General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

CR-115743

ELECTRONICS LABORATORY • SYRACUSE, N.Y.

Final Report

ELECTRONIC SCENE GENERATOR EXPANSION SYSTEM

December 1971

Contract No. NAS 9-11065

Prepared for

MANNED SPACECRAFT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HOUSTON, TEXAS

RECEIVED AUG 1972 NASA STI FACILITY INPUT BRANCH

(NASA-CR-115743) ELECTRONIC SCENE GENERATOR EXPANSION SYSTEM Final Report W.H. Sharp (General Electric Co.) Dec. 1971 26 p CSCL 09E N72-28232 Unclas G3/09 37589

GENERAL ELECTRIC

Final Report

ELECTRONIC SCENE GENERATOR EXPANSION SYSTEM

by

W. H. Sharp

Electronics Laboratory
General Electric Company
Syracuse, New York

December 1971

Contract No. NAS 9-11065

Prepared for

MANNED SPACECRAFT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HOUSTON, TEXAS

Prepared by

Electronics Laboratory
General Electric Company
Syracuse, New York

ABSTRACT

This is the final report submitted in accordance with the provisions of Contract NAS 9-11065, Electronic Scene Generator Expansion System.

The program encompassed the design, fabrication, and installation of additions, and modifications to the Electronic Scene Generator located at the NASA Manned Spacecraft Center, Houston, Texas. The equipment delivered on this contract was incorporated into the Electronic Scene Generator to enhance its capabilities by providing:

1) Additional source computer interfaces
2) Additional edges thereby allowing more detailed scenes
3) The ability to share edges to effect economies in complex scenes
4) The ability to use edges without the constraints of a configuration catalog
5) The simplified implementation of new environments and environment modifications.

This report contains a summary of the Contract effort and a description of the delivered equipment.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

The Electronic Scene Generator (ESG) in the Guidance and Control Division at the NASA Manned Spacecraft Center in Houston, Texas, provides scenes for out-the-window views for engineering simulation studies. The Scene Generator Expansion System delivered to NASA on Contract NAS 9-11065 was incorporated into the ESG to enhance its capabilities by providing:

1) Additional source computer interfaces
2) Additional edges, thereby allowing more detailed scenes
3) The ability to share edges to effect economies in complex scenes
4) The ability to use edges without the constraints of a configuration catalog
5) The simplified implementation of new environments and environment modifications.

The effort on this program was divided into two parallel, independent tasks, the Input Expansion effort and the Scene Generator Expansion effort. The Input Expansion effort, conducted as a six-month program, resulted in one item of delivered equipment, the Input Expansion Unit, and its associated software. This effort was completed in December 1970 and documented in the final report titled Expansion of Input Capability for Electronic Scene Generator. For further information on the Input Expansion Unit refer to this document. The Scene Generator Expansion effort, conducted as an eighteen month effort, resulted in one item of delivered hardware, the Edge Processor Unit (EPU), and its associated software. The EPU replaced the two Object Generator Units supplied on Contract NAS 9-3916. The expanded Scene Generator System is shown in Figure 1. The software development effort on the program was divided into two parts, the Offline software and the Online software. The Offline software used for preprocessing the environment data was generated by Lockheed personnel resident at the NASA Manned Spacecraft Center, Houston, Texas, under the direction of General Electric personnel. The Online programs used for real-time operation of the ESG were generated by General Electric personnel. The EPU and associated software were delivered and installed in the Guidance and Control Division at the NASA Manned Spacecraft Center in Houston, Texas, in November, 1971.

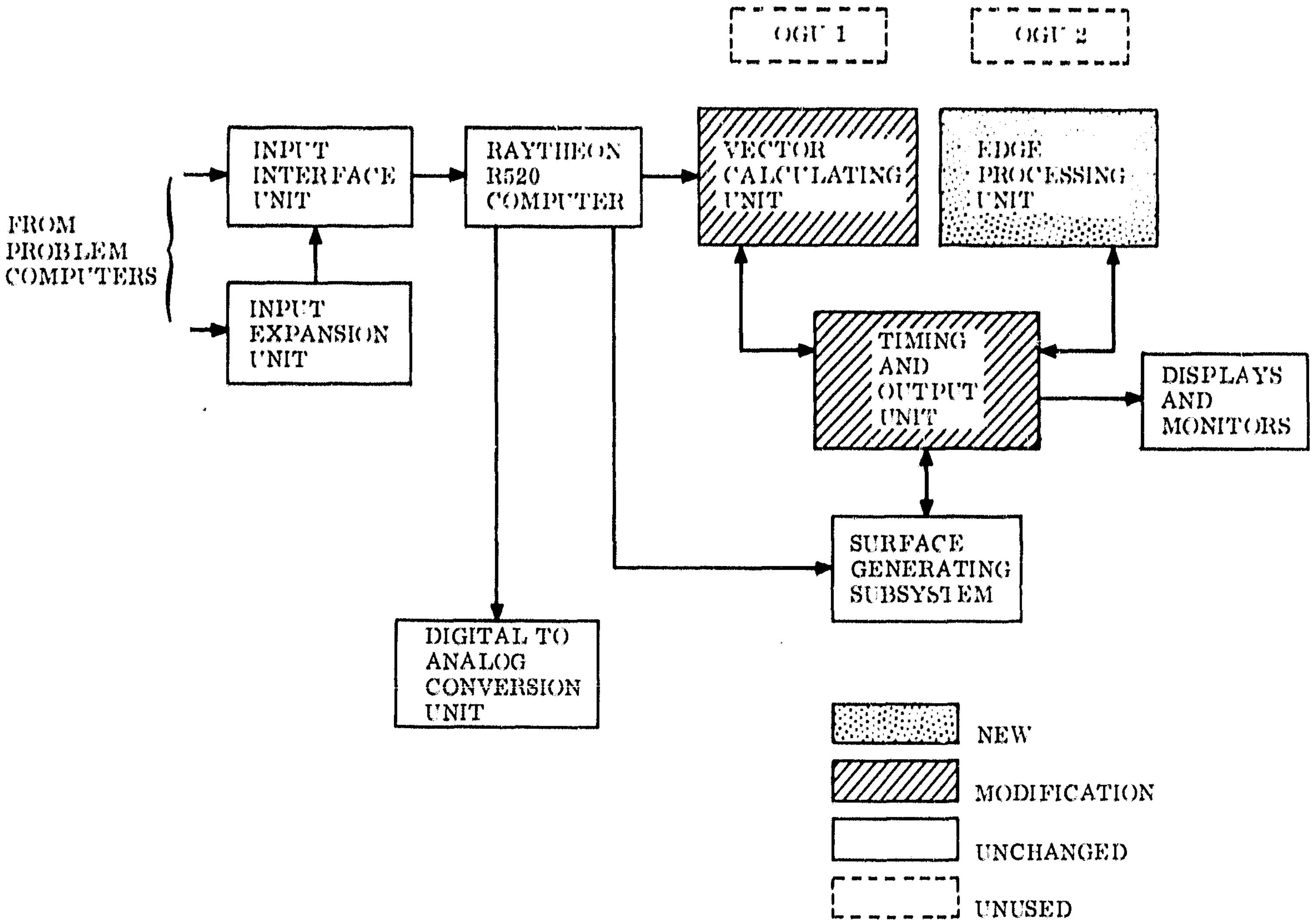

Figure 1. Expanded Scene Generator System

2. BACKGROUND

The Electronic Scene Generator built for NASA by the Electronics Laboratory of the General Electric Company on Contracts NAS 9-3916 and NAS 9-1375 is an electronic system that simulates the external visual environment of a space vehicle. The equipment generates textured surfaces, three-dimensional objects, and certain other special pictorial effects such as horizon dip and curvature, a moving vehicle's shadow, and a point-source flashing beacon. The interface capability allows communication with up to five source computers furnishing attitude and position data for multivehicle studies or for several studies run simultaneously.

Digital descriptions of the location, size, shape, and color of objects used to simulate the visual environment are stored in the ESG. Inputs to the equipment from the source computers describe the attitude of from one to three observers in the environment, and perspective transformations are performed at the frame rate of the kinescope displays to present each observer with his correct perspective view of the simulated environment. For further details of this system, see the Final Report for Contract NAS 9-3916, Modifications to Interim Visual Spaceflight Simulator.

3. SCENE GENERATOR EXPANSION SYSTEM

3.1 System Specifications

The expansion of the capabilities of the Electronic Scene Generator is implemented primarily by the Edge Processing Unit (EPU). The EPU is capable of generating color video scenes, once every display frame time (1/20th second), containing the following scene content:

Edges:	320
Edge References:	768
Faces:	192 active faces per raster line
	256 entries in face list
Views:	5 (faces assignable to views in blocks of 16)
Color Information:	256 discrete color memory addresses per view

The peripheral hardware in the Electronic Scene Generator (Raytheon 520, Vector Calculating Unit, Timing and Output Unit, etc.) is not capable of supporting full utilization of the EPU; the EPU is therefore restricted to scenes containing the following content:

Edges:	320
Edge References:	768
Faces:	192 composed of up to 20 edges per face
Views:	3 (faces assignable to views in blocks of 16)
Color Information:	13 discrete color memory addresses per view

3.2 Major Technical Changes in Scene Generator Expansion System

3.2.1 General

The Scene Generation Expansion System (hereafter called the NASA III system) is based on essentially the same algorithms used in the system delivered on Contract NAS 9-3916 (called the NASA II system). For details, see Volume I, Instruction Manual for Modifications to Interim Visual Spaceflight Simulator. In three areas, however, significant changes have been made. The first of these is the use of list priority rather than matrix priority. Second, the architecture of the NASA III system allows the sharing of edges. Finally, the concept of Start/Stop numbers has been used to reduce the requirement for video rate hardware. These changes are described in paragraphs 3.2.2, 3.2.3 and 3.2.4, following.

3.2.2 List Priority

The edge processing techniques used in the Scene Generation Expansion System are based on a solution of the hidden face problem referred to as List Priority. The solution requires that the environment be structured so that, for any given view of it, the faces may be ranked from highest to lowest priority. List priority is not quite as general as priority implemented by the previous matrix technique, and there are some situations (rarely encountered in practical problems), that cannot be handled by the list approach. On the other hand, the list approach, which deals with faces, can often handle situations that a matrix, dealing with complete objects, cannot. One example of this is an object within an object. If the smaller object is completely within the larger, list priority allows the outside faces of the outer object to have priority over the inside object, as well as over its own inside faces. The inside object's faces are given priority over the inside faces of the outer object, and priority is correct. The matrix solution used previously did not differentiate between the inside and outside faces of the larger object and could not solve the problem. The principal advantage to list priority is that image-generation hardware can be expanded indefinitely without a square-law growth of either hardware or computing time.

List priority makes use of planes to separate clusters of faces, much the same as the matrix approach. Clusters are defined as groups of faces whose order of priority is always the same. A convex object would be a cluster, since its outside faces can never conflict with each other, and, if inside faces are used, they always have lower priority than outside faces. The rule for an environment to be suitable for list priority is that every subset of three clusters must be separable by two planes. Stated in another way, each cluster is to be separated from any other cluster by one plane, and the total number of separating planes will be at most one less than the number of clusters.

Although clusters and separating planes must be chosen by the environment designer, experience with this approach indicates that it is easier and less subject to designer's errors than the matrix approach.

3.2.3 Edge Sharing

The capabilities of the Scene Generator Expansion System cannot be compared with the present system solely on the basis of the number of edges. The new edge-processing techniques provide edges that are more powerful and offer the potential for greater scene detail per edge. The relative value of new and old edges depends entirely on the geometric arrangement of the environment model. Therefore, any evaluation of the equivalent capacities of the two systems must consider their differences, and, to be concrete, must reference specific applications. The following paragraphs discuss the mechanisms by which improvement is attained and illustrate the relative merits of the two systems with examples.

The expanded scene generator employs edge-processing hardware capable of 320 edges. These edges may be used to form convex planar polygons (faces) employing up to 20 sides. Faces, in turn, may be geometrically arranged in space to form three-dimensional objects subject only to the restriction that they be non-intersecting and amenable to priority-list processing (see Section 3.2.2).

The fact that faces and objects can now be formed at the discretion of the environment designer to meet the needs of the model is an important advantage of the new system and contrasts with the former requirement to make the model from a limited number of basic shapes and to conform to bin-configuration rules necessitated by the physical partitioning of the hardware into 24 edge groups called bins. Clearly, modeling is simplified and more efficient. Compound objects, either convex or concave, can be modeled directly without the duplication of edges and faces that results in the NASA II system when simple solids are combined. The selection of one object type does not influence the choice of others as it does in the NASA II system with bin constraints; a change to one part of a model does not propagate to other parts, and one is not faced with the problem of substituting complex shapes for simpler ones because the latter are not available.

The new edge-processing techniques permit the sharing of edges, so that a single edge can participate in a number of faces, not only within an object but on other objects as well. Edge sharing makes use of the fact that the machine representation of an environment edge is infinite in length and not limited by its defining vertex pair. Figures 2 and 3 show how sharing can be used to advantage, to make both plane figures and solids.

The planars in Figure 2 are being used for runway threshold markings, while edges 1 and 2 serve to bound the five faces on the top and bottom, respectively. A total of 12 edges is needed, whereas the same five faces constructed with P4 objects would require 20 edges. Moreover, if the P4 objects could not be obtained in conjunction with other bin objects, four of the faces would require the use of a 24-edge bin and the total would be 28 edges.

Figure 3 shows one edge participating in six faces of a group of objects. Seven other edges participate in three or more faces and the total edge count is 32. Implementing the objects with four S12s requires 48 edges. Note that several edges are saved at the joining faces of the compound object.

The ability to share edges introduces the requirement for another parameter that helps to define system capability — edge references. The number of edge references considers each edge and the number of times it is used in faces. It is found simply by summing the number of edges in every face in the environment. The objects of Figure 3 require 80 edge references, assuming that each has one bottom face. If these objects were to be placed on the ground, the bottom faces would be unnecessary and they would require 72 edge references. The EPU will provide for 768 edge references, thus allowing an average sharing ratio of about 2.5:1.

The amount of sharing needed is a function of the type of environment. Isolated planars may allow no sharing, simple solids require about two references per edge, and compound objects use more. An extreme example of sharing is shown in Figure 4, where edges are used to construct texture patterns. The photograph shows a plan view of an area approximately 15 by 20 miles, which uses about 50 edges and 400 references. The sharing ratio for this system was selected to allow the generation of a texture pattern of about one-half the complexity shown when used in conjunction with more conventional planar and three-dimensional detail.

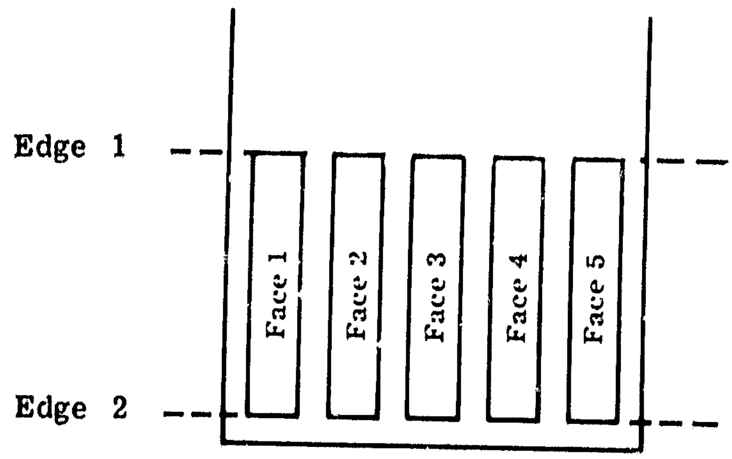

Figure 2. Edge-Sharing – Planar Features

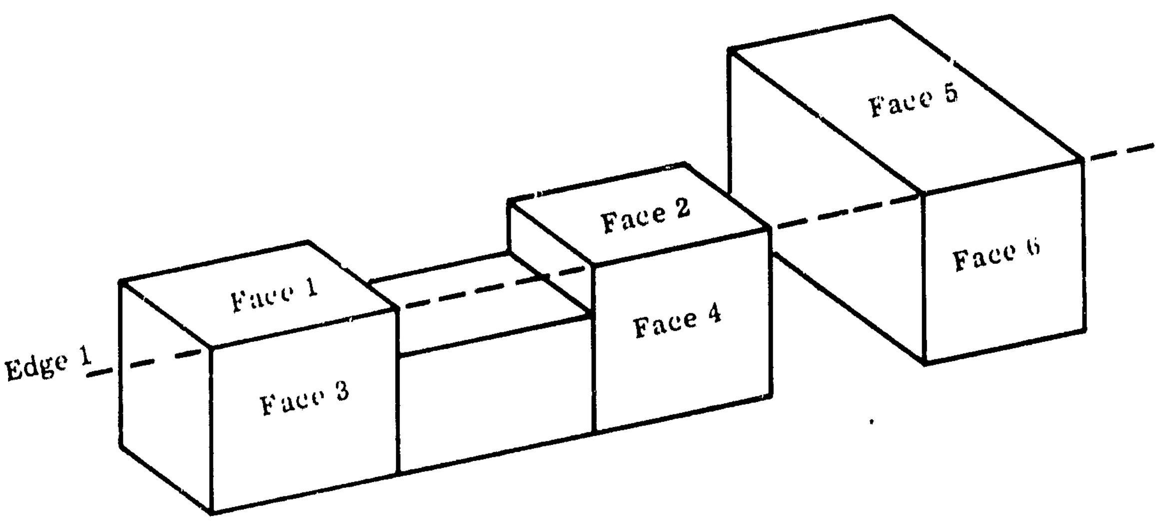

Figure 3. Edge-Sharing – Objects

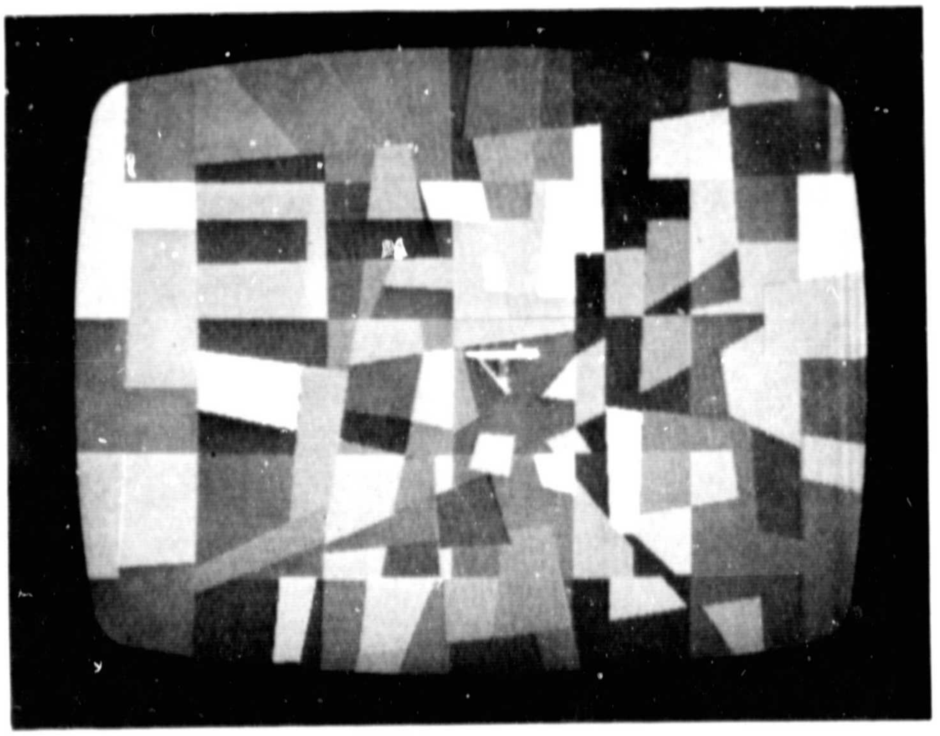

Figure 4. Edge-generated Texture
(Photo # 123169-5-A)

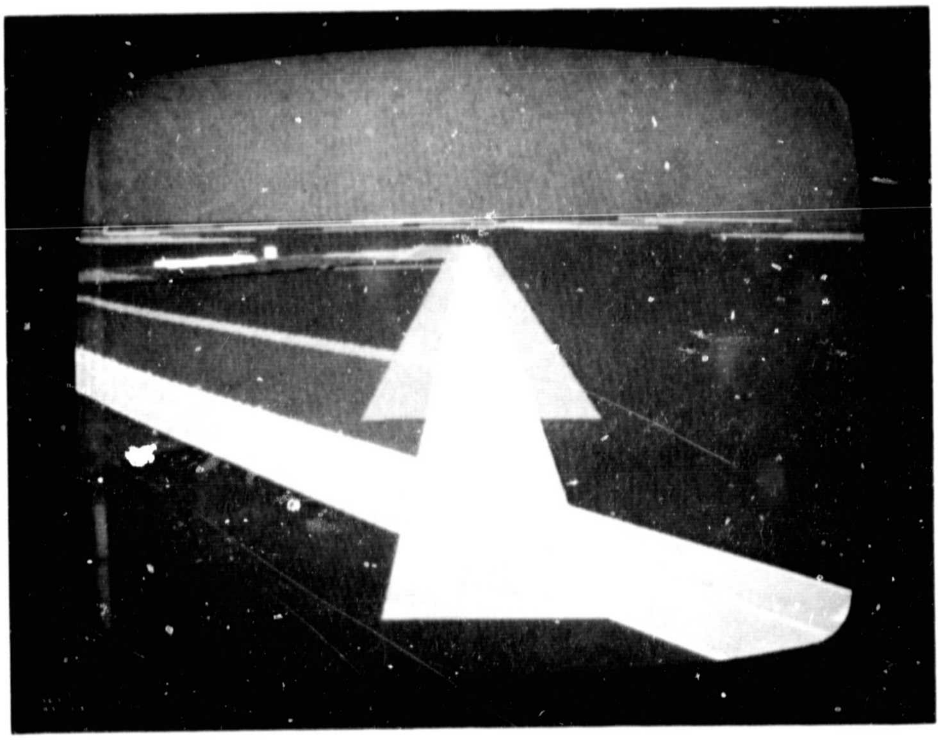

Figure 5. Basic Instrument Runway
(Photo # 123169-5-F)

An example will illustrate what might be achieved with the new system and its equivalent complexity in terms of existing capability. The example will consider the environment models for three independent problems; an airport, a space shuttle, and a section of a space base. Approximately 100 edges are devoted to each model.

The airport consists of a 10,000-ft. runway, a taxiway and ramp area, a tower, and a hangar. The runway has basic instrument markings, as shown for runway 32 in Figure 5, except that the numerals are omitted and the centerline extends for only 2000 feet (nine sections). These features would require 71 edges with the proposed system, rather than 120. The difference is due, in part, to the extensive use of quadrilateral faces. Additionally, 26 edges are devoted to background texture generation over a 20-by-20 mile area. These edges are not included in the comparison because they have no meaningful equivalent. The effectiveness ratio of new edges to old edges is 120/71 or 1.7:1.

The space shuttle model includes a fuselage formed with two S18s and wings and horizontal stabilizers made with S12s. Two S6s and three P8s make up the remaining detail. A total of 102 edges is required to make this model, instead of 120.

The space base consists of one central hub modeled with an S24, four symmetrically placed arms (S12s), and four symmetrical outer modules modeled with S18s. By virtue of the symmetry involved, this 144-edge scene could be implemented with 116 edges.

Table I summarizes the results of this example. The three environments, modeled with the full capability of the proposed system, are the equivalent of 384 edges plus the surface texture pattern.

TABLE I

CAPABILITY COMPARISON

ENVIRONMENT	NASA II EDGES	NEW EDGES	EDGE REFERENCES
Airport	120	71 (96)	118 (280)
Space Shuttle	120	102	256
Space Base	144	116	210
TOTAL	384	289 (315)	584 (746)
		( ) includes edge texture	

In addition to the number of edges and the number of edge references, one other parameter must be specified to fix the system capability — the number of faces. The number of faces is the number of separate convex planar polygons defined by edges. This does not include the multitude of regions (convex or concave) that may be formed by overlaying faces of different priority, such as in ground texture. Faces are one-sided, so that a so-called solid object will normally have no inside faces. If inside faces are desired, they are specified as separate faces and require additional edge references, but not edges. An inside face uses the same edges as the outside face, but references them in the reverse order.

In summary, the capabilities of the expanded system are:

Edges:	320
Edge References:	768
Faces:	192

3.2.4 Start-Stop Implementation

In the NASA II system, the intersection of every edge with the raster is generated at the video rate. In the NASA III system, only the bounding edge intersections of the face are generated at the element rate. The bounding element numbers are referred to as Start and Stop numbers, which correspond, respectively, to the lowest and highest element numbers occupied by the face.

The Start and Stop numbers are determined by specifying the bounding edges of the face as being either Start or Stop edges, and then selecting the appropriate edge intercepts that define the extremities of the face. Figure 6 shows a face bounded by four edges. In this case, edges 1 and 4 are Start edges and edges 2 and 3 are Stop edges. On any given raster line (line q for example), the face (if it appears) will be bounded on the left by one of the Start edges and on the right by one of the Stop edges. The selection of the bounding edges is accomplished by (1) comparing all the Start intersections, selecting the largest one, and (2) by comparing all the Stop intersections, selecting the smallest one. On line q in Figure 6, for example, the bounding Start and Stop edges will be edges 1 and 3. The selected Start and Stop numbers are stored for use by the face generation section during the next raster line. If the face does not appear on the present raster line, the largest Start number will be greater than the smallest Stop number, and the numbers are not stored. This is the case for line k, Figure 6.

During the next active raster line, the two numbers are decremented at the video rate (in the EPU the ones complements of the numbers are incremented but the result is the same). The face is active from the time the Start count reaches zero until the Stop count reaches zero. The priority network determines which of the current active faces should be displayed.

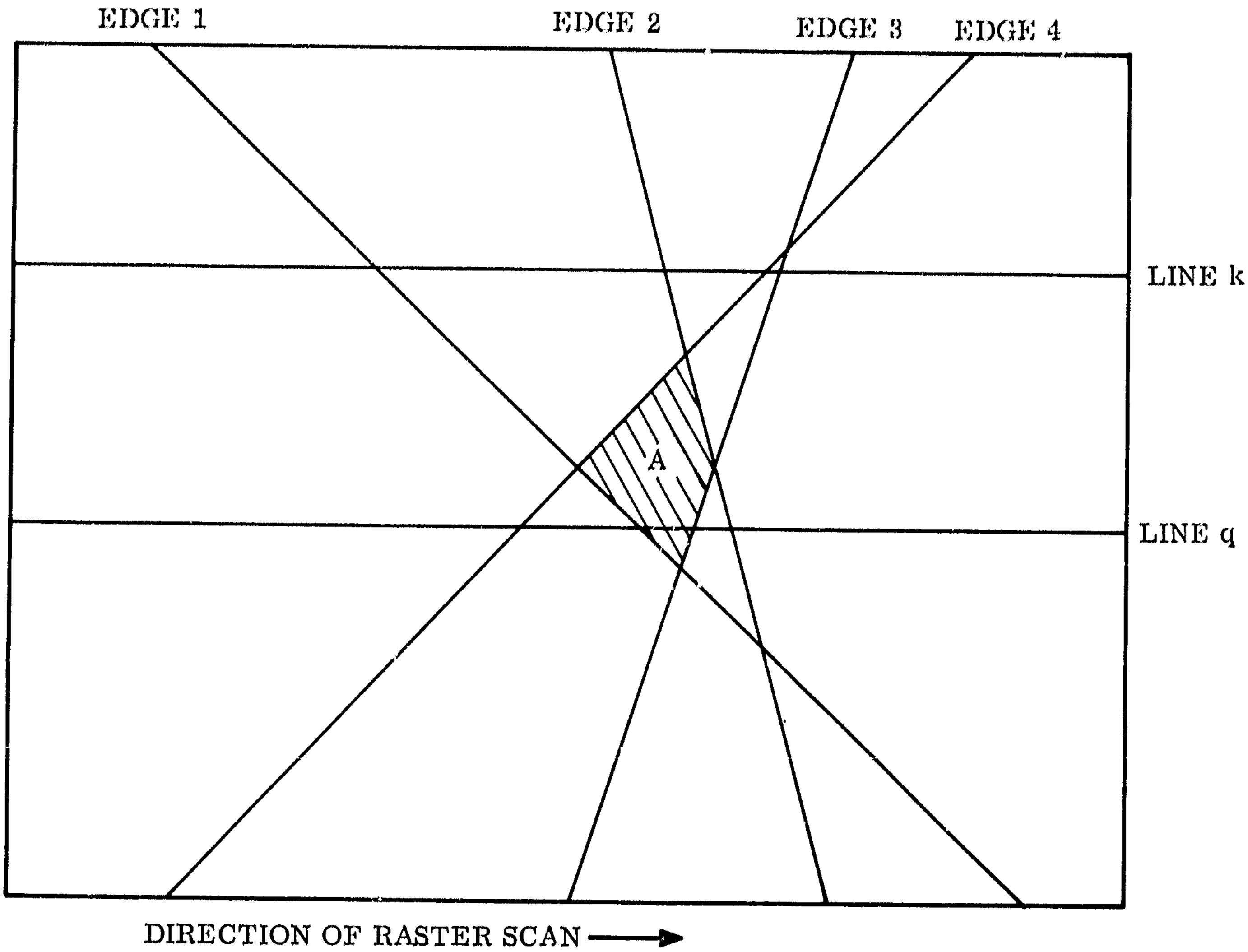

Figure 6. Face Formation

4. EDGE PROCESSOR UNIT DESCRIPTION

4.1 General

Computations made by the Edge Processor Unit during the active frame time consist of a series of sequential processing steps or cycles. The basic processing time unit is a raster line-time and the several tasks required to form a complete raster line of video are performed in successive line-time operations. Three main tasks are performed in generating the video data. They are:

1) Edge Update - Find for each raster line the distance in elements from the left side of the picture to the intersection of each edge with the raster line.

2) Face Determination - Find for each raster line the edges which bound the intersection of each face with the raster line.

3) Face Generation, Selection, and View Display Assignment - Generate for each raster line the faces intersecting the line and select the highest priority face for each view. Then assign each view to the correct display.

4.2 Implementation

The block diagram for the Edge Processor Unit (EPU) is shown in Figure 7. Each functional unit is contained on one motherboard. All input data from the Scene Generator Vector Calculator Unit are transferred through the Timing and Output Unit and received in the Frame Buffer Unit (FBU). All synchronizing timing signals are sent from the TOU to the General Timing Unit (GTU). All output data from the EPU are transmitted from the Priority View Assignment Unit (PVU) to the TOU.

The Frame Buffer Unit (FBU) provides the input data interface for the EPU. The data for the EPU are transferred serially from the TOU, converted to a parallel format, and transferred to the appropriate unit within the EPU. The destination within the EPU is determined by a steering field code from the VCU. Four distinct data transfers are accomplished through the FBU. The Edge Sequence List, which is loaded as part of the environment setup, is transferred from the VCU through the FBU to the List Sequencing Unit. During system operation, the edge quantities (A's and B's) are transferred into the FBU during the early part of vertical blank time and are temporarily stored in buffers within the FBU. When all 320 A's and B's have been received, they are transferred to the two Edge Update Units. Also during vertical blank time, the List Sequencing Unit is loaded with the Face List. The final transfer through the FBU during vertical blank time is the Display Assignment Word, which is transferred through the FBU to the Line Buffer Unit.

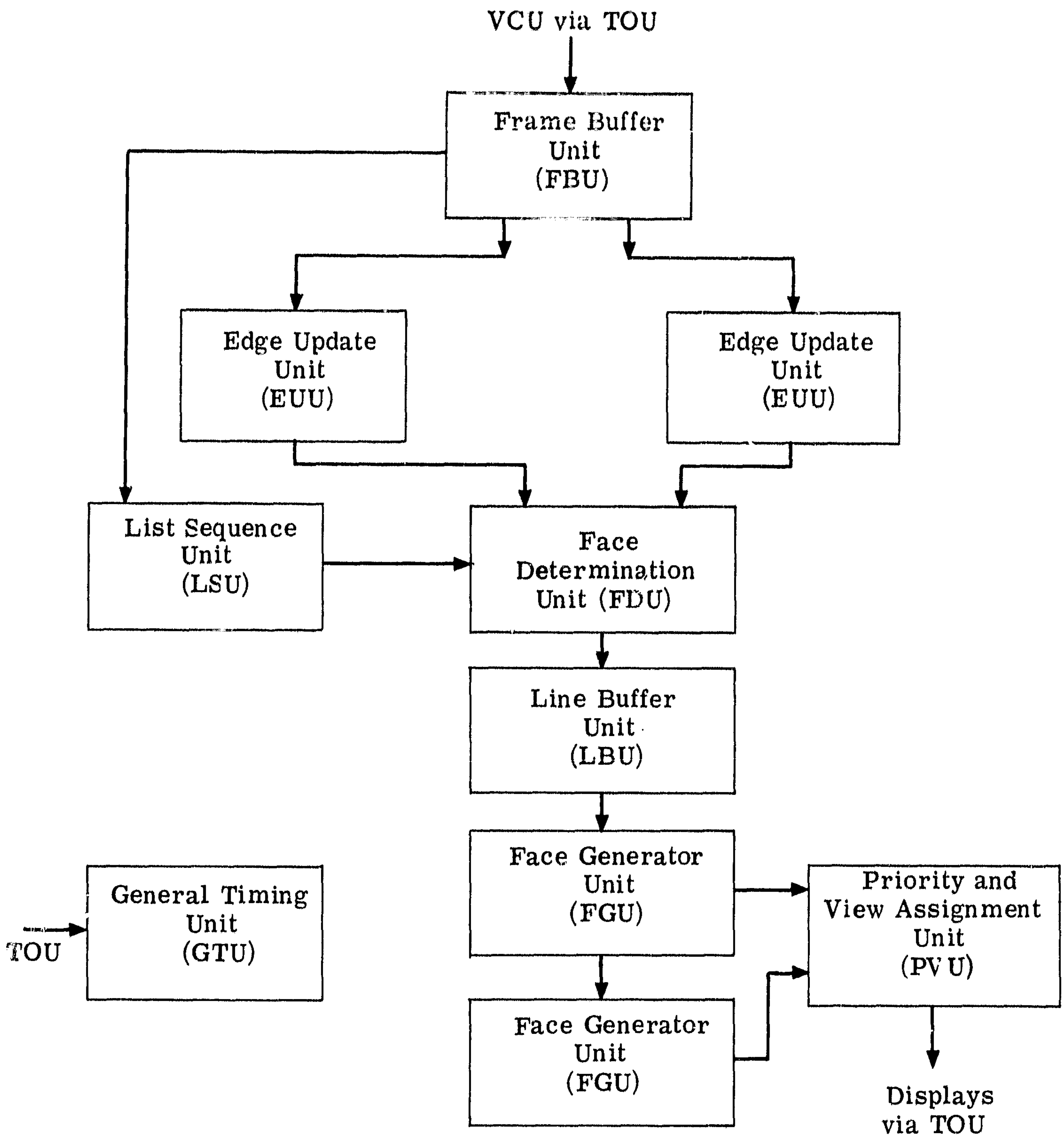

Figure 7. Edge Processing Unit (EPU) System Block Diagram

Each Edge Update Unit (EUU) performs the A plus B operation for 160 edges. The A and B quantities are loaded into the EUU's during even field vertical blank time. When the computation cycle starts, the B's are added to the A's once every line time. The accumulating A's are examined for numbers off the display, saturated to all zeroes or ones if appropriate, and transferred to the Face Determination Unit. Each EUU contains field buffer memories, which are used to refresh the A quantities during odd field vertical blank time.

The List Sequencing Unit (LSU) generates a list of addresses of edges every line time for use in the Face Determination Unit. The addresses refer to the locations of the edge quantities in the buffers in the Face Determination Unit. The addresses are grouped by face, ordered by faces in priority order, and grouped by view in that ascending order. The LSU generates this list every line time, using two lists, the Edge Sequence List and the Face List. The Edge Sequence List contains the face-grouped addresses. The Face List contains a view-grouped, priority-ordered list of starting addresses in the Edge Sequence List. The Face List also contains the color code and view assignment of each face. These quantities are buffered temporarily and then transferred to the Line Buffer Unit. Both Edge Sequence List and Face List are loaded from the FBU — the Edge Sequence List during environment setup and the Face List during even field vertical blank time.

The Face Determination Unit (FDU) contains two high-speed buffer memories and the face determination logic. The two memories are used in a multiplexed mode to store data from the EUU's and to provide data to the face determination logic. On a raster line, one memory is storing data from the EUU's and the other is providing data to the face determination logic. The data from the EUU's are loaded sequentially. The data for the face determination logic are unloaded using addresses provided by the LSU. The face determination logic examines edges to find the bounding edges for each face on a raster line. The edge is examined to determine if it is a Start edge or a Stop edge and the element intercept number is compared with the last stored Start or Stop intercept number. If the edge is a Start edge and the intercept number is larger than the stored intercept number, the new edge intercept is stored. If the edge is a Stop edge and the intercept number is less than the stored Stop intercept number, the new intercept number is stored. When all edges in a face have been processed, the selected Start and Stop numbers are transferred to the Line Buffer Unit. If the Start number is greater than the Stop number, the transfer is disabled and the face is discarded.

The Line Buffer Unit (LBU) is loaded with the Display Assignment Word during even field vertical blank time from the FBU. During the active line time, the LBU is loaded with Start and Stop numbers from the FDU and face color and view assignment data from the LSU. During horizontal blank time, the data are transferred to the Face Generator Units. The LBU monitors the view assignment code during the data transfer to the Face Generator Units and insures that all view changes occur on a modulo 16 face count. If a view change occurs and the number of faces shifted into the Face Generator Units is not modulo 16, the unloading of faces is stopped and dummy Start/Stop numbers are transmitted. When the modulo 16 count is reached, the reading of faces is restarted. Also during horizontal blank time, the Display Assignment word is transferred to the Priority and View Assignment Unit to control the view/display assignment logic.

The two Face Generator Units (FGU's) are loaded with Start and Stop numbers from the LBU during horizontal blank time. Each FGU is capable of generating 96 faces during the active raster time. Each face is generated using a pair of counters, a Start counter and a Stop counter. The ones complements of the Start and Stop numbers are loaded into the counters and incremented using a video clock from the TOU. The face active indicator is turned on when the Start counter reaches all ones and turned off when the Stop counter reaches all ones. First-level priority is provided by grouping 16 faces of Start and Stop counters. During the active line time, a face active indicator and the address of the highest priority face active in each 16-face group are transferred to the Priority View Assignment Unit.

During horizontal blank time, the Priority View Assignment Unit is loaded with face color, view assignment, and view/display assignment data from the LBU. During the active line time, the view assignment code is used to determine the highest active face for a specific view. The address from the FGU's is used to determine the color word for the highest priority face. The view/display assignment word is then used to gate the color word to the appropriate display.

The General Timing Unit provides horizontal and vertical timing signals and digital clock signals to the various units in the EPU. The primary clock standard is a 25-MHz crystal oscillator. The horizontal and vertical counters in the General Timing Unit are synchronized by signals from the TOU.

4.3 Mechanical Information

4.3.1 General

The Edge Processor Unit is contained in a double-bay cabinet. (See Figure 8.) The cabinet is similar in appearance to the enclosures provided on Contract NAS 9-3916. The cabinet contains the digital logic, required power supplies and filtered blower assemblies. Primary power is 220-VAC 60-Hz 3-ϕ All interconnecting signal and power cables were furnished as part of the Contract.

4.3.2 Logic Cards

The digital logic used to implement the EPU is contained on 16 purchased memory cards, 28 multilayer cards, and 66 hand-wired logic cards. The cards are inserted into hand-wired motherboards that provide for power distribution, fusing, and interconnection.

Cogar 08C03 High-Performance memory cards are used for high-speed buffer memory. These cards supply 128 16-bit words with a cycle time of 80 nanoseconds. A General Electric-designed multilayer card was used to adapt the Cogar edge connector to the EPU format. (See Figure 9.)

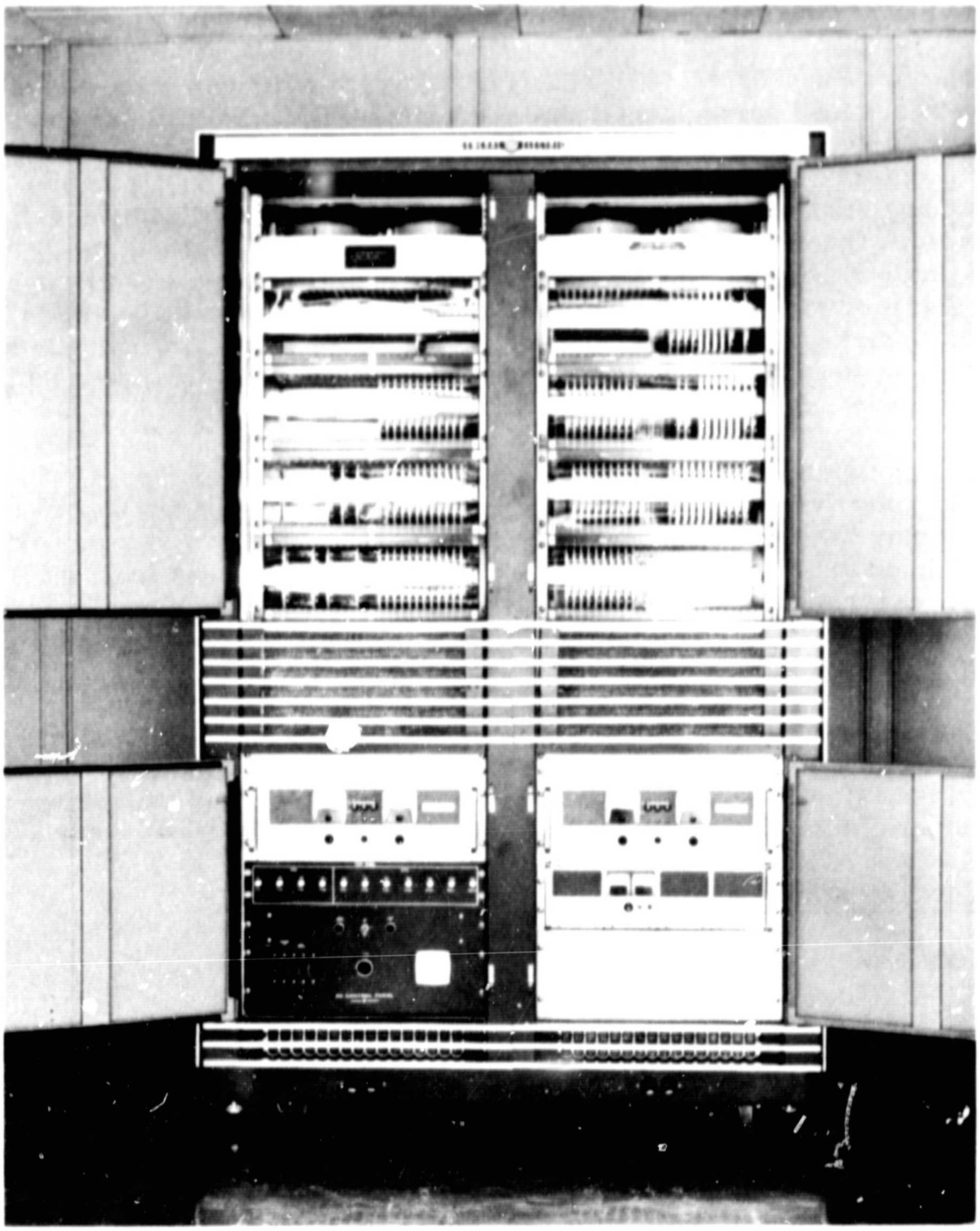

Figure 8. Edge Prccessor Unit
(Photo No. 102771-7 F11)

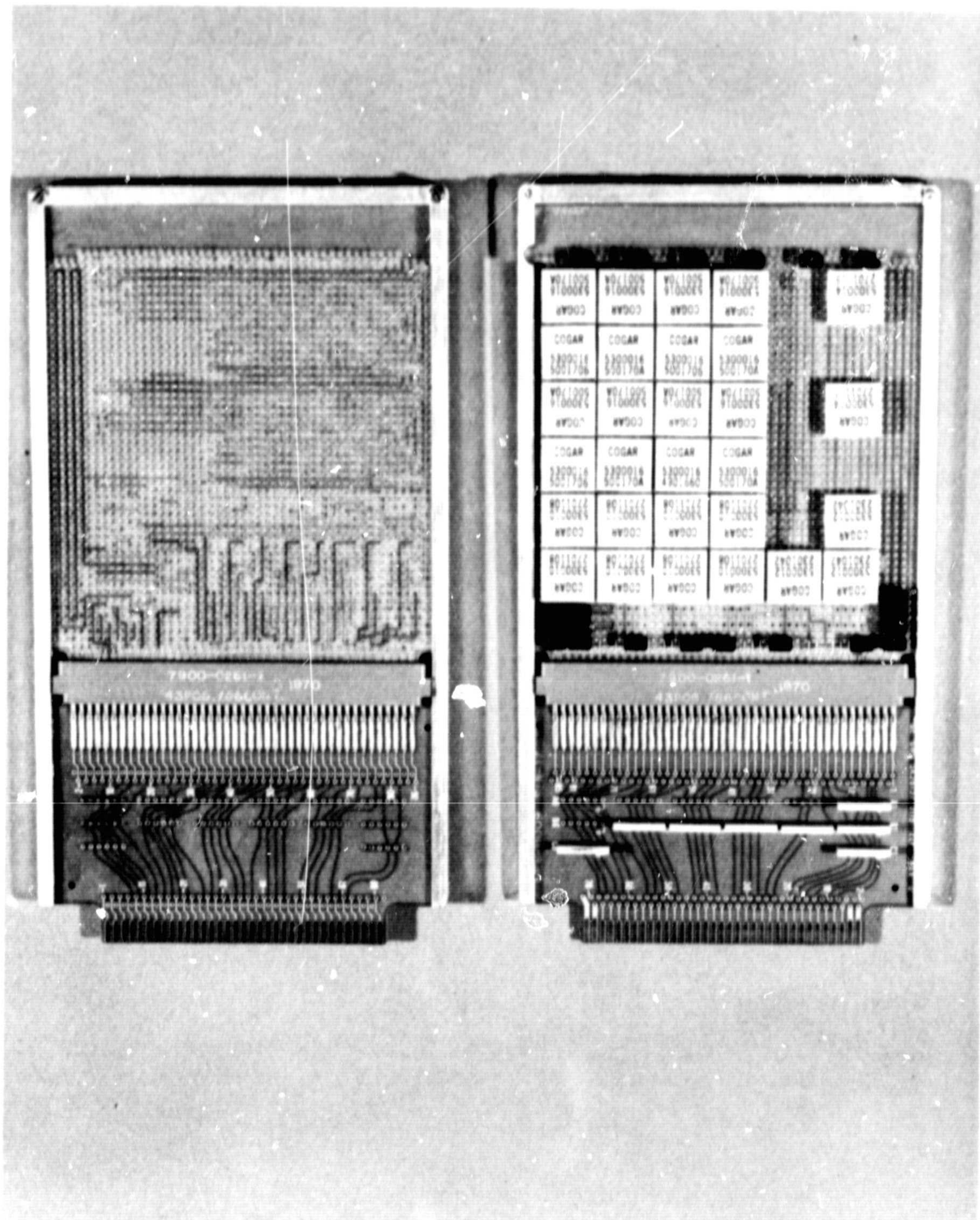

Figure 9. Cogar Memory Card 08C03
(Photo No. 102771-6 F1)

Multilayer cards were used when multiple cards of one design were required. The multilayer cards accept up to 80 dual-inline packages. (See Figure 10.)

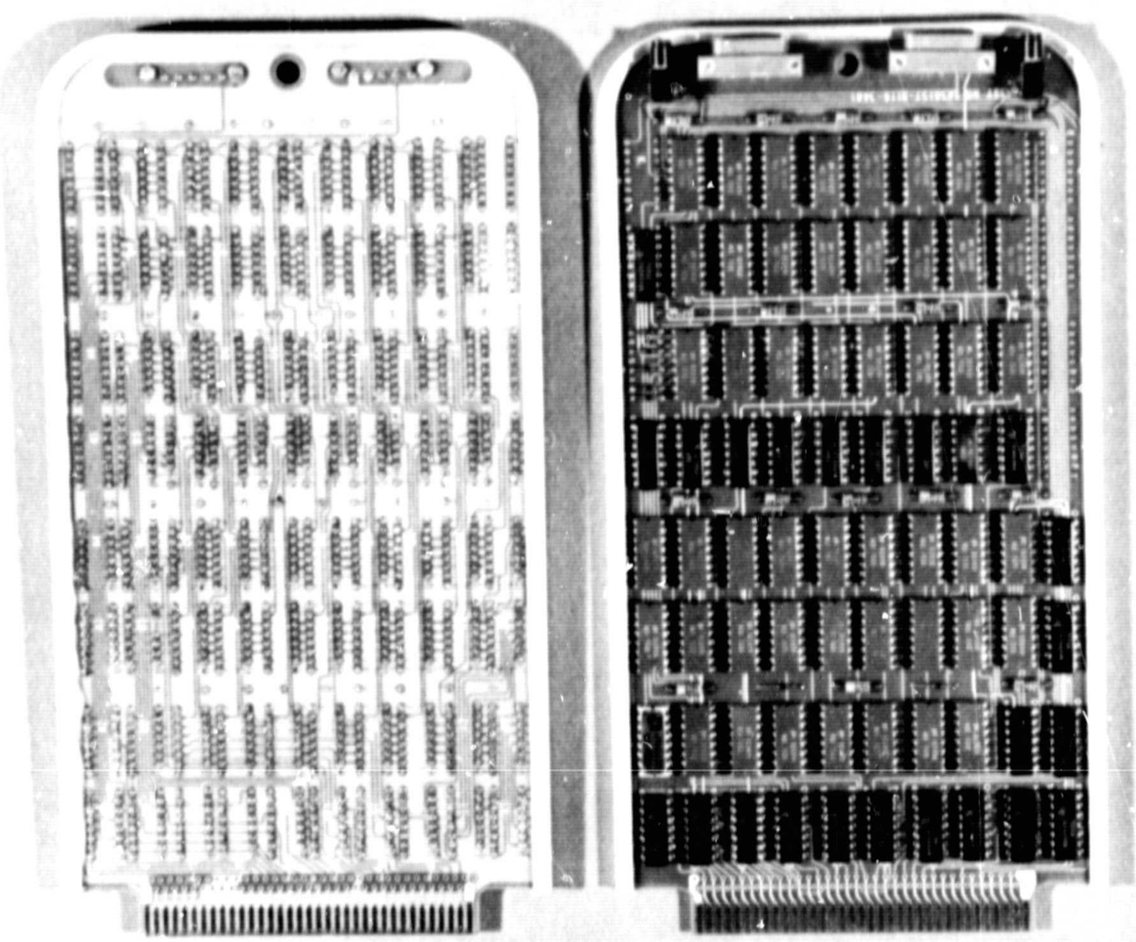

Figure 10. Multilayer Card
(Photo No. 102771-6 F8)

The remaining logic in the system was implemented on hand-wired general-purpose cards. These cards accept up to 64 dual-inline packages. (See Figure 11.)

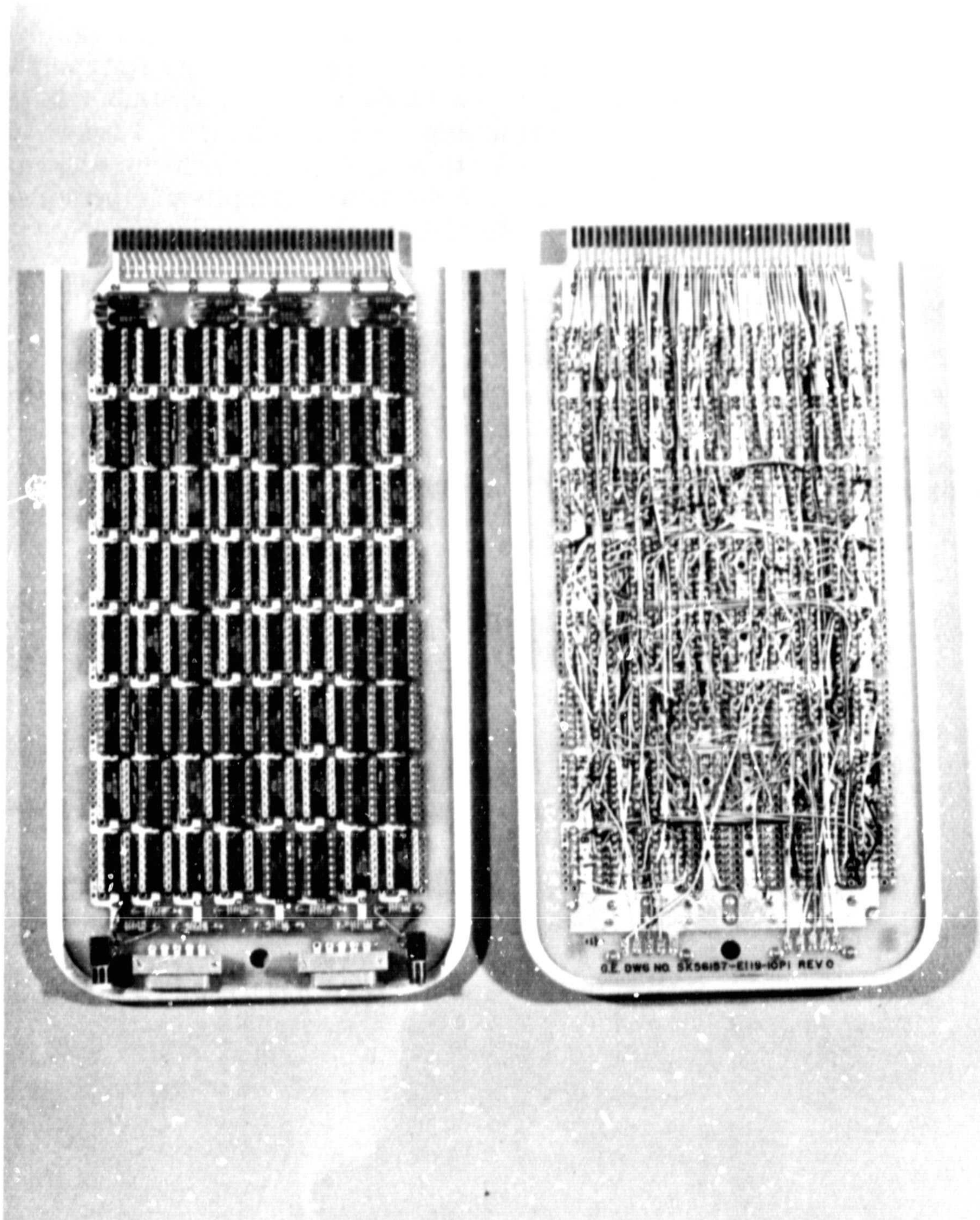

Figure 11. Hand-wired, General-purpose Card
(Photo No. 102771-6 F6)

The logic cards are inserted into hand-wired motherboards that provide for power distribution, fusing, and interconnection. The motherboards are interconnected with twisted-pair, 50-ohm coax and 92-ohm coax. All coax interconnections were made with miniature pull-type coax connectors.

4.3.3 Cooling Provisions

Cooling air for the digital circuitry is provided by McLean 500 CFM centrifugal blowers at the bottom of the logic card bins and Rotron Feather fans at the top of the bins. Air interlock switches are incorporated into the bottom blowers to protect the circuitry if the blowers should fail. Temperature sensors are located at the top of the bins to sound an alarm if the exhaust air should reach 95°F. Additional cooling air for the power supplies is provided by McLean 1E2206 blowers located at the bottom of the cabinet.

4.3.4 Power Generation and Distribution

Main logic power is provided by two Lambda LB-701 power supplies. Each supply is capable of providing 300 amps at 5 volts. One additional bias voltage is provided by a Lambda LMCC-10 power supply. The main logic voltages, plus 5 volts and minus 5.2 volts, are distributed in the cabinet by laminated bus bars.

5. SOFTWARE

5.1 General

The software effort on the Scene Generator Expansions System program was divided into two separate tasks. The offline software used for processing the environment data into a form suitable for use with the online software was generated by Lockheed personnel at NASA MSC in Houston, Texas, under the direction of General Electric personnel. The online software used when operating the system was generated by General Electric personnel.

5.2 Offline Software

The offline software processes the environment data into a form suitable for use by the operating or online software. The environment data are accepted by the program, tested for errors, and assembled into the environment data tables required in the R520, VCU, and EPU. At the completion of the program, a complete card deck is punched; this deck is suitable for loading the environment data and online programs into the ESG.

5.3 Online Software

The online software is divided into two parts, the R520 programs and the VCU programs. The algorithms used in the online software are essentially as described in Volume I, Instruction Manual for Modifications to Interim Visual Spaceflight Simulator. The R520 performs the input processing, the L and P vector generation, and the priority calculations. The VCU performs the aspect test on each face, assembles the Face List, and performs the A and B calculations.