships Electronics Div. (AD-609 491)

106. Epstein, D.W. and Maloff, I.G. "Projection Television", Journal of the Society of Motion Picture Engineers, Volume 44, No. 6, June 1945, pp. 443-445.

107. Fry, Glenn A. Fusion of the Lines of a Television Display, Tech Paper No. (696)-24, Rep. to Rome Air Development Ctr., Air Res. & Dev. Com., Griffiss AFB, N.Y., for Project No. 1763, Task No. 39855, under Contract No. AF30(602)-1580, OSURF Project 696. (AD-251 460)

108. Graham, R.E. Sequential Scan Television with Line Interpolation, 3,051,778

109. Gurevich, S.B. Analogy of Characteristics of Reproduction in Television and Photography (Translation), U.S. Dept of Commerce, Off. of Tech. Services, Joint Publications Research Service, Bldg. T-30, Ohio Dr. & Independence Ave., S.W. Washington 25, D.C., JPRS:16,930. (AD-298 915)

110. Herold, P. et al Applied Research on High Resolution Camera Tubes Electronic Tech. Div., AF Avionics Lab. Aero. Systems Div., AF Systems Command, Wright-Patterson AFB, Ohio. Prepared under Contract No. AF33(657)-7939, BPSN No. 2 (670-4156-41653) by Electron Tube Div., RCA, Industrial Tube Prods., Lancaster, Pa. (AD-417 752)

111. Inouye, G.T. Bandwidth-Reduction System, 3,037,083.

112. Kaiser Aircraft & Electronics, Summary Report of Kaiser Army, Navy Instrumentation Program (ANIP) Participation, Kaiser Aircraft & Electronics, Palo Alto, California. Prepared for Douglas Aircraft Co., Inc. Subcontract DAC 61-102 under Office of Naval Research, Prime Contract Nonr 1076(00). Prepared by Kaiser WCEI Staff. (AD-410 016)

113. Kennedy, E.J. et al Criteria for Group Display Chains for the 1962-65 Time Period. RADC-TDR-62-315, Griffis AFB, New York. (AD-283 390)

114. Krasil'nikov, N. N. Noise Immunity of Television Systems Random Noise in Television (Translation), Foreign Technology Div., AF Systems Command Wright Patterson AFB, Ohio. (AD-603 550)

115. Kretzmer, E.R. High Resolution Scanning System, 2,911,463.

116. Lakjer, L.E. Wide Screen Television Apparatus, 3,051,779.

117. "Large Screen Color Television Projector", Current Topics, May 1963, pp. 460-461.

118. Lechner, B.J. Solid-State Raster Scanning for Display, Electronic Tech. Lab., Research & Tech. Div., AF Systems Command, Wright-Patterson AFB, Ohio, Contract No. AF33(615)1193 by RCA Laboratories, Princeton New Jersey.
(AD-460 950)

119. Mikus, F.F. and VanNoy, B.W. Research & Development of Cathodo-luminescent Phosphor with Excitation-Time-Dependent Color. Sylvania Electric Prods. Inc. - Tawanda, Pa. Rep. No. 3, Contract DA36-039 AMC-03228 (E), DA Task No. 1G6-22001-A-055-03, U.S. Army Electr. Res. & Dev. Labs, Fort Monmouth, N.J.
(AD-441 298)

120. Pourciau, L.L. Video Resolution Control, 2,911,468.

121. Rado, J.A. Flying Spot Camera Tube, 3,011,019.

122. Rabinow, Jacob Narrow-Band Television Picture Reproduction, 3,108,155.

123. Radio Corporation of America, Princeton, N.J. Research & Development on Photoconductive Photo Tape, AF Avionics Lab., AF Sys. Com., ASD, Wright-Patterson AFB, Ohio, Proj. No. 6263, Task No. 626302, Prepared under Contract No. AF33(657)-11485 by the Astro-Electronics Div. of RCA, Princeton, N.J., Contractor's No. R-2354.
(AD-440 278)

124. Rutman, A. et al Electronic Camera Systems Study & Investigation, Contract No. DA28-043 AMC-00117 (E), DA Task No. 1P6 20801 A18603, US Army Electronics Labs., Ft. Monmouth, N.J., DuMont Labs Divs., Fairchild Camera & Instr., 750 Bloomfield Ave., Clifton, N.J.
(AD-453 848)

125. Schade, O.H., Sr. et al Applied Research on High Resolution Camera Tubes Technical Docum. Report No. AL TDR 64-171, 8 July 1964, Proj. No. 4156, Task No. 415605.
(AD-602 425)

126. Schlesinger, Dr. K. Design, Development and Fabrication of An Ultra-High-Resolution Cathode-Ray Tube, G.E. Co., Syracuse, N.Y., Contract No. DA36039 SC-90726 (E), Technical Requirements - SCL-7001/69, dated 8 Nov. 1961 - DA Task No. 1G6-22001-A-055-03. (AD-414 484)

127. Schlesinger, Dr. K. Design, Dev. & Fab. of an Ultra-High-Resolution Cathode-Ray Tube. Report No. 4 - 21 Feb. through 20 May, 1963, Contract No. DA36-039 SC-90726 (E), DA Task No. 1G6-22001-A-055-03 GE Pickup Tube Operation, Syracuse, New York. (AD-414 484)

128. Schlesinger, Dr. K. and Rate, E.T. Design, Dev. & Fab. of an Ultra-High Resolution Cathode-Ray Tube: Report No. 8. General Electric, Syracuse, N.Y. Final Report, 21 May 1962 through 1 September 1964. Contract DA 36-039 SC-90726(E). (AD-457 825)

129. Schlesinger, Dr. K. Camera Tube with Internal Image-Motion Compensation GE Tube Dept., Syracuse, N.Y., Contract No. DA 36-039 AMC-00128(E) DA Task No. 1G6-22001-A-055-03, U.S. Army Electronics Labs, Ft. Monmouth, N.J. (AD-462 700)

130. Schreiber, W.F. Bandwidth Reduction System for Television Sigs. 3,017,456.

131. Seyler, A.J. and Budrikis, Detail Perception after Scene Changes in Television Image Presentations, IEEE Transactions on Information Theory, Vol. IT-11, No. 1, Jan. 1965.

132. Shelton, C.T. Study of Army Television Problems, Contract DA-36-039-ac-56653, placed by US Army, Signal Corps Eng. Lab., Fort Monmouth, N.J., Eng. Prods. Div., RCA, Camden, N.J., SCL-1449A, 25 May 1953 SC Proj. No. 2115(C), DA Proj. No. 3-27-05-053. (AD-44143)

133. Space Television (A documentary survey) SID 62-613, Prepared by Technical Information Center, North American Aviation, Inc. (AD-282473)

134. Taylor, F.E. et al Spiral Scanning Circuit, 2,995,678.

135. Teacher, C.F. et al Time-Bandwidth Reduction System for Image Signal Transmission, 3,128,338.

136. Technical Information Center, Space Television. North American Aviation, Inc., Space and Information Systems Division, SID 62-613, 23 May 1962.
(AD-282 473)

137. Vine, B.H. et al Applied Research on High Resolution Camera Tubes Electronic Tech. Div., AF Avionics Lab., ASD, Air Force Systems Command, Wright-Patterson AFB, Ohio, Contract No. AF33(657)-7939, BPSN No. 2 (670-4156-41653), Electr. Comps & Dev., RCA, Industrial Tube & Semiconductor Div., Lancaster, Pa.
(AD-427 824)

138. Waldorf, A. Plural Beam Cathode Ray Tube, 3,071,706.

139. Wallace, K.F. et al Electrical Readout for Wideband Electron Beam Recording. Prepared for Rome Air Development Ctr., Griffis Air Force Base, New York, Contract No. AF30(602)-2474, Ampex Corp. Redwood City, Calif.
(AD-293 201)

140. Wilhelm, C.R. Lab. Report No. 25 - Introduction to Waveform (Pulse & Bar) Testing. Australian Broadcasting Company, 195 Pacific Highway, Artarmon, N.S.W., Australia. File No. 10.6.25.

141. Wilhelm, C.R., Laboratory Report No. 26, Methods of Waveform (Pulse & Bar) Testing, Australian Broadcasting Company, Alderson Bldg., 508 Pacific Highway, St. Leonard's N.S.W., Australia. 102/26.

142. Winner, R.N. and Zilgalvis, A. Cathode-Ray Tube Instrument Synthesis System, Report No. AMRL-TDR-63-84, Behavioral Sciences Lab., 6570th Aerospace Medical Res. Labs., Aerospace Med. Div., AF Systems Command, Wright-Patterson AF Base, Ohio. Prepared under Contract AF33(616)-7859.
(AD-424 542)

143. Wittlig, P.F. Methods and Apparatus for Television Montage, 2,969,428.

E. Human Factors

144. Allen, M. J. et al A Moving Target Optical Projector For Use in Air Traffic Control Research. Aviation Psychology Laboratory, The Ohio State University, Research Foundation, WADC Technical Report 53-417, January 1954. Contract No. AF33(616)-43, RDO 694-43. (AD-30062)

145. Amorelli, D. et al Space Flight Training Programs. North American Aviation, Downey, Calif., Publication No. 543-E/3-63, 16 January 1963. (AD-457 792)

146. Applied Psychology Corporation, Arlington 7, Va. Pilot Judgments of Simulated Collisions and Near Misses. Technical Report No. 5, April 1961, Contract No. FAA/BRD-127.

147. Army Medical Research Laboratory, Fort Knox, Kentucky. Effects of Injured Imbalance on Depth Judgments. Report No. 201, Project No. 6-95-20-001, Subtask AMRL 5-2, MEDEA, 12 August 1955. (AD-68 466)

148. Baker, C.A. and Grether, W.F. Visual Presentation of Information. Aero Medical Laboratory, WADC Technical Report 54-160, August 1954, Project No. 7180. (AD-43064)

149. Bell Helicopter Co., Fort Worth, Texas. Human Factors Quarterly Progress Report, July 1 through Sept. 30, 1960. Army-Navy Instrumentation Program Contract Nonr 1670(00). (AD-247 030)

150. Brown, J.L. Sensory and Perceptual Problems Related to Space Flight. National Academy of Sciences - National Research Council, Washington, DC., Publication 872, 1961. (AD-257 215)

151. Catalano, J. and McKown, C. A Study of Requirements for a Pilot Warning Instrument for Visual Airborne Collision Avoidance. Systems Research and Development Service, Federal Aviation Agency, Atlantic City, N. J., Final Report, Dec. 1963. Contract No. FAA/BRD-322, Project No. 110-504, Report No. RD-64-88.

152. Cave, R.T. "The Role of Simulation in Apollo Spacecrew Training". Paper presented at AIAA/AFLC/ASD Support for Manned Flight Conference, Dayton, Ohio, April 21-23, 1965.

153. Fitts, Paul M. Human Engineering for an Effective Air-Navigation and Traffic-Control System. National Research Council, Washington, D.C. ATI 133954.

154. Gogel, W.C. et al. The Tendency to See Objects as Equidistant and Its Inverse Relation to Lateral Separation. Psychology Department, Army Medical Research Laboratory, Fort Knox, Kentucky, Report No. 146, Project No. 6-95-20-001, Subtask AMRL S-2, MEDEA.
(AD-44 670)

155. Horowitz, M.W. James J. Gibson on Visual Perception: Analysis of Selected Papers. Educational Research Corporation, Cambridge, Mass. February 1964. Technical Report: NAVTRADEVCEN 294-5, Contract No. N61339-294.
(AD-602 283)

156. Huang, T.S. The Subjective Effect of Two-Dimensional Pictorial Noise, IEEE Transactions on Information Theory, Vol. IT-11, No. 1, Jan. 1965.

157. Kasten, D.F. Human Performance in a Simulated Short Orbital Transfer. 6570th Aerospace Medical Research Laboratories, Tech. Docu. Report No. AMRL-TDR-62-138, December 1962. Project No. 7184, Task No. 718405.
(AD-400 484)

158. Leininger, W.E. et al. Aerial Terrain Orientation By Means of Television Display. U.S. Naval Missile Center, Point Mugu, Calif., Technical Memorandum No. NMC-TM-63-39, 11 Dec. 1963.
(AD-425 538)

159. Matheny, W.G. Human Factors Program and Progress Report, Army-Navy Instrumentation Program - Rotary Wing. Bell Helicopter Co., Fort Worth, Texas, Bell Report D228-400-003, January 1961. Contract Nonr 1670(00).
(AD-250 052)

160. McRuer, D.T. and Krendel, E.S. Dynamic Response of Human Operators. Flight Control Laboratory (Contract AF33(616)-3080, Project 365, and Aero Medical Laboratory (Contract AF33(616)-2804, Project 1182), WADC Tech. Report 56-524, October 1957.
(AD-110 693)

161. Muckler, F.A. et al Psychological Variables in the Design of Flight Simulators for Training. Aviation Psychology Lab., U.of Ill., Contract No. AF33(616)-2725, Aero Medical Laboratory, USAF, Wright-Patterson Air Force Base, Ohio.
(AD-97130)

162. National Academy of Sciences, The Training of Astronauts. National Research Council, Washington, D.C. Publication 873, 1961.

163. Sampson, P.B. et al Literature Survey on Human Factors in Visual Displays The Institute for Psychological Research, Tufts University, Medford 55, Mass., RADC TR 61-95, June 1961. Contract No. AF30(602)-2358.
(AD-262 533)

164. Schaefer, H. and Ebner, F. A New Stereoscopic Effect and Its Physiological Interpretation. W.G. Kerckhoff - Institut, Bad Nauheim, FIAT Report No. 1176, 18 April 1947. In German.
(ATI-9003)

165. Schohan, B. Human Engineering Recommendations for a Visual Reconnaissance Ground Trainer. American Institute for Research, Pittsburgh, Pa., September 1954. Aero Medical Laboratory Contract No. AF33(616)-2080.
(AD-78440)

166. Smith, S.W. Time Required for Target Detection in Complex Abstract Visual Display. Institute of Science and Technology, The University of Michigan, Memorandum of Project MICHIGAN, 2900-235-R, April 1961. Contract DA-36-039-SC-78801.
(AD-256 039)

167. Wulfeck, J.W., et al Vision in Military Aviation. Jackson and Moreland, Inc., and Tufts College, WADC Technical Report 58-399, Nov. 1958. Contract No. AF33(616)-2906.
(AD-207 780)

F. Photographic and Other Instrumentation

168. Applied Research on Photoconductive Photo-Tape, AL-TDR-64-18, AF Avionics Lab., Res & Tech Div, AF Sys. Com., Wright-Patterson AFB, Ohio, Project No. 6263, Task No. 626302, Prepared under Contract No. AF33(657)-8843 by Astro-Electronics Div. of RCA, Princeton, N.J.
(AD-434 360)

169. Bennett, Reeves, et al Research on High Density, Large Capacity, Thermoplastic Film Data Storage System. Report No. 4, Signal Corp. Contr. No. DA-36-039-SC-85118, Dept. of Army Proj. No. 3A-99--22-001-04, 4th Quarterly Prog. Report, 1 Sept. 1960 to 30 Nov. 1960, U.S. Army Sig. Res. & Dev. Lab., Ft. Monmouth, N.J., General Electric Co., Computer Dept. 13430 N. Black Canyon, Phoenix, Arizona.
(AD-254 431 L)

170. Science Publishing House, Moscow, Quality of the Photographic Image (Translation) ATD Report T-65-10, Translations of Soviet-Bloc Scientific & Tech. Literature, Aerospace Technology Div., Library of Congress.
(AD-460 800)

171. Wallace, K.F. et al Applied Research on High Resolution Film Scanning Third Quarterly Interim Report, Contract AF33(657)-11091 (Ampex Proj. No. 7119), for the Aerial Reconnaissance Laboratory at Wright Patterson AFB.
(AD-432 459)

Section IV

TELEVISION SURVEY

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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 (l) above, to be procurable within one year.

3. Preliminary specifications for a Closed Circuit TV System adhering to (l) 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

FOCI

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° or more. For a 140° 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° 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 168×10^6 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
   I 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 I
    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. 1, 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

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. Grumman Aircraft Engineering Corporation, Bethpage, Long Island, N.Y.

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 1 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. <u>MGD Research & Development Corporation, Subsidiary of Miehle-Goss-Dexter, Incorporated, Fair Lawn, New Jersey 07410</u>

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^{o} in azimuth and 120^{o} 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.

1. Armor Leader Tactical Trainer (Device X17AR1)

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 3π 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° on the diagonal. (It is reported that the price of a system with field of view greater than 60° 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 Bella-rama 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 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

References

1. Whittenburg, J.A. and Wise, J.E. Feasibility for Research Application of Visual Attachments for Dynamic Flight Simulators, Report No. 2: Requirements and State-of-the-Art Evaluation, Contract No. FAA/BRD-401, Project No. 421-12R, February 1963. AD-401 129.

2. Clay, B.R. et al. Investigation of 360-Degree Non-Programmed Visual Presentation, Technical Report: NAVTRADEVCEN 1053-1, June 5, 1962. AD-291 468.

3. Hutchinson, C.H. Automobile Driving Simulator Feasibility Study, Final Report, Report No. YM-1244-V-6, Contract No. SAph 69692, November 18, 1958

4. Molnar, A.R. et al. Basic Development Accomplished on Wide-Angle Non-Programmed, Visual Presentations, Technical Report: NAVTRADEVCEN 404, Vol. 1, April 1959. AD-227 192.

5. Woodson, R.A. "Space Flight Visual Simulation System, Space Rendezvous, Rescue and Recovery"; Proceedings of the American Astronautical Society Symposium, (Advances in the Astronautical Sciences), Vol. 16, Part 2, Petersen, N.V., editor, Western Periodicals Co., North Hollywood, Calif., 1963, pp. 188-205.

6. H.A. Wagner Co. Preliminary Proposal: Trainer, Tank, Platoon Leader, Device 17-AR-1, May 1957.

7. Fairchild Stratos Corp., Electronic Systems Division. Trainer Attachment, Visual Simulator SMK 22/F37 A-T, Technical Report No. ASD-TDR-63-335, October 1963. AD-425 682.

8. Carey, P.M. "Pilot's Eye View is Projected on Screen in Visual Simulation Flight Trainer", Canadian Electronics Engineering, Vol. 7, Feb. 1963, pp. 31-35, 46.

9. Hellings, G. and Emms, E.T. "A Visual System for Flight Simulators", British Communications and Electronics, Vol. 7, May 1960, pp. 334-337.

10. Aronson, M. "Wide Angle Visual Simulation Requirements and Experience", AIAA Simulation for Aerospace Flight Conference, August 26-28, 1963, Columbus, Ohio, American Institute of Aeronautics and Astronautics, N.Y., 1963, pp. 175-185.

11. Doty, A.B., Jr. "Visual Simulation of Aerospace Flight", AIAA Simulation for Aerospace Flight Conference, August 26-28, 1963, Columbus, Ohio, American Institute of Aeronautics and Astronautics, N.Y., 1963, pp. 154-174.

FACI

12. Fox, P.L. Design Study for Trainer, Visual Flight Attachment for Aircraft Flight Simulators, Part I, WADC Technical Report 57-137, March 1957. AD-216 438.

13. deFlorez Co. The Development, Application, and Study of the Point Light Source Technique, Technical Report: NAVTRADEVCEN 1628-16, September 1963. AD-435 547.

14. Schaper, O.F. Carrier Landing Trainer, U.S. Patent No. 2,883,763. April 28, 1959, Patent Office, Washington, D.C.

15. "AMB Research Tool: Runway Lighting Simulator", American Aviation Magazine, Vol. 22, No. 12, Nov. 3, 1958, pp. 56.

16. Austin Co., Torpedo and Rocket Attack Trainer, Device 14B3, Overhaul and Maintenance Manual NAVEXOS P-424, Contract N5ori-49.

17. Bell Aircraft Corp. & deFlorez Co. Handbook of Maintenance and Operation and Parts Catalog for Device 2-FH-2, Research Tool for Helicopter Flight Simulation, NAVEXOS P-1551, August 1956.

18. Butler, L.F. and Havron, M.D. Evaluation of Training Effectiveness of the 2-FH-2 Helicopter Flight Trainer Research Tool, Technical Report NAVTRADEVCEN 1915-00-1, April 1957.

19. deFlorez, L. and Smith, E.K. "Helicopter Flight Trainer", Aeronautical Engineering Review, Vol. 15, No. 5, May 1956, pp. 114-125.

20. Gartner, W.B. and Lybrand, W.A. F-151 Fixed Gunnery Trainer, Visual Presentation Evaluation, Psychological Research Associates, Inc., April 1957.

21. Link Aviation, Inc., Binghamton, N.Y. The Link Visual System - Mark I, Proposal No. 172, April 1958.

22. The Reflectone Corp. Design Study Report - Contact Analog Landing Trainer Research Tool, Device 20-L-10A, Contract Nonr-1960(00), U.S. Naval Training Device Center, Port Washington, N.Y.

23. Special Device Center, Port Washington, N.Y. Final Engineering Report on the Carrier Landing Trainer Development, Devices 12BK-5 and 12BK-5a, NAVEXOS P-1473, Contracts N80nr 79300 and Nonr 1050(00), Dec. 1, 1955.

24. Sulpizio, T J. Image Projector Design - Runway Lighting Attachment for Aircraft Simulators, Report No. 138-R-806, Rheem Mfg. Co.

25. U.S. Naval Training Device Center, Port Washington, N.Y. Improving Landing Performance Using a Contact Landing Trainer, Technical Report SPECDEVCEN 71-16-11, Contract N60ri-71(16).

26. H.A Wagner Co., Van Nuys, California, Final Report to U.S. Naval Training Device Center, Port Washington, N.Y., on Trainer, Tank Platoon Leader 17-AR-1, Phase 1, Contract N61339-25, July 26, 1957.

27. Laird, J.P., Jr. Optical Projector and System, U.S. Patent No. 2,482,115, Sept. 20, 1949. Patent Office, Washington, D.C.

28. The Marquardt Corp., Pomona, California. The VueMarq, Excerpted sections of a Marquardt Corp. proprietary report. Undated.

29. Wise, J.E. and Whittenburg, J. A. Feasibility for Research Application of Visual Attachments for Dynamic Flight Simulators. Report No. 1: State-of-the-Art Survey of the Visual Simulation Industry, Contract No. FAA/BRD-401, Project No. 421-12R, July 1962.

30. The Oxford Corporation, Buffalo, N.Y. Phase 1 Engineering Report, Carrier Landing Flight Simulator. Report No. 6102, 1 August 1961. BuWeps Contract NOw 60-0721-c.

31. FOCI Operating Manual, Farrand Optical Company, Inc., N.Y., Contact Flight Simulator, Operation and Maintenance Instructions Device 14-L-2. Prepared for ONR under Contract N5-ori-82, 12 January 1945.