

# STUDY OF VIRTUAL IMAGE OUT-THE-WINDOW DISPLAY SYSTEMS

VOLUME 2

PREPARED BY

FARRAND OPTICAL CO. INC.  
NEW YORK, N.Y.

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS

CONTRACT NO. NAS 9-3678

JANUARY 1966



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

January 1966

Prepared by:

Farrand Optical Co., Inc.  
New York, N.Y.

FOR:

National Aeronautics and Space Administration  
Manned Spacecraft Center  
Houston, Texas

Contract No. NAS-9-3678



VIRTUAL IMAGE OUT-THE-WINDOW  
DISPLAY SYSTEM STUDY

Volume II

APPENDIX

Prepared by

Matthew Baum  
Raymond Bull  
Joseph LaRussa  
Lester Mayer  
Martin Shenker

Farrand Optical Company, Inc.  
New York, New York

Prepared for

National Aeronautics and Space Administration  
Houston, Texas  
Contract NAS 9-3678



## 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.



## ACKNOWLEDGMENTS

The success or failure of any attempt to survey an industry depends to the largest measure on the amount and spirit of cooperation extended by members of the industry itself. That this survey was as thorough and comprehensive as we feel it is, is due to the interest and efforts of makers and users of visual simulation equipment. Firms participating in the television and simulation surveys are listed in Sections IV and V, respectively. We wish to single out, in particular, those individuals who received the Farrand research team on facility visits, and gave so unselfishly of their time: M. Aronson and R. Klaiber of Naval Training Device Center, Port Washington, N.Y.; E. Pazera of Federal Aviation Agency, Atlantic City, N.J.; R. Heintzman of Wright-Patterson Air Force Base, Ohio; T. Momiyama and P. Vandenberg of Naval Air Test Center, Patuxent River, Md.; J. Renfro, H. Christensen, M. Deigert, and F. Longwell of International Business Machines, Owego, N.Y.; R. Hayes of Dimensions Unlimited, Inc., Plainview, N.Y.; and V. Malcolm, R. Slater, and B. Tucker of General Dynamics/Electric Boat, Groton, Conn.



## TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
	ABSTRACT	i
	ACKNOWLEDGEMENTS	ii
I	INTRODUCTION	1.1
II	ABSTRACTS	2.1
III	BIBLIOGRAPHY	3.1
IV	TELEVISION SURVEY	4.1
	A) State-of-the-Art Questionnaire	4.2
	Technical Discussion	4.3
	B) Organizations Surveyed	4.5
	C) Summary of Replies	4.11
V	SIMULATION SURVEY	5.1
	A) State-of-the-Art Questionnaire	5.2
	B) Organization Surveyed	5.3
	C) Summary of Replies	5.7
VI	FACILITY VISITS	6.1
VII	A GUIDE TO THE LITERATURE OF VISUAL SIMULATOR DEVICES	7.1



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: NAVTRA-DEVCEN 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 (NAVTRADEVCEEN), Port Washington, N.Y., to achieve these requirements are described. The compromises and limitations of the equipment are discussed.

Over the years NAVTRADEVCEEN 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 NAVTRADEVCEEN, 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 ( $5^\circ$  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

NAVTRADEVCCEN 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  $150^{\circ}$ . 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 defocused 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 astronomical 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  $60^{\circ}$  to  $80^{\circ}$ .

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.

Authors: Choi, O., Gray, S., Herald, 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: NAVTRADEVCEEN 1053-I, 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: NAVTRADEV CEN 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  $160^{\circ}$  in azimuth are off-the-shelf items. More sophisticated point source projectors can provide displays up to  $200^{\circ}$  in azimuth. A claim is made for full  $360^{\circ}$  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: NAVTRADEVCCEN 1628-2, March 1959.  
(AD-227 558)

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

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

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

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

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

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

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

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



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

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

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

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

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

The Development, Application, and Study of the Point Light Source Technique. Technical Report: NAVTRADEVCCEN 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: NAVTRADEVCCEN 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, NAVTRADEVCCEN 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 NAVTRADEVCCEN 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 NAVTRADEV CEN 1628-12 through 1628-14 cover the preliminary design data.

Report NAVTRADEV CEN 1628-15 covers the final test report.

Report NAVTRADEV CEN 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.P., 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 inseting. 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.



2.5. 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 persistence of vision will blend the successive images into a continuous band or horizontal field.

The terrain image extends from horizon-to-horizon and  $360^{\circ}$  in azimuth. The instantaneous field of view of the optical viewing and projection lenses, which comprise the telecentric lens system, are  $45^{\circ}$  each. A central image field will be generated by a stationary telecentric lens system of  $90^{\circ}$  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 juxtaposition 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  $200^\circ$  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:  $200^\circ$  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  $15^\circ$  to  $45^\circ$  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 N0bsr-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.



**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

2.52



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 performed 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 consisted 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  $-90^\circ$  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.

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 perspective 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 observer's 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.



Authors: 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: NAVTRADEVGEN 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", IEEE Transactions on Information Theory, January 65, Vol. IT-11, No. 1, pp. 43-53.

SUMMARY: A study was made of the subjective effects of the class of independent additive rectangular low-pass Gaussian noises. The pictures were digitized, noise of a predetermined 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 merely as a "black box", whose input/output function was to be determined.

Isopreference surfaces were determined in the 3-space defined by horizontal and vertical noise bandwidths and RMS noise amplitude. For the small number of observers tested the agreement among subjects was rather good. They were more in agreement as to the effects 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 objectionable than that with horizontal streaks, although details of the isopreference surfaces were 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  $180^{\circ}$ . 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  $90^\circ$  horizontal by  $75^\circ$  vertical field of view, with a 4-1/2 inch diameter exit pupil. This system was capable of a full  $360^\circ$  panoramic view by picking off azimuth head motions and rotating the projection assembly within a  $360^\circ$  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 gimbaling 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-

finiteness 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  $110^{\circ}$  horizontal by  $84^{\circ}$  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.

**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, empirically 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  $3\pi$  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  $180^\circ$  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  $345^{\circ}$  azimuth by  $120^{\circ}$  elevation. The field of view of the viewer was set at  $180^{\circ}$  azimuth and  $30^{\circ}$  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  $110^\circ$  horizontally by  $40^\circ$  vertically.

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

Title: Basic Development Accomplished on Wide-Angle, Non-Programmed, Visual Presentations. Volume I. Camody Corporation, Buffalo, N.Y. Technical Report: NAVTRADEVCEM 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: NAVTRADEVCEM 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  $30^\circ$  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.



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  $180^\circ$  azimuth by approximately  $30^\circ$  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

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;  
NAVTRADEVCEEN 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 I51 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 I51 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 I51 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  $0^\circ$  when the object is distant, to  $90^\circ$  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 I51 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 reinstated, 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



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  $60^\circ$ ) 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  $30^\circ$  off-axis. It covers a  $60^\circ$  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).



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.



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

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

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 preceding 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.)

