A SYNTHETIC DISPLAY TECHNIQUE FOR COMPUTER-CONTROLLED SIMULATOR AND AIRBORNE DISPLAYS

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1. Summary

Interest in airborne, computer-driven, integrated displays has resulted from the problem of effectively displaying greater quantities of rapidly changing control information. A new concept for implementing computer-controlled simulator and airborne displays is described. This concept employs the synthetic generation of desired instrumentation at the cockpit interface of the man-machine loop utilizing a programable electronic display system. The synthetic display concept utilized is based on an "electronic animation" technique which allows the cockpit display designer to proceed directly from static (cardboard) instrument mockups to dynamic displays which are simulated in the cockpit by high resolution closed-circuit monochrome TV.

Experimental synthetic display hardware is described from the viewpoint of relating the operational capability and flexibility of the "electronic animation" technique. The performanced achieved to date is illustrated through photographs of synthetically generated electro-mechanical instrumentation. The potential of the technique for synthesizing experimental displays at lower costs, at higher speed, and in new integrated formats is discussed.

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2. Introduction

Information display for the manual control of aerospace vehicles is a field which is receiving much attention because of the increasing complexity of pilot's tasks during advanced missions. In complex, multiphased missions, man is faced with greater quantities of control information, events which occur more rapidly, and the requirement for more exacting control. This recognized trend toward increasingly more complex pilot's tasks along with studies which reveal a great deal of pilot scanning activity using conventional instrument arrays[1] have led to many proposals for an integrated, time-shared display using a computer-driven general purpose device such as a cathode ray tube.[2,3,4]

A general-purpose display concept seems to offer the potential for more effective display as well as for less equipment and panel space, which would afford lower total weight and volume. In addition, a general-purpose display device is more easily integrated with a central avonics system computer than are a host of individual panel instruments. The capabilities attendant to most computer-generated displays for programing, panel space time-sharing, and display integration could be made available in the cockpit. Yet there is general disagreement among flight control-display system designers as to whether the general-purpose display concept or the conventional instrument array concept offers the greatest potential.[5]

Such disagreements point out the need for sound simulator research programs to determine the effectiveness of general-purpose display concepts and to explore the problems (both from a human factors and hardware standpoint) which would be encountered in the transition from conventional instrument arrays to a small number of central, computer-driven, general-purpose displays. This paper reports on the investigation and development of a synthetic display technique having applications for programed, integrated display in simulators and in airborne vehicles. The objective of the work described has been to provide for a more effective, less costly, and less time consuming means of creating dynamic instrument replicas for use in the simulator evaluation of integrated and general-purpose display concepts.

3. Motivation for Synthetic Display Development

3.1 The Display Problem

Even though the time-proven research simulator is in widespread use both for human factors research and for control-display interface design, it has inherent deficiencies which can be improved upon. The procedure of constructing or procuring physical instruments for use as dynamic replicas has led to problems with development time lags and costs and has produced generally single-purpose instruments. The creation of dynamic instrument replicas can call for many of the following time-consuming techniques:[6,7]

- The selection and/or design of many types of electromechanical instruments
- Modification of meter faces or tapes
- Construction and/or modification of servo-driven gear trains
- Construction of special oscilloscope drive circuitry
- Modification of image projectors

In the case of more sophisticated electronic displays, new instrument designs require even longer lead time, and can prove to be quite costly. An additional disadvantage to the above-mentioned techniques for implementing research simulator display panels is that instruments chosen or developed frequently must be discarded subsequently because of pilot opinion, poor pilot performance, and/or system design changes.

The constraints put on spacecraft displays with regard to weight, reliability, and reluctance to use untried techniques make the aero-spacecraft display system a field full of new ideas, but the hardware being developed is mostly conventional.[1] The main trend is to push conventional displays into as highly an integrated form as possible, without taking the major step of going to a single time-shared, general-purpose display and the consequent removal of the traditional maze of instruments. Single-purpose instruments and arrays of these instruments are, by their nature, limited in flexibility and provide no means of evaluating general-purpose display concepts. Thus it becomes imperative that a new capability be established to evaluate general-purpose display concepts utilizing the research simulator as a means of providing experimental data for a basis of comparison.

3.2 A Potential Solution

A solution to the above-mentioned display problems appears to lie in a new concept proposed in July, 1962, by the author, who later found that a similar concept was being investigated at Wright-Patterson Air Force Base under contract to North American Aviation, Inc.[6,7]

This concept is based on the premise that a programable electronic display system can be developed which synthesizes desired instrumentation at the control-display interface. A pictorial diagram representing this concept in terms of simulator signal flow is shown in Figure 1. It can be seen that such a system would operate in conjunction with a flight simulation computer and the simulated cockpit control-display interface. The synthesized displays would be driven dynamically in accordance with the flight equations as perturbed by pilot control inputs.

Assuming that such a display synthesis system could be developed, it would reduce a basically hardware problem to that of a software problem. If the design allowed for rapid and efficient programing and was sufficiently universal in nature, it would have the potential for producing research simulator displays at lower cost, at higher speed, and at more advanced levels than conventional techniques will allow. For maximum efficacy such a display synthesizer should have many of the following characteristics:

(1) Rapid and efficient programing with a minimal turn around time

(2) Synthesis of desired instruments with the completed system requiring little or no new hardware design

(3) Universal in nature; thus, capable of the synthesis of a wide spectrum of displays including electro-mechanical as well as electronic and electro-optical displays

(4) Employing a combination of devices not exceeding the state-of-the-art and producing a feasible, reliable system

(5) Capable of use at a central location with remotely driven displays, which are compatible with fixed-base and dynamic flight simulator cockpits

(6) Compatible with flight simulation computers and associated trunking networks

(7) Utilizing, if possible, new techniques being proposed for, and directly applicable to, next generation flight vehicles, thereby making it useful as a test bed as well as a simulation research tool

The remainder of this paper will be devoted to (1) a discussion of the technique chosen as a basis for synthetic flight display generation, (2) the description of a programable display synthesis system utilizing this technique, and (3) the discussion of initial system performance.

4. Synthetic Display Technique Chosen

4.1 Potential Techniques

Of the display techniques studied, which are applicable to the synthetic generation of flight displays, those classes of displays known as programed electronic displays afford the most promise for providing a repertoire ranging from simple electro-mechanical displays to sophisticated general-purpose displays.[8] Most programed electronic displays come under the category of computer-generated CRT displays which have the desired advantages of unrestricted display format, of good image quality, and of programability.

A major problem is encountered, however, in the area of programing, in attempts to apply existing computer-CRT displays to the task of flight display synthesis. The programing requirements for effective display can be very extensive, often running to many thousands of digital words.[9] Specific disadvantages are encountered with the character and vector generation schemes generally in use with CRT displays.[10] These disadvantages may be categorized as follows:

(1) Stylized display - Since all dynamic displays must be composed of alphanumerics and vectors, the visual image takes the form of rudimentary line drawings or stylized displays rather than continuous tone, photographic-type displays.

(2) Lengthy programs - Since all characters and lines in the dynamic portions and many times in the static portions of visual displays must be selected, positioned, and unblanked on an element-by-element basis, the computer word program can become quite lengthy.

(3) Regeneration rates - Since each element of the visual display must be manipulated individually and regenerated individually at a rate no less than 25 cps to avoid flicker, the digital word rate required for generation of complex displays can become high enough to prohibit interlacing the display program with other computer control and arithmetic sequences. In these cases a separate recirculating memory is required in the display console for regeneration of the display.

(4) <u>Character change</u> - Display symbols can be changed only through the substitution of new circuit modules, scanning tubes, or display tubes.

The disadvantages of these character generation schemes limit, but do not preclude, the direct use of existing computer-CRT combinations as a synthetic flight display generator. However, in an effort to implement a more-easily-programed and a truly utilitarian flight display synthesizer a new means of dynamic pattern image generation was investigated. This dynamic pattern image generation method is described in the following two sections.

4.2 Principle of Operation

The techniques selected for dynamic and static image generation and for overall display synthesis are based upon the principle illustrated by Figure 2. This principle asserts that most desired flight displays are composed of static patterns and dynamic patterns which can be separated for photographic storage and, under the control of programed instructions, machine dynamics inputs, and manned inputs, can be electronically recombined for composite, dynamic display. A programed display synthesis technique based on this principle can best be described by the term, "electronic animation."

4.3 Rudimentary System Requirements

The basic requirements for electronic animation consist of (1) the means for calling up static and dynamic display patterns from random access film storage, (2) the means for electronically modifying scanned dynamic patterns (in accordance with flight dynamics equations) to convey motion, and (3) the means for combining static and dynamic portions of the display to form animated composited.

The basic system components required to achieve electronic animation are shown in the conceptual system diagram of Figure 3. For the conceptual system, high resolution closed-circuit monochrome TV is chosen as the display means. This choice provides for flexibility and economy of display since closed-circuit TV displays are available in many configurations and are relatively inexpensive. In addition, the use of closed-circuit TV as the display means allows for use of the synthetic display generator at a central location with remotely driven displays, which can be made compatible with fixed-base and dynamic flight simulator cockpits.

The use of the TV display technique allows the combining of static and dynamic portions of the composite, animated display through simple video mixing. The video mixing; however, requires that both static and dynamic video picture information be in the closed-circuit TV format of the display monitor, which is 1203 lines/ 60 fields/ 2-to-1 interlace. Thus, static pattern storage can be accomplished utilizing a random access slide projector. Video pickup of static picture information is accomplished by a closed-circuit TV vidicon film scanner into which the static image is projected.

The dynamic (animated) portion of the composite display is gotten into a closed-circuit TV format through the use of the scan converter. The scan converter is necessary for this function since multiple dynamic patterns must be scanned and manipulated individually at the input to this interface and yet must be arrayed in the correct geometrical pattern and scanned as a whole at the output of the interface.

The choice of the dynamic image generation method is by far the most important factor in the shaping of an electronically animated display system. This is because it is this method that sets the requirements for control sequences, storage capacity, regeneration rates, and programing. The dynamic image generation method shown in rudimentary pictorial form in Figure 3 is that of a random access flying spot film scanner.

The random access flying spot film scanner performs the function of calling up from photographic storage those patterns which are to be the dynamic portion of the composite, synthetic display. Since most flight display panels contain multiple dynamic display patterns, each of which must relate motion individually, the use of multiple pattern photographic storage and of individual pattern scanning with diminutive rasters is indicated.[11]

The use of a raster-scan pickup for dynamic image generation implies the use of a raster-scan input to the scan converter interface, where the pickup and display (interface) raster are scanning in synchronism. Each pickup raster must be positioned to the appropriate dynamic element on the film store and its corresponding display raster must be positioned to the appropriate display location in the scan converter at the appropriate time in the display composing sequence. Additionally, some means must be provided for animating or providing appropriate motion to each dynamic element of the display. This animation is provided in the conceptual diagram of Figure 3 by electronic modification of the position, size, shape, and/or orientation of each display raster before it is written into transient storage in the scan converter. The electronic animation is accomplished in accordance with the appropriate sampled flight dynamics channel from the flight simulation computer.

The final requirement for implementation of a conceptual electronic animation system is for some form of program storage and control sequence generation. This function can be performed by a small digital computer or by a special purpose programable control unit as is shown in Figure 3.

5. Description of Experimental Hardware

The synthetic flight display generation equipment actually implemented at Langley Research Center will not be described in detail, but rather generally from the viewpoint of a potential user. Programing techniques, operational modes, and flexibility of the "electronic animation" technique will be emphasized. Those readers requiring a more detailed description of the display hardware are referred to References 8 and 12.

5.1 General Configuration

A photograph of the hardware developed to implement electronic animation techniques for research simulator display applications is shown in Figure 4. Emphasis in the design of the system was on (1) reliability, through the use of solid state components wherever possible; (2) maintainability, through the use of laboratory-sized as opposed to microminature construction; (3) programability, through the minimization of software and coded digital instructions; (4) universality, through the employment of rapidly changeable static and dynamic film-store patterns, the latter of which are electronically animated; and (5) flexibility, through the use of closed-circuit TV as the readout means.

The system design for the synthetic display generator is based on the conceptual system diagram of Figure 3. The major subsystems involved are identified in the system photograph of Figure 4.

The random access flying spot film scanner shown in Figure 4 utilizes digitally controlled beam positioning and raster generation for access to film-stored dynamic elements for the synthetic display. The emphasis in the design of the scanner is on (1) providing high-speed random access to any pattern in the addressable transparency store matrix, (2) the scanning of the pattern in such a manner as to hold horizontal and vertical resolution constant, and (3) maximizing the beam utilization efficiency regardless of the size and shape of the scanned pattern. The scanner is designed for the scanning of 4-inch by 5-inch cut film, lantern slides, 2 1/4-inch by 3 1/4- inch cut film and double-frame, 35-mm slides in conjunction with a precision detent mechanism for accurate subject positioning. Optical magnification and demagnification of scanned subject material is available over a total range of 5-to-1.

The video generated by the diminutive, random access raster-scan format of the flying spot scanner is not usable for direct display on a closed-circuit TV monitor. It must be scan converted to the specified closed-circuit TV standard of 1203 lines/60 fields/ 2-to-1 interlace for display of instrument dynamics. The scan conversion system utilized is shown also in Figure 4.

The scan conversion system is capable of simultaneous recording and readout of dynamic pattern information through the use of two single-gun recording storage tubes. Read and write modes take place in different tubes alternately and independently, but in phase. The scan conversion system's modes and beam positioning are digitally controlled by the programable control unit. Display dynamics are attained in the scan converted output by the dynamic modification and positioning of the diminutive input rasters, which are updated at up to 15 cps to prevent motion breakup.

A portion of the static pattern film scanner is shown in the upper right hand corner of Figure 4. Shown is the vidicon film camera into which 35-mm random access slide projectors project through an optical multiplexer. The random access slide projectors are under the control of the programable control unit and can be controlled manually by either the test subject or an experiment controller. The drum slide holder has an average access time of 2 1/2 seconds between slides. The projectors can be sequenced digitally, however, with optical multiplexer shutter control so as to eliminate time lapses between slide changes. The two projectors are capable of holding ninety-six static patterns in random access storage.

As shown in Figure 4, the stored program control system is broken up into a digital portion and a hybrid portion. The design of the digital portion of this subsystem is based on the utilization of program storage in a random access magnetic core memory. The memory is sequentially scanned in a recirculating manner to produce the control sequence of digital words necessary for display generation. The manner in which the parallel memory word output is utilized for display system control is based on the one-address instruction type of coding format used in digital computers in which a portion of the digital word contains the operation code and another portion of the digital word contains the operand address. This coding format was selected on the grounds of machine simplicity and simplicity of coding.[13]

In addition to the memory, processing logic, and coded instruction tape readers, the digital portion of the stored program control system contains decoding logic for the selection of static patterns stored in the random access slide projectors. The hybrid portion of the stored program control system shown in Figure 4 contains(1) a digitally controlled raster generator for the scanning of dynamic patterns, (2) 4-channels of digital-to-analog conversion for scanner beam positioning to programed dynamic patterns and for scan converter beam positioning to programed display locations, (3) an analog signal multiplexer for sampling animation control signals from a flight dynamics analog computer, and (4) a raster modification and positioning unit for electronic animation of scanned dynamic patterns as they are being written into the scan converter.

A portion of the display console is shown in the foreground of Figure 4. This console houses remote controls for the display system, the video mixer, and closed-circuit TV monitors for the monitoring of static, dynamic, and composite display formats. Space is provided in the console for a future on-line compiler to facilitate programing which, while the system is being completed, is done directly in machine language.

Once the synthetic display generator is completed, a variety of closed-circuit TV display techniques may be used at remote simulator cockpit sites. Figure 5 shows several of the television display techniques which could be made available. At present the display system is not tied in with a fixed-base or dynamic simulator; therefore, the only display means of Figure 5 being employed is that of the TV kinescope display. Figure 6 illustrates the two basic techniques which could be employed to channel closed-circuit TV video to remote sites. Coaxial cable links are feasible at ranges of up to several miles. Microwave relay links could be used for more distant ranges and for airborne simulations of advanced control and display systems. Work at Langley Research Center[14] has shown that such airborne simulations are feasible using standard IRIG telemetry channels for the transmission of sensor and pilot control data for the simulated display system.

5.2 Programing and System Operation

The goal in programing the electronically animated synthetic display generator is to allow the flight control-display systems designer to proceed directly from his concepts in the form of cardboard mockups to simulated flight displays through the preparation of static pattern transparencies, a dynamic pattern transparency, programed punched tapes, and patch-board programs. The programing is thus composed of three phases - (1) technical illustration, (2) slide preparation, and (3) coded instruction and patchboard programing.

Technical illustration begins with a sketch of the desired instrument face or of the desired display formats (in the instance of a general-purpose, time-shared display). These sketches can be magnified or reduced and projected onto a drawing board by the equipment shown in Figure 7(a) for fabrication of cardboard mockups. To increase the speed of the operation short-cut drafting aids such as tapes, shading sheets, and stickon symbols are used wherever possible. Mockups are separated into a dynamic pattern mockup and multiple static pattern mockups as is shown in Figure 7(b).

Slide preparation begins with the photographing of the static pattern and dynamic pattern cardboard mockups using the Polaroid industrial view camera shown in Figure 8(a). High quality transparencies can be obtained within five minutes using Land projection film types 46L or 146L. The resulting dynamic pattern transparency (3 1/4 X 4 in. sized) is used directly in one of the flying spot scanner film holders shown in Figure 8(b). The static pattern transparencies produced must be punched for a precision requistration slide mount for 35 mm film scanning. The precision registration and punch equipment is shown in Figure 8(c) and the precision 35 mm television slide mount is shown in Figure 8(d).

The final step in programing, the preparation of patchboard programs and coded instructions, is effected by those equipments shown in Figures 9(a) and 9(b), respectively. The removable patch panel analog computer is shown in Figure 9(a) is programed for a simulation of flight dynamics. This 58-amplifier computer is suitable for small-scale simulations; however, for very complex problems a tie-in with a larger computer will be necessary.

The tape punch shown in Figure 9(b) prepares 4-level tapes using the keyboard and will be capable of preparing 8-level tapes with external electrical inputs from an on-line compiler. Thus, the instructions for the stored program control system are loaded into its memory from the punched tape in the form of 24-bit words composed of six 4-bit bytes or three 8-bit bytes.

The five basic types of control system information words utilized and the functions of each are illustrated in Figure 9(c). Programing of the synthetic display system is greatly symplified through the use of only these five basic types of information words. The first type of information word, as can be seen from Figure 9(c), is devoted to selection of static patterns from each of the two random access slide projectors. Since the static portion of any given display format is unchanging, this instruction word is programed only once for any given display. The remaining four instructions must be programed once for each dynamic element which is to be animated. The programer selects, with the first of these remaining four instructions, the size and shape of the raster for scanning a dynamic element or for erasure of dynamic elements stored on the scan conversion interface. He selects, with the second and third information words, the address of the dynamic element in film store and the display location for this dynamic element on the scan conversion interface, respectively. The final instruction listed in Figure 9(c) is the selection of an animation control channel and an animation function (or functions) for that channel.

Animation functions which are to be available in the completed system are the following: (1) horizontal and vertical translations of dynamic pattern pickup raster, (2) horizontal and vertical translation of dynamic pattern display raster, (3) separate or simultaneous magnification of horizontal and vertical size of dynamic pattern pickup or display raster, (4) rotation of dynamic pattern pickup or display raster, and (5) oscilloscope-mode character or symbol writing directly onto the scan conversion interface.

Special attention has been given in the design of the experimental synthetic display hardware to the providing of operational modes which would be required by the simulation researcher interested in exploring time-shared, general-purpose display formats (which could be computer-driven.) Consequently, the programmer has available the following time-shared operational modes:

(1) Pre-programed time-shared display - The display format may be changed automatically as the simulated mission progresses from phase to phase.

(2) Pilot adaptive time-shared siaplay - Test subject has manual control over dynamic display format through a programable pushbutton array.

(3) Machine adaptive time-shared display - Control system can automatically display control parameters exceeding thresholds or having alarming trends.

6. Performance Achieved to Date

It is felt that a graphic demonstration of system performance is shown by photographs and motion picture films of typical synthesized displays. At the time of preparation of this paper the only animation functions available for synthetic display generation were translational and oscilloscope mode dynamics. Additional animation functions are being incorporated and a motion picture film is being prepared in which the animation functions incorporated to date will be utilized in the generation of typical synthetic displays.

Figures 10(a), 10(b), and 10(c) show three types of vertical indicators synthetically generated using translational electronic animation dynamics. These displays were photographed directly from a display system monitor and show the static and dynamic portions of the composite display and the composite display produced by the video mixing of the static and dynamic video signals. These displays were synthesized from the dynamic pattern mockup and the three static pattern mockups shown in Figure 7(b). The displays shown are fully animated with no ambiguities or discontinuities. For instance, in the three-window vertical tape display the static pattern is seen to be a window with a lubber line. The dynamic pattern is a vertically oriented tape which appears to move up or down within the confines of the window according to the dynamics of a flight control parameter. Short-term stability (over a 1-hour period) for the dynamic elements of typical displays, such as those shown in Figures 10(a), 10(b), and 10(c), is such that changes in position are less than 0.5 percent of full-scale value.

System performance in the area of programing complexity is indicated by the program length, or number of digital words, required for the generation of specific displays. In the case of those displays shown in Figures 10(a), 10(b), 10(c), the program lengths are 36, 18, and 18 digital words, respectively. These program lengths are shorter than those required with conventional computer-CRT stylized displays, specifically, more than a factor of ten (10) shorter in the instance of the vertical tape display.[12] It is felt that the shorter program length of many displays will ease the burden on the programer.

The electronic animation technique, at this stage of its development, is not without its limitations. Resolution in the static portions of displays is quite good; however, resolution in the dynamic portions of displays requires some improvement. Some distortion is produced in dynamic portions of the display due to digital noise and a skewing of dynamic pickup rasters. Some flicker is evident in dynamic portions of the synthesized display due to the use of a two-tube scan conversion system. These limitations are in the process of being minimized. In addition, the capabilities for the synthesis of digital displays and displays having rotational dynamics are being incorporated.

7. Conclusions

The research and development required to implement the system described has established the feasibility of rapidly programing a portion of the displays generally encountered in simulation and presenting them at the display interface via closed-circuit television.

In addition, this work has developed a man-machine communications research tool providing for a systems engineering approach to flight display panel design through the programed synthesis of electronically animated flight displays. This research tool provides for the study of time-shared, general-purpose display concepts through its basic time-shared control modes.

A new concept has been investigated and proven feasible - that of electronic animation. The advantages which this concept can have in terms of programing complexity, display format changeability, and image quality for synthetic flight display generation in simulators have been pointed out.

In addition, electronic animation may have potential as an avoinics display technique, either for simulation utilizing a ground-to-air microwave link or for self-contained general-purpose, computer-generated display. The stored program generation technique lends itself nicely to interlacing the display program with the control and arithmetic sequences of a central avonics computer, since so few digital words are required. Electronically animated TV displays are seen as a special advantage in a space vehicle such as a large space station, which would require integrated displays at multiple locations throughout the vehicle. However, much work remains to be done both from a hardware and a human factor's standpoint, before a specific system design could be recommended.

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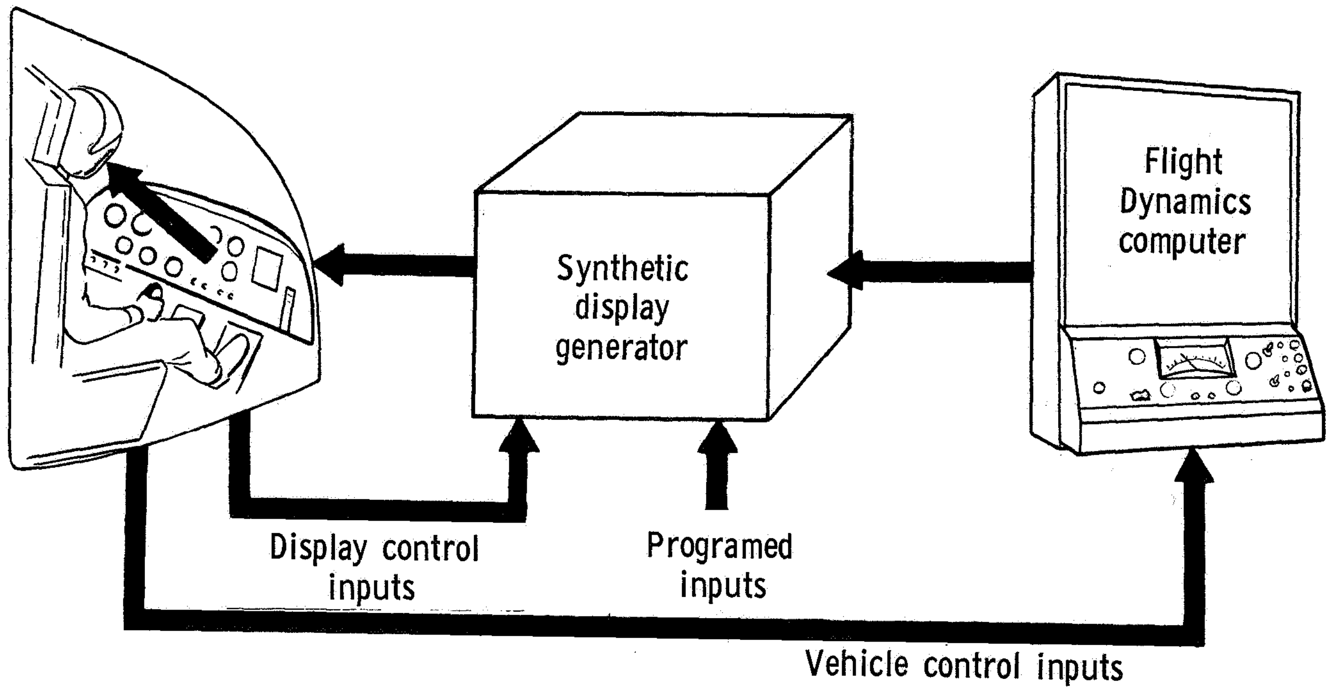


Figure 1.- Pictorial diagram showing simulator signal flow using programed synthetic display generation.

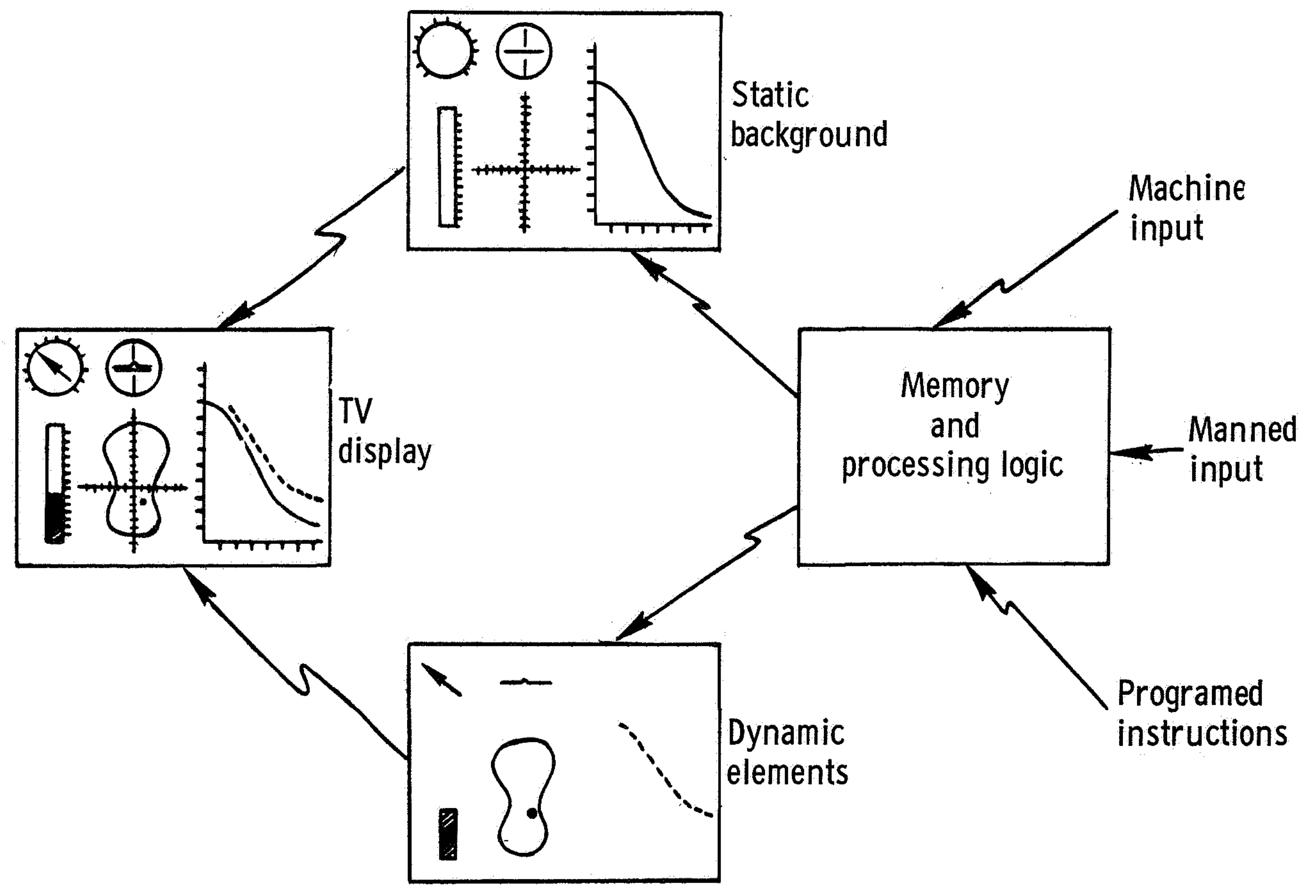


Figure 2.- Display synthesis principle - electronic animation.

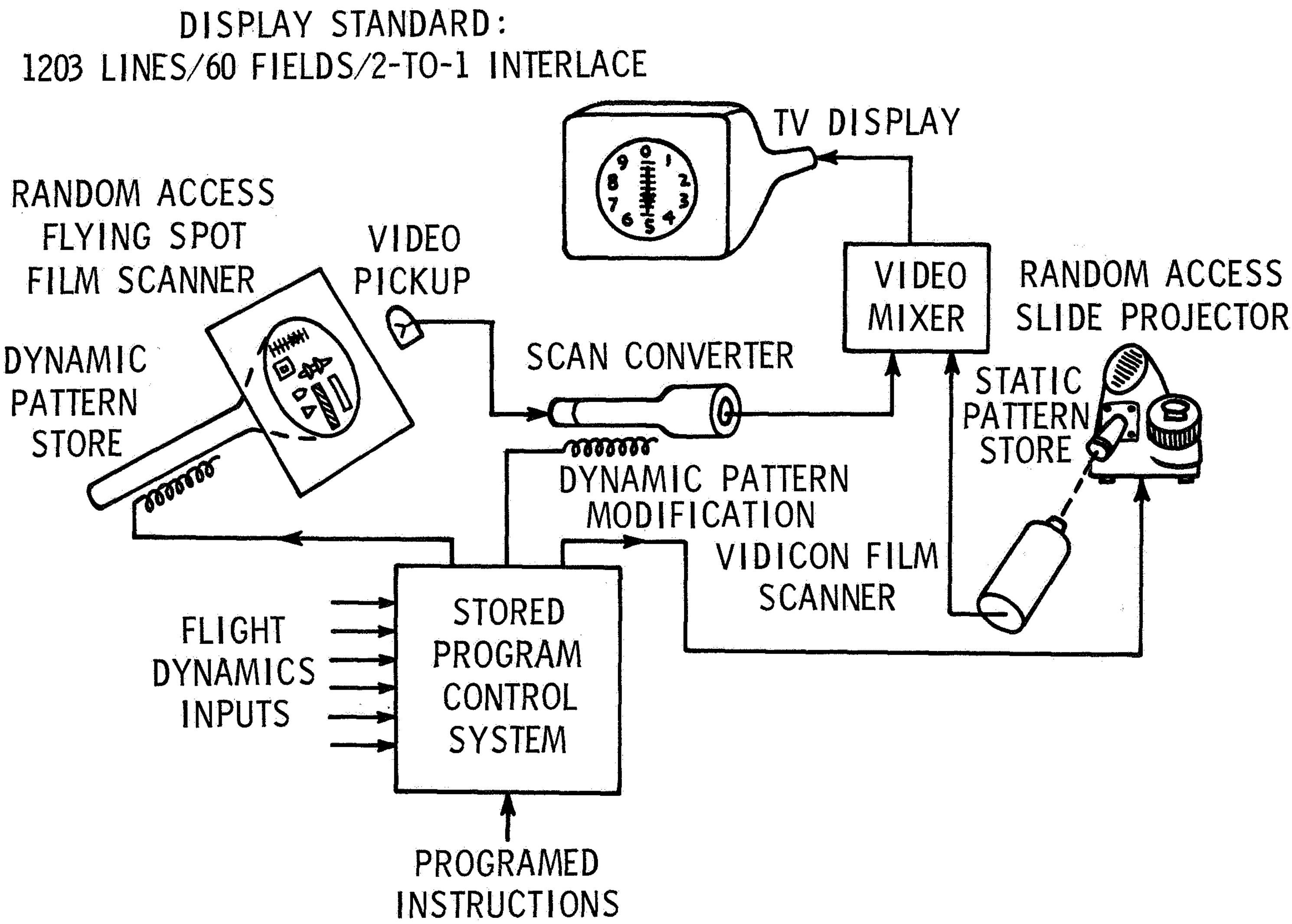


Figure 3.- Conceptual system diagram showing basic components required for electronic animation.

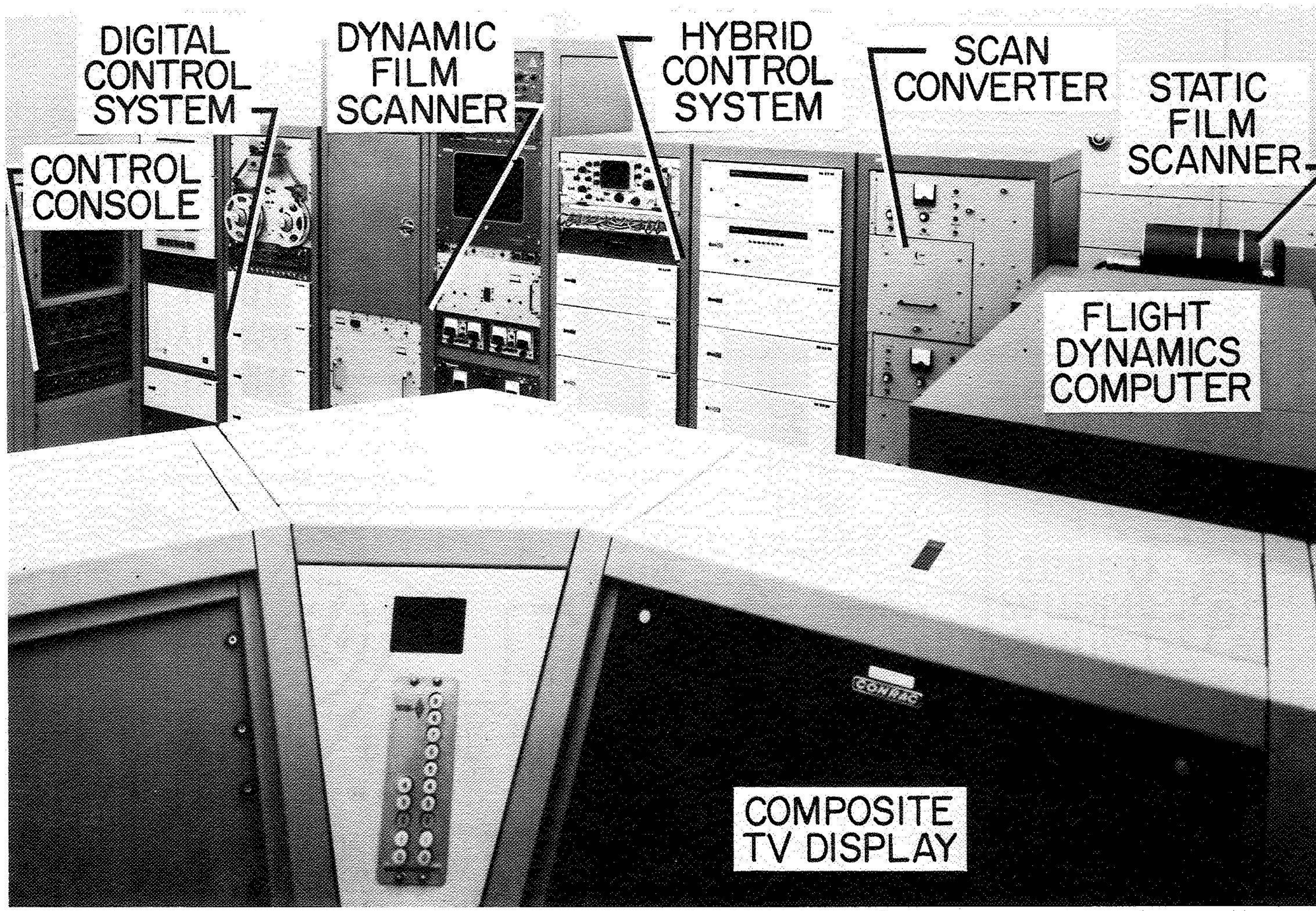


Figure 4.- Experimental synthetic flight display generation equipments showing all major components.

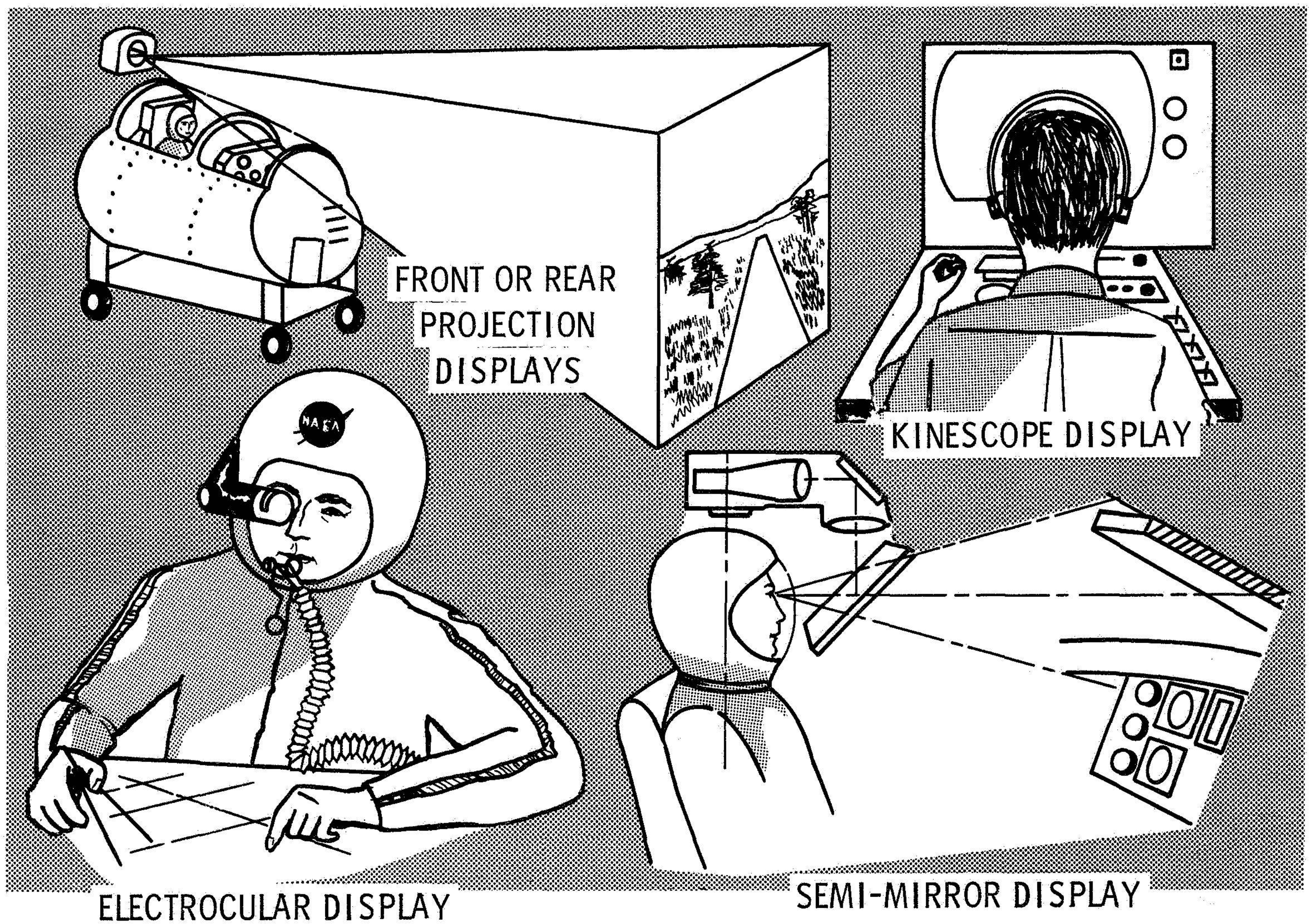


Figure 5.- Several closed circuit television display techniques.

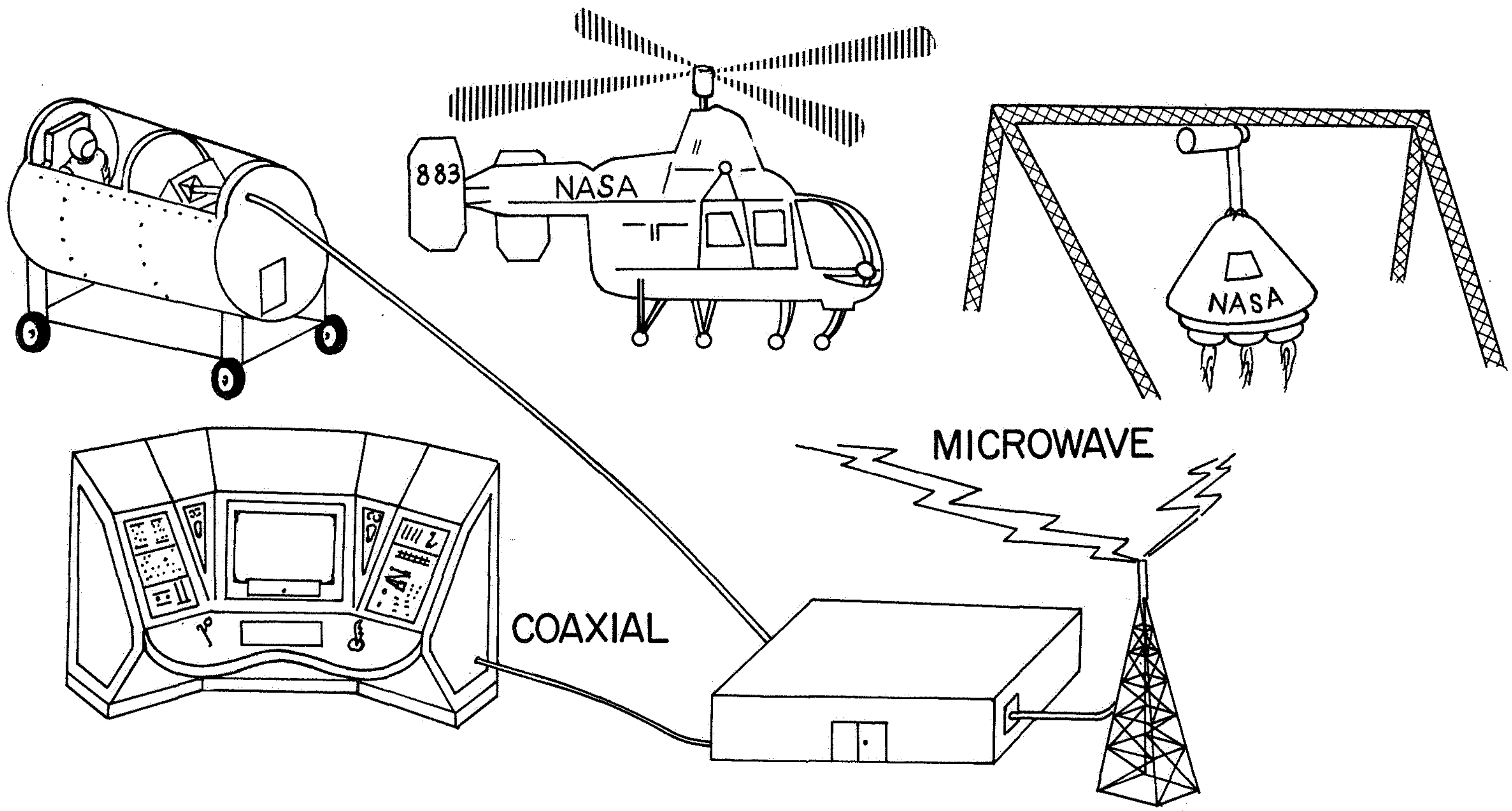


Figure 6.- Pictorial illustration of TV distribution techniques for providing synthetic flight displays to remote dynamic or fixed-base simulators.

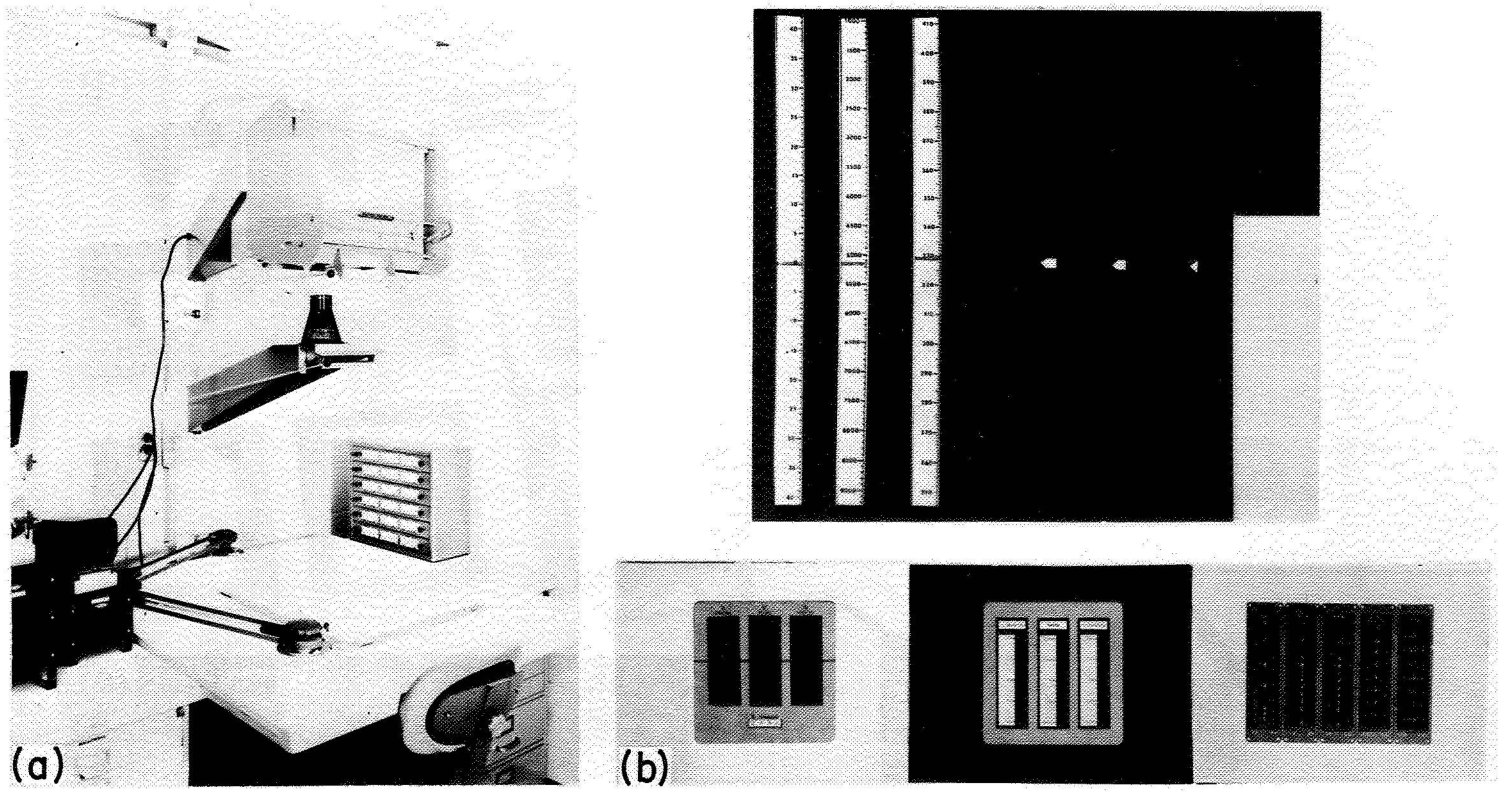


Figure 7.- Instrument mockup preparation showing: (a) technical illustration aid and (b) typical dynamic and static patterns fabricated.

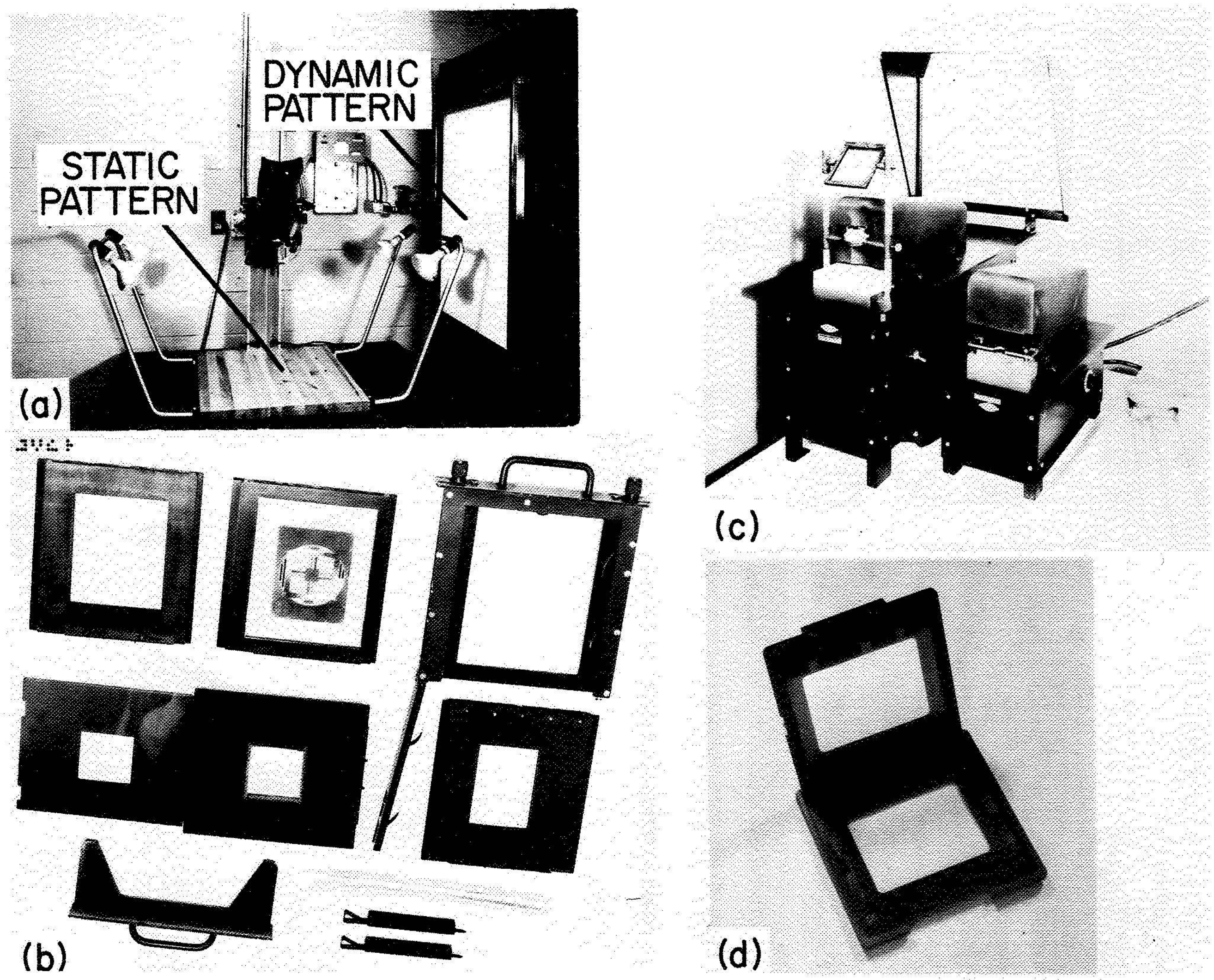
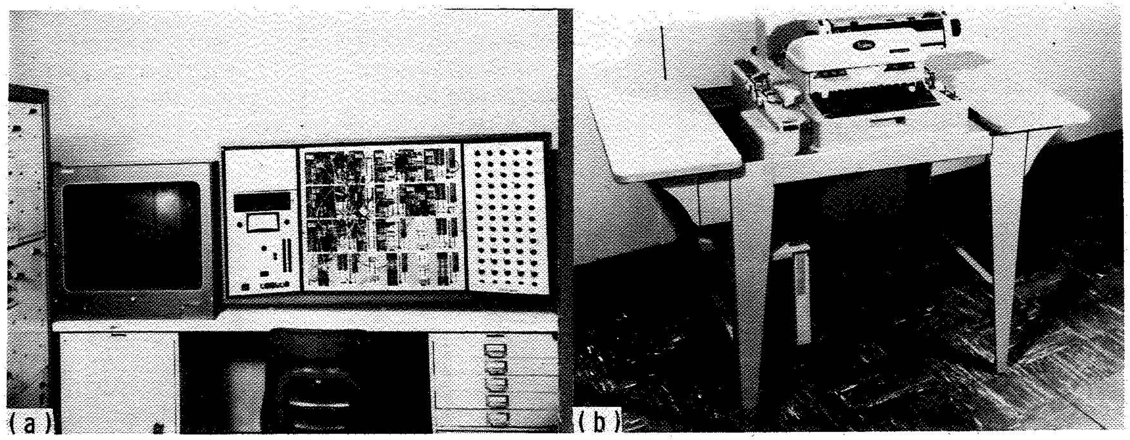


Figure 8.- Transparency preparation equipments showing: (a) Industrial view copy camera, (b) Dynamic pattern film holders, (c) Precision TV slide registration unit and punch, and (d) Precision 35mm television slide mount.



FLIGHT DYNAMICS COMPUTER

KEYBOARD TAPE PUNCH

SUBSYSTEM BEING ADDRESSED	INFORMATION BIT NUMBERS 0 1 2 3 4 5 6 7 8 9	INFORMATION BIT NUMBERS 10 11 12 13 14 15 16 17 18 19	CONTROL 20 21 22 23
STATIC PATTERN SELECTION	PROJECTOR A CODE	PROJECTOR B CODE	0 1 0 0
DYNAMIC RASTER SELECTION	SIZE AND SHAPE CODE	WRITE OR ERASE CODE	1 0 0 0
DYNAMIC PATTERN SELECTION	X ADDRESS CODE	Y ADDRESS CODE	0 0 0 1
DYNAMIC PATTERN DISPLAY LOCATION	X ADDRESS CODE	Y ADDRESS CODE	0 0 1 0
ANIMATION CONTROL SELECTION	CONTROL CHANNEL CODE	ANIMATION FUNCTION CODE	1 0 0 1

(c)

PROGRAMED INSTRUMENTATION FORMAT

Figure 9.- Programed instruction preparation equipments showing: (a) Flight dynamics analog simulation computer, (b) Keyboard tape punch, and (c) coding format.

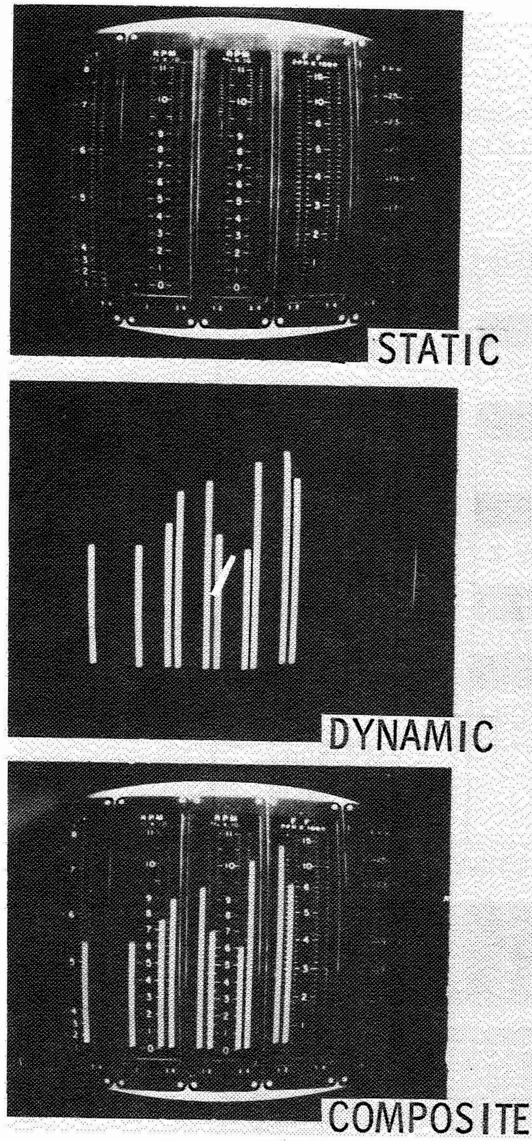


Figure 10(a).- Dynamic vertical bar indicator display photographed directly from 21-inch monitor showing static, dynamic, and composite pictures.

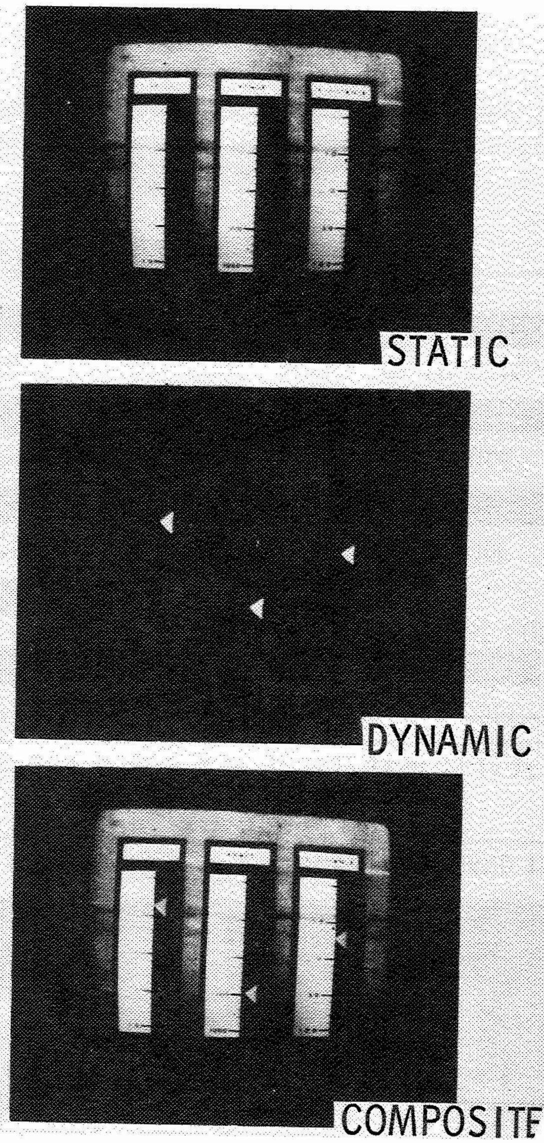


Figure 10(b).- Dynamic vertical pointer indicator display photographed directly from 21-inch monitor showing static, dynamic, and composite pictures.

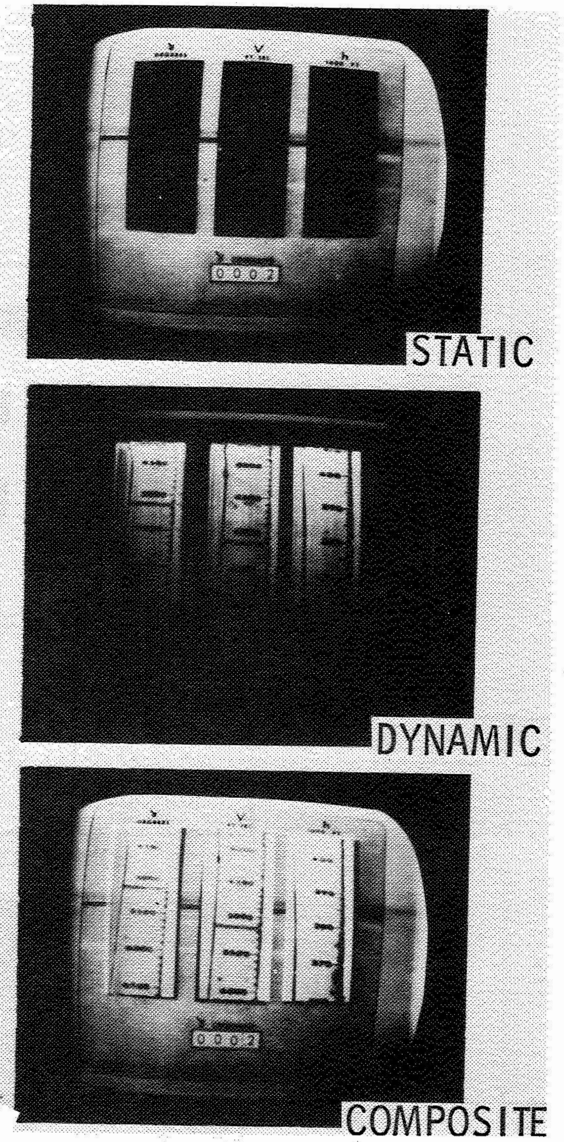


Figure 10(c).- Dynamic vertical tape indicator display photographed directly from 21-inch monitor showing static, dynamic, and composite pictures.

NASA-Langley, 1967