[redacted]

~~TOP SECRET~~ ARGON

HANDLE VIA [redacted] CONTROL SYSTEM

FILE ARGON

TECHNICAL REPORT

Follow-on
Geodetic-Mapping Satellite

Special Projects Office

Directorate of Topography and Military Engineering

Declassified and Released by the N R O

In Accordance with E. O. 12958

on NOV 26 1997

28 June 1963

Prepared by
OFFICE, CHIEF OF ENGINEERS
DEPARTMENT OF THE ARMY
Washington 25, D.C.

DISSEMINATION RESTRICTION

THIS PUBLICATION IS TO BE DISSEMINATED ONLY ON A "MUST KNOW" BASIS, IN KEEPING WITH THE PROVISIONS OF [redacted] AS INDICATED BY THE [redacted] REQUIRED CONTROL STAMP THE USE OF THIS PUBLICATION IS LIMITED TO PERSONNEL WHO REQUIRE THE INFORMATION

Copy [redacted]

[redacted]

28 Pages

~~TOP SECRET~~ ARGON

HANDLE VIA [redacted] CONTROL SYSTEM

GROUP 1
Excluded from automatic
downgrading and declassification

TECHNICAL REPORT

Follow-on
Geodetic-Mapping Satellite

[redacted]

28 June 1963

Prepared By
OFFICE, CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY

WARNING

"This document contains information affecting the National Defense of the United States within the meaning of the espionage laws, Title 18, USC, Secs.793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law".

Reproduction, excision, or extraction in whole or in part of this document, is forbidden without the written consent of the Office, Chief of Engineers.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FOLLOW-ON GEODETIC-MAPPING SATELLITE

TECHNICAL DATA

This report describes an earth satellite data acquisition system designated as the ARGON PRIME (A'), a follow-on program to the ARGON GEODETIC SATELLITE. For convenience of reference, the original ARGON GEODETIC SATELLITE is herein designated A and the FOLLOW-ON GEODETIC-MAPPING SATELLITE is designated A PRIME (A').

1. OBJECTIVE

The proposed A' will produce an optimum system for collection of data for: (1) photogrammetric establishment of a dense network of geodetic control points for target location use and for controlling the compilation of charts and maps and, (2) preparation of 1:250,000 scale topographic maps. It will provide an improved geodetic data collection capability and, at the same time, provide the first satellite system suitable for collection of data for medium scale mapping. This system will not require the development of a data reduction system since the Universal Automatic Data Reduction System now under development by the Corps of Engineers will be ideally suited for this purpose. The Universal Automatic Data Reduction System is described briefly in the Appendix.

2. ASSUMPTIONS

The system design is based on the following assumptions:

a. Essentially, world wide photographic coverage, using satellite sensors, is necessary to meet Department of Defense requirement for target location, charting and the production of standard 1:250,000 and provisional 1:50,000 scale topographic maps.

b. Ground control is not presently available in sufficient quantity for target location use or for preparation of charts and maps in most areas. Therefore, additional ground control must be established by photogrammetric or other means.

c. The Thrust Assisted Thor/Agena D vehicle will be used. Film will be recovered using a recovery capsule which is limited to a load of 100 pounds of film.

d. The A' photography must be designed to provide the geometric quality necessary for compilation of standard 1:250,000 scale maps and for establishment of supplemental photogrammetric control for compilation of provisional 1:50,000 scale maps using the photography described in par. e below.

e. Supplemental high resolution, relatively large scale photography will be required for use in adding planimetric data to a basic 1:250,000 scale compiletion and for direct use in compilation of 1:50,000 scale maps using a dense network of control points established from the A' photography.

3. GENERAL DESCRIPTION OF SYSTEM

The primary data collection equipment making up the payload of the A' system will consist of two cameras. A precision vertical mapping camera will be used to obtain stereoscopic photographic coverage of the earth. This camera, hereafter referred to as the mapping camera, will have a 12 inch focal length and a 9 x 14½ inch format equipped with reseau. The 14½ inch dimension of the format will be parallel to the flight direction. The camera will be operated at a cycling rate which will produce exposures at distances along the flight line equal to 0.4 of the altitude. Alternate exposures will be used to form stereomodels for compilation, producing an effective base/height ratio of 0.8. A second precision camera, having a 6 inch focal length lens, will be used to obtain simultaneous stellar photography for precise determination of attitude data for each terrain photograph. The axis of this camera will be perpendicular to the plane of the orbit. The precise time of each exposure of both cameras will be determined from a clock included in the Agena D vehicle and will be recorded on the respective terrain and stellar films. After exposure the film from the mapping and stellar cameras will feed into the recovery capsule for eventual return to earth. The vehicle will be operated in a nominally circular polar orbit at an altitude of 153 statute miles. The 100 pound payload of the recovery capsule will allow a film capacity on each

FOLLOW-ON GEODETIC-MAPPING SATELLITE

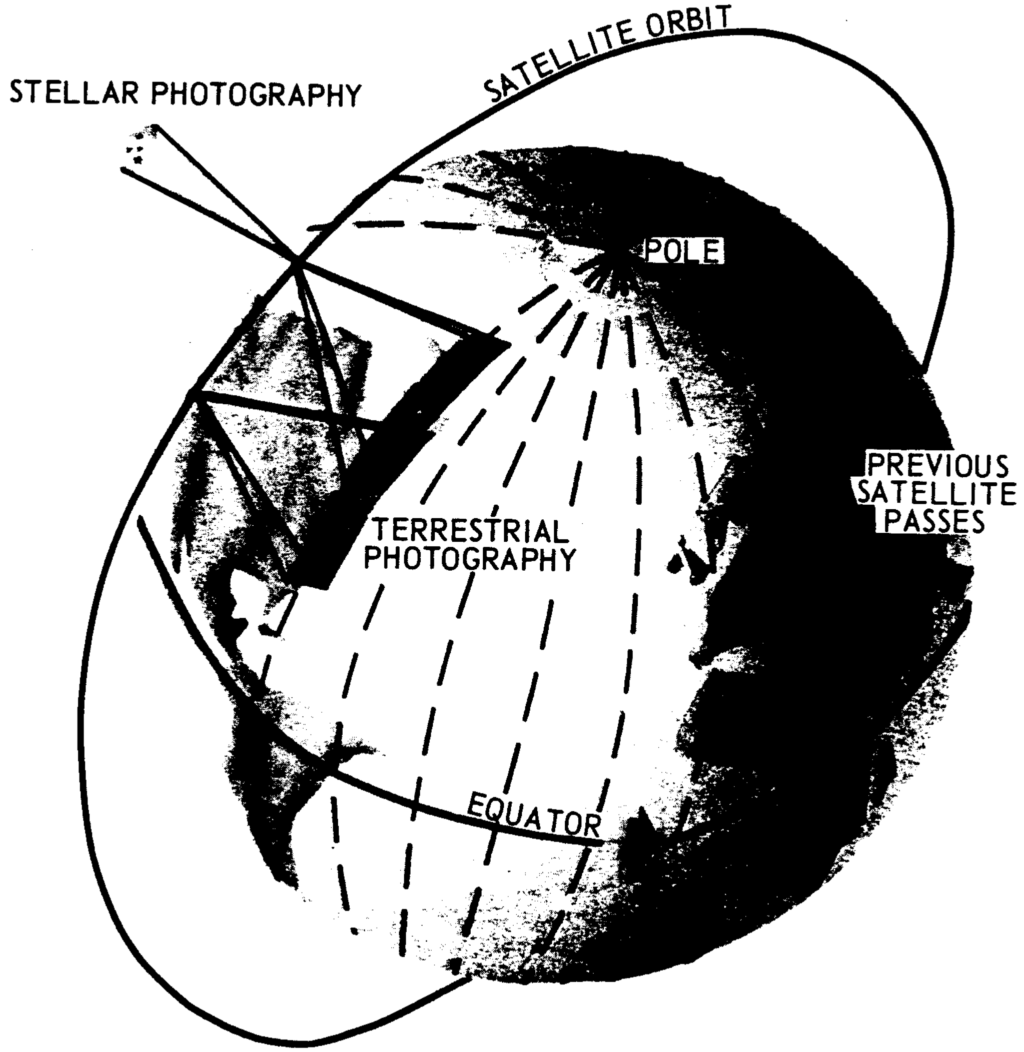


FIGURE I

mission sufficient to photograph slightly more than one half of the land area of the world, neglecting gaps in coverage caused by cloud cover. Figure 1 illustrates the general configuration of the system.

4. SYSTEMS DESIGN CONSIDERATIONS

a. General

The mapping camera parameters described in paragraph 3 were selected as a result of the evaluation of vertical and convergent mapping camera configurations having a wide range of focal lengths and format sizes. Most of the cases considered would use existing camera lens designs or modifications of existing designs. The focal lengths and format sizes of the camera systems considered are shown in Tables I and II.

TABLE I

Vertical Frame Photography

Focal Length	Format	Focal Length	Format
1½"	2¼" x 2¼"	12"	9" x 18"
3	4½ x 4½	12	12 x 12
6	9 x 9	12	12 x 14½
7½	9 x 9	12	9 x 14½
8¼	9 x 9	15	9 x 18
8½	12 x 12	15	18 x 18
10	9 x 9	18	9 x 18
10	12 x 12	18	18 x 18

TABLE II

Convergent Frame Photography

Focal Length	Format
8¼"	4½" x 9"
18	9 x 18
24	9 x 18
36	9 x 18

b. Mapping Camera Configuration

In selecting the optimum system the relative merits of vertical and convergent mapping camera configurations were studied. Some of the factors considered were:

(1) Continuous strip triangulation may be performed only with vertical photography, thus providing significant advantages in data reduction;

(2) Unavoidable changes in the elements of camera interior orientation which occur between camera calibration and actual flight are less degrading to accuracy in a vertical camera configuration than they are in convergent configuration;

(3) The scale of vertical photography is essentially uniform throughout each exposure, a significant advantage in both manual and automatic data reduction, while convergent photographs have large variations in scale;

(4) The reliability of a single camera system, as with a vertical camera, is higher than that of a dual camera system, required for convergent photography;

(5) Deviations from a normal circular orbit are less likely to cause gaps in stereoscopic coverage with vertical photography than with convergent photography;

(6) Convergent photography, with a given format size, will provide a higher base/height ratio than vertical photography with the same format size. The higher ratio increases the accuracy of elevation determinations during data reduction;

(7) The vertical effect of radial distortion is less in convergent stereo models,

resulting from approximate superimposition of the distortion patterns of the two photographs forming the model. Consideration of these factors, coupled with extensive experience in recent years with the two types of photography, indicate that vertical photography is superior for this particular application. Further consideration, therefore, was not given to convergent photography.

c. Camera Parameters

(1) Mapping Camera

The four major characteristics of a mapping camera which determine the geometric quality and information collection ability of the camera are focal length, angular coverage, lens distortion, and lens resolution. These cannot, of course, be considered as independent when selecting optimum values for a particular system. For example, Figure II, shows the inter-relationship of focal length and resolution on the geometric precision (excluding distortion) of a camera.

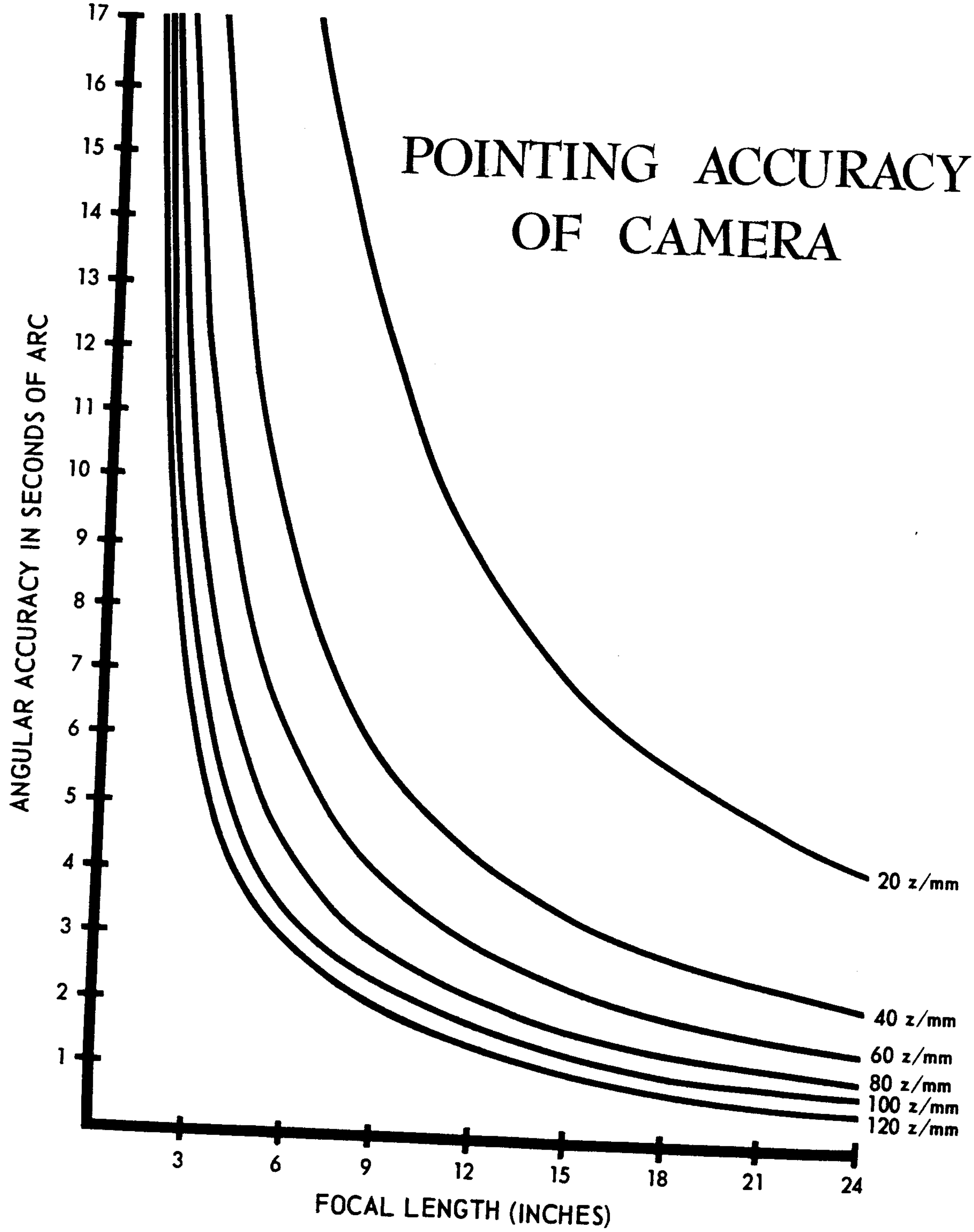

POINTING ACCURACY OF CAMERA
ANGULAR ACCURACY IN SECONDS OF ARC
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
3
6
9
12
15
18
21
24
FOCAL LENGTH (INCHES)
20 z/mm
40 z/mm
60 z/mm
80 z/mm
100 z/mm
120 z/mm

FIGURE II

Evaluation of Figure II, alone, would indicate that a long focal length, high resolution, lens is to be preferred. Other factors, however, place limits on both focal length and lens resolution. A major consideration in focal length selection, in the case of the A' system, is the 100 pound film limitation imposed by the recovery capsule. Other camera parameters remaining the same, an increase in focal length causes an increase in film weight proportional to the square of the ratios of the focal lengths. Similarly, an increase in angular field of the lens is often desirable since it may be used to increase the B/H ratio and hereby increase the vertical accuracy in the stereomodel; the increase in the angular field, however, tends to reduce the averaged resolution.

This complex interaction of camera parameters, stereomodel geometry, weight limitations, etc., precludes presentation herein of a detailed derivation of the optimum camera parameters. In brief, it was determined that the present state-of-the-art lenses and photographic films would require a photographic scale of 1:800,000 or larger to provide the data collection ability required. This scale would required a focal length of 12 inches or more, at the altitude range considered practical. The 100 pound film load limit of the recovery capsule would require two missions with a 12 inch focal length vertical system to provide world-wide photographic coverage of land areas. Increasing the focal length beyond 12 inches would increase the number of missions required. Consequently, 12 inches was selected as the terrain camera focal length. Remaining camera parameters compatible with this focal length, existing lens design data, and flight requirements were then chosen. The camera parameters are summarized in Table III and illustrated in Figure III.

TABLE III

Characteristics of the Mapping Camera

Focal length	12 inches
Relative aperture	f/5.6
Half field angle	36 degrees
Visual resolution (AWAR)	190 lines/mm
Maximum radial distortion	10 microns
Maximum tangential distortion	4 microns
Minimum transmittance	55 percent
Filter	Wratten 21
Photo format	9 x 14½ inches, with reseau
Film length	5,100 feet
Film width	9½ inches
Film type	EK 4400 (formerly SO 130)
Film base thickness	2.5 mils
Cycling time	12.5 seconds
Film per exposure	16 inches
Image motion compensation	None
Shutter speeds	Variable up to 1/1000 sec
Film flattening method	pressurization
Exposures per mission	3,800

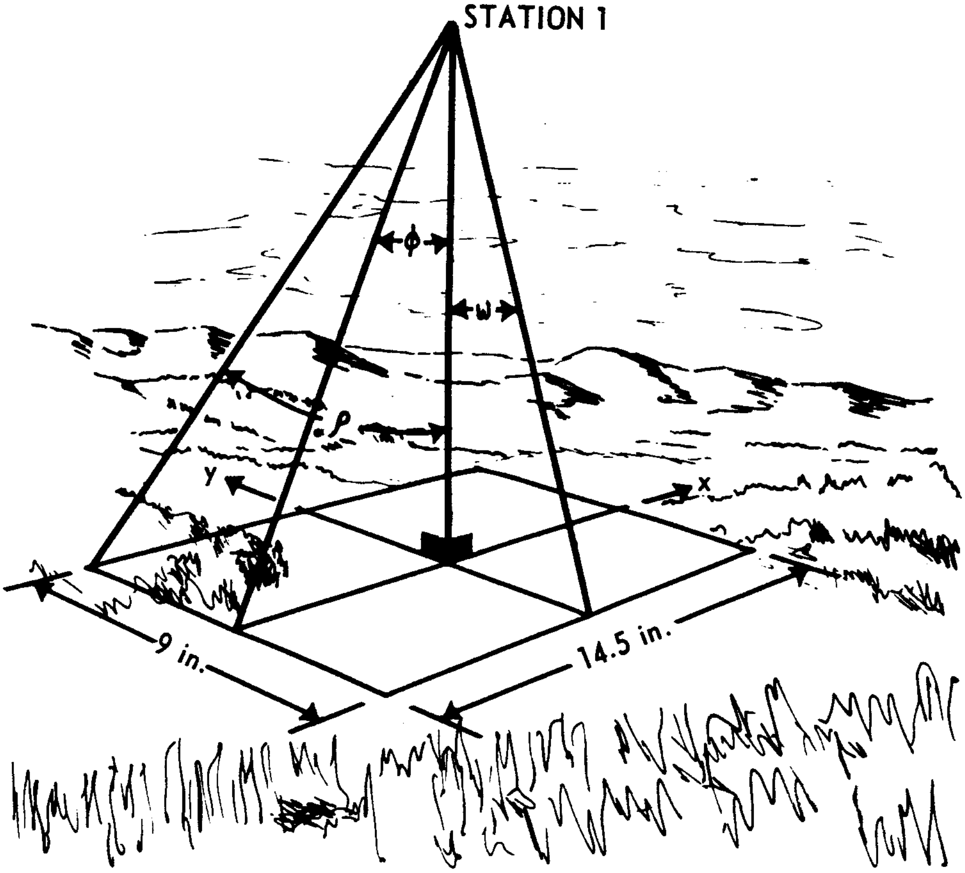


FIGURE III Basic geometry of single photograph

$\phi = 31^\circ\ 08'.3$

$\omega = 20^\circ\ 33'.3$

$\rho = 35^\circ\ 24'.3$

(2) Stellar Camera

The stellar camera exposures will be synchronized with those of the mapping camera. The relationship of the lens axes of the stellar and mapping cameras will be precisely calibrated before launch. The lens axis of the stellar camera will be oriented nominally perpendicular to the plane of the orbit; this orientation will result in all stellar photographs containing essentially the same stars. In this orientation the sun will never be directly in the field of view of the stellar camera. However, it is expected that some shielding against reflected sunlight may be required. The lens used in the stellar camera may be considered to be less critical than the mapping camera lens. Low lens distortion is not essential since corrections based on lens calibration data are easily applied to the stellar photo coordinates. However, a large aperture is an important requirement for the stellar lens, to permit exposure time to be as short as possible. The stellar lens recommended for this system is based on a modification of an existing lens design and will be capable of producing satisfactory stellar photography. The parameters for the stellar camera are given in Table IV.

TABLE IV
Stellar Camera Parameters

Focal length	6 inches
Relative aperture	f/2.5
Half field angle	17°
Maximum radial distortion	15 microns
Maximum tangential distortion	2 microns
Photo format	2¼ x 3 inches
Film length	1270 feet
Film width	70 mm
Film type	SO-135
Film base thickness	4 mils

d. Precision Clock

A precision clock will be furnished in the payload to provide time data to the two cameras. The time of each exposure, precise to .001 second, will be recorded in binary form in the data block for each terrain and stellar exposure. This data will be an aid in determining both absolute and relative positions of the exposure stations along the orbit.

e. Orbit Selection

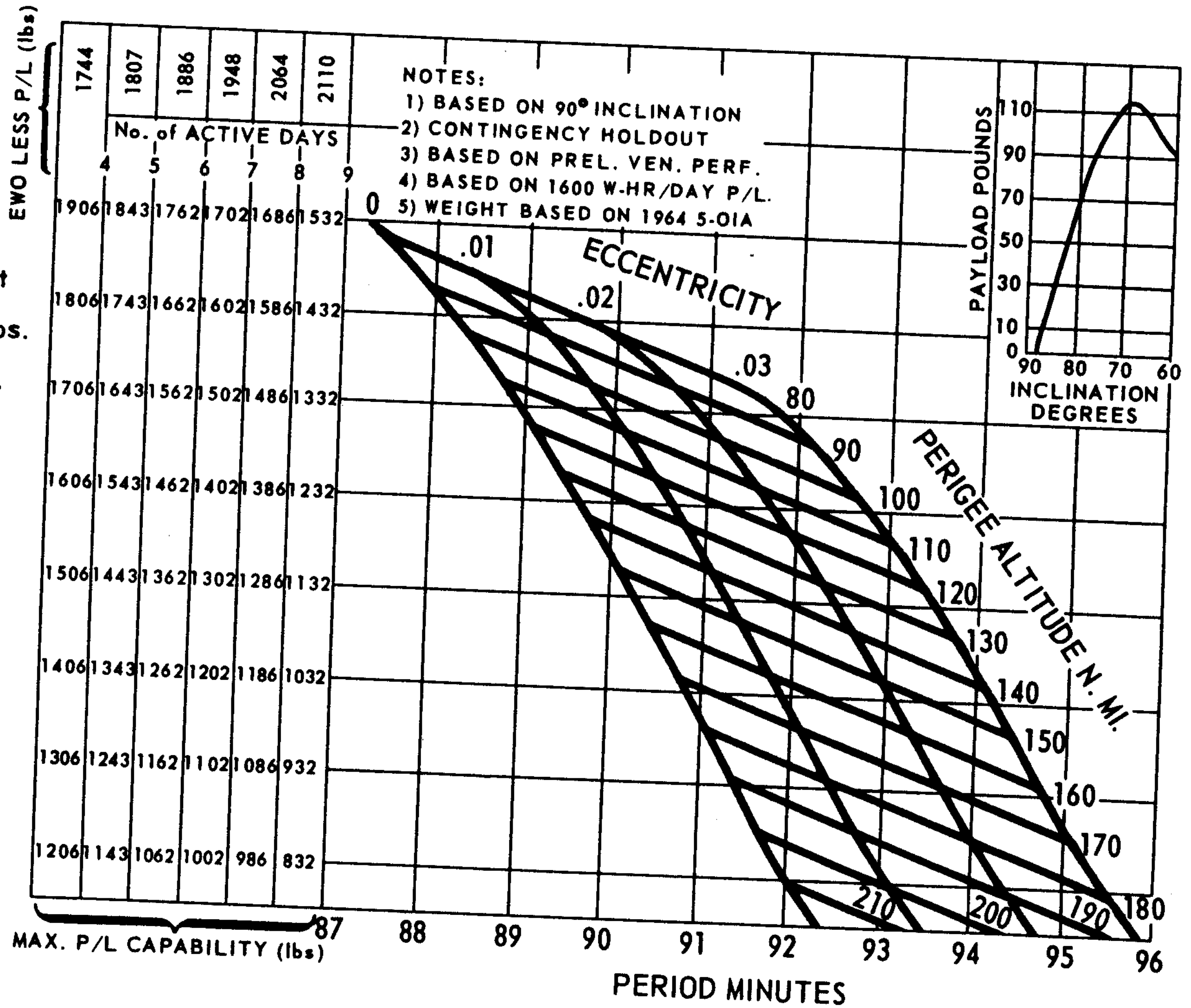
The A' parameters have been selected assuming the use of the Thrust Assisted Thor/Agena D vehicle. Since the camera parameters and the orbit characteristics are interrelated, the capabilities of this vehicle combination were, of course, considered during the selection of the camera design. Similarly, the camera parameters were a governing factor in selection of the orbit characteristics. For instance, the perigee altitude and the eccentricity determine the scale and coverage of each mapping photograph. The eccentricity should be kept to a minimum to prevent undesirable variations in photographic overlap. The period of the satellite, influenced by both the altitude and eccentricity, will establish the sidelap achieved and is a key factor in obtaining the desired photographic coverage. The inclination of the orbit will determine the northern and southern limits of the area which will be photographed. Some of the variables related to the Thrust Assisted Thor/Agena D vehicle are shown in Figure IV. From this data, and more detailed computations of orbit characteristics, the following are established for the A' Program orbit:

Perigee altitude	153 statute miles (133 n. mi.)
Maximum eccentricity	.003
Type of orbit	Polar
Orbit period	89.4 minutes
Missions required	2*

* This is the number of missions required to photograph the land area of the world, neglecting reflights required to photograph areas covered by clouds on initial missions, and reflights brought about by any other reasons.

TAT PAYLOAD CAPABILITY

NOTE:
Recoverable Film Weight Limited to 100 lbs. Recovery Capsule 360 lbs. Hence, Camera Not Severely Weight Limited.



1744	1807	1886	1948	2064	2110
1906	1843	1762	1702	1686	1532
1806	1743	1662	1602	1586	1432
1706	1643	1562	1502	1486	1332
1606	1543	1462	1402	1386	1232
1506	1443	1362	1302	1286	1132
1406	1343	1262	1202	1186	1032
1306	1243	1162	1102	1086	932
1206	1143	1062	1002	986	832

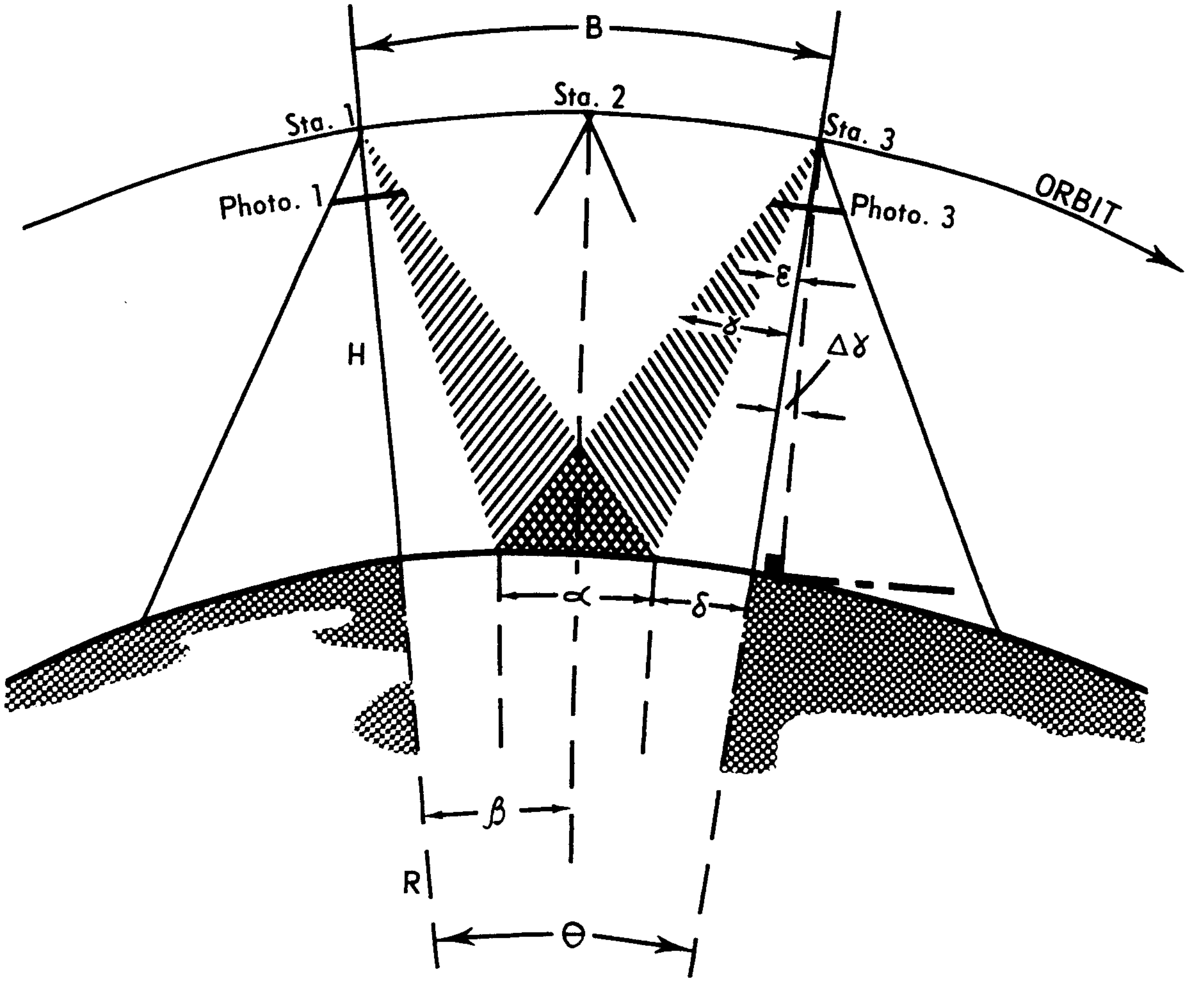
NOTES:
1) BASED ON 90° INCLINATION
2) CONTINGENCY HOLDOUT
3) BASED ON PREL. VEN. PERF.
4) BASED ON 1600 W-HR/DAY P/L.
5) WEIGHT BASED ON 1964 5-OIA

FIGURE IV

5. STEREOMODEL CHARACTERISTICS

The camera parameters and orbit characteristics establish the geometry of the stereomodels which will be formed with the A' mapping photography. As mentioned previously, stereomodels made up of alternate exposures (exposures 1 and 3, 2 and 4, etc.) will be used to provide a favorable base/height ratio. The geometry of the A' models are depicted in Figures V and VI. Basic characteristics of the stereomodel are as follows:

Ground width of stereomodel	114 statute miles
Ground length of stereomodel	61 miles
Area of stereomodel	6954 square miles
Altitude (nominal)	153 miles
Model base length (along orbit)	127 miles
Nominal photo scale	1:800,000



DESIGNATION	SYMBOL	DIMENSION Miles	DIMENSION Feet
Altitude	H	153	8.07 x 10^5
Base (air)	B	127	6.07 x 10^5
Earth Radius	R	3959	20.90 x 10^6
Max. Earth Curvature	D	–	2.1 x 10^3
Angles Between		ANGULAR VALUES	
Sta. 1-2	β	0°	53'
Sta. 1-3	θ	1	46
Stereo model	α	0	53
Station normal to near edge of model	δ	0	26
Divergent Angle	Δγ = θ	1	46
Scale	S	1:800,000	

FIGURE V Elevation view of Stereo model

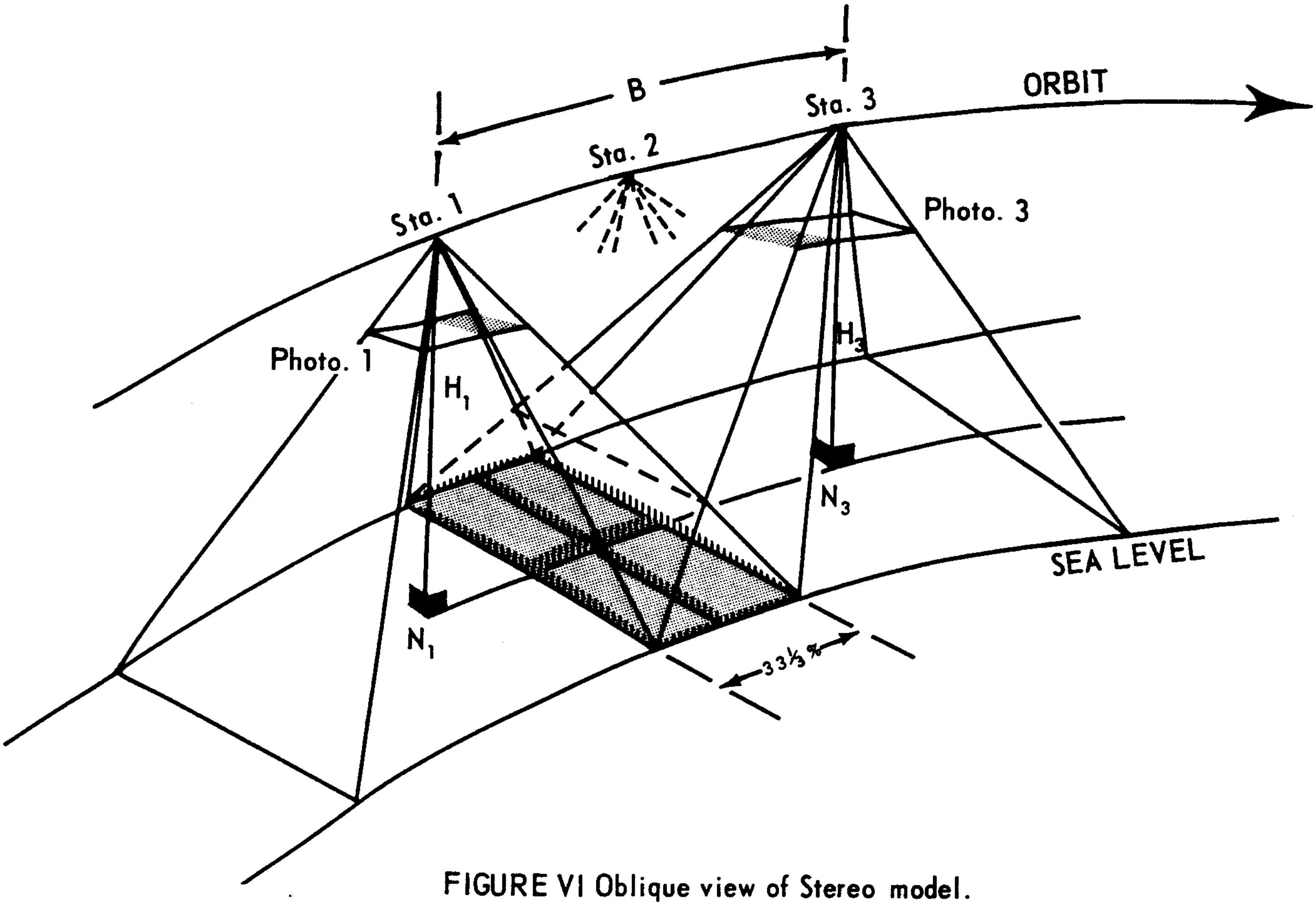


FIGURE VI Oblique view of Stereo model.

6. PREDICTED ACCURACY OF FINAL PRODUCTS

The geometric fidelity and other characteristics of the A' photography do not indicate directly the accuracy of the geodetic control, charts or maps which may be produced from the materials. The accuracy of the geodetic control established by photogrammetric procedures for target location, charting, and control of map compilation will depend on (1) accuracy and density of geodetic control source data and (2) accuracy of the photogrammetric triangulation and related orbit computations. In the case of the compilation of 1:250,000 scale maps directly from the A' materials a third consideration, the accuracy of photogrammetric compilation of individual stereomodels, also affects the final accuracy. Estimates of the general accuracies in these three areas are given below, with a prediction of the overall accuracy of 1:250,000 scale maps prepared with the A' materials.

a. Accuracy and Density of Geodetic Control Source Data

Present indications are that in the near future extensive geodetic control will be established by ground based photogrammetric observations on passive satellites of the ECHO type and electronic ranging data from the SECTOR system. A primary network of about 50 stations, spaced 1800 to 2500 miles apart and a secondary network, with 400 to 600 mile spacing, will be established in accessible areas. The absolute horizontal accuracy of these stations with respect to a world datum will be approximately 16 meters (standard error). The elevation accuracy will be equal to, or better than, the horizontal accuracy. In addition to these stations, existing geodetic control and map data will be utilized and will be especially useful in inaccessible areas of the world. The accuracy and density of this data will vary greatly; only that data which will contribute to the accuracy of the maps will be used.

The ground control source data described above will be used to establish photogrammetrically the additional geodetic control points required for target location, charting, and preparation of both 1:250,000 and 1:50,000 scale maps. Spacing of the points will be approximately 50 miles for all areas except those where 1:50,000 scale maps are to be prepared and areas where a denser network is required by the user for special purposes. The spacing for 1:50,000 compilation will be as little as 5 miles, depending on the characteristics of the compilation photography. Error analyses indicate that the photo control points established by photogrammetric triangulation, with orbit characteristics used as an aid in the triangulation, will have horizontal and vertical accuracies of about 20 meters (standard error) with respect to the control points spaced 400 to 600 miles apart. Thus, the total error of the photo control points, relative to a world datum, will be approximately 26 meters (standard error) under these conditions. In those inaccessible areas where the desired density of control points cannot be established by observations on passive satellites, three courses of action are available. These are (1) photogrammetric triangulation using existing control and map data,

(2) determination of satellite orbit and positions of exposures along orbit and (3) a combination of (1) and (2). None of these will, in general, produce photo control points with accuracies as high as the 20 and 26 meters mentioned immediately above. Accuracies achieved in a given area will depend on the quality of the input materials available for that area and will, unless degraded by breaks in stereoscopic coverage by cloud cover or similar flaws, provide geodetic control points to an absolute horizontal and vertical accuracy of at least 450 feet (90%) for target location use and control points suitable for Class A 1:250,000 scale maps.

It should be noted that all of the errors stated above were errors in photo control points with respect to ground control and the world datum. Relative accuracies of photo control points within single stereomodels, about 61 by 114 miles, will be approximate 8 meters horizontally and 14 meters vertically.

c. Compilation of Individual Stereomodels for 1:250,000 Scale Maps

Primary sources of error in the compilation of individual stereomodels of A' photography to produce 1:250,000 scale maps are the geometric quality of the photographic materials and the accuracy of the map compilation equipment. The distortion characteristics and some of the other camera parameters which affect the geometric quality are shown in Table III; however, many other factors contribute to the quality of the end product, making a meaningful error analysis of the photography both difficult and lengthy. A similar situation exists with the Universal Automatic Map Compilation Equipment, described in the appendix, which will be used for the compilation. However, the investigations which have been carried out to date, and the technical requirements established for the compilation equipment, indicate that the A' materials may be used in the compilation equipment at a "C-Factor" (ratio of flight altitude to contour interval) of about 5000. This would enable contours, sufficiently accurate relative to the photo control points, of 50 meters to be produced. The vertical accuracy of the photo control points discussed in paragraph b, above, combined with this C-Factor, will permit a 100 meter contour interval meeting National Standards of Map Accuracy to be achieved where the 400 to 600 mile spacing of fill-in control points are available. A 100 meter interval also will be achievable in all inaccessible areas except where the establishment of photo control points has been weakened by breaks in stereoscopic coverage as mentioned in paragraph b above. With regard to horizontal accuracy, this combination of photography and compilation equipment is expected to produce horizontal position errors of about 30 meters (standard deviation) with respect to the photo control point positions, or absolute position errors relative to the world datum of about 40 meters in areas where fill-in control points from observations on passive satellites are used. 90% of all features will have a horizontal error of less than 281 feet, well within the 416 feet allowable under National Standards of Map Accuracy. In inaccessible areas, as a result of the lower accuracy of the photo control points, the total horizontal error will be larger but will not exceed the limits of National Standards except in occasional areas where the establishment of the photo control points has been unusually degraded.

7. SUMMARY

a. The proposed A' will provide data for:

(1) Establishment of geodetic ground control for target location use and for charts and topographic maps.

(2) Direct compilation of 1:250,000 scale maps meeting Class A accuracy standards, but slightly sub-standard in planimetric content.

(3) Direct compilation, supplemented by high resolution photography, of 1:250,000 scale maps meeting Class A accuracy and content standards.

b. The program will exploit fully existing space systems and will require a minimum of new equipment development. The equipment that is presently available and that which is to be developed is listed as follows:

AVAILABLE EQUIPMENT	EQUIPMENT TO BE DEVELOPED
Thrust Assisted Thor Booster	Precision mapping camera
Agena D vehicle	Stellar camera
Telemetry, tracking beacons, etc.	Mounting structures
Recovery capsule	
Vehicle stabilization system	
Vehicle clock	
Vehicle and camera programmer	

c. A schematic diagram summarizing the A' equipment, materials, and products is shown in Figure VII.

DATA FLOW

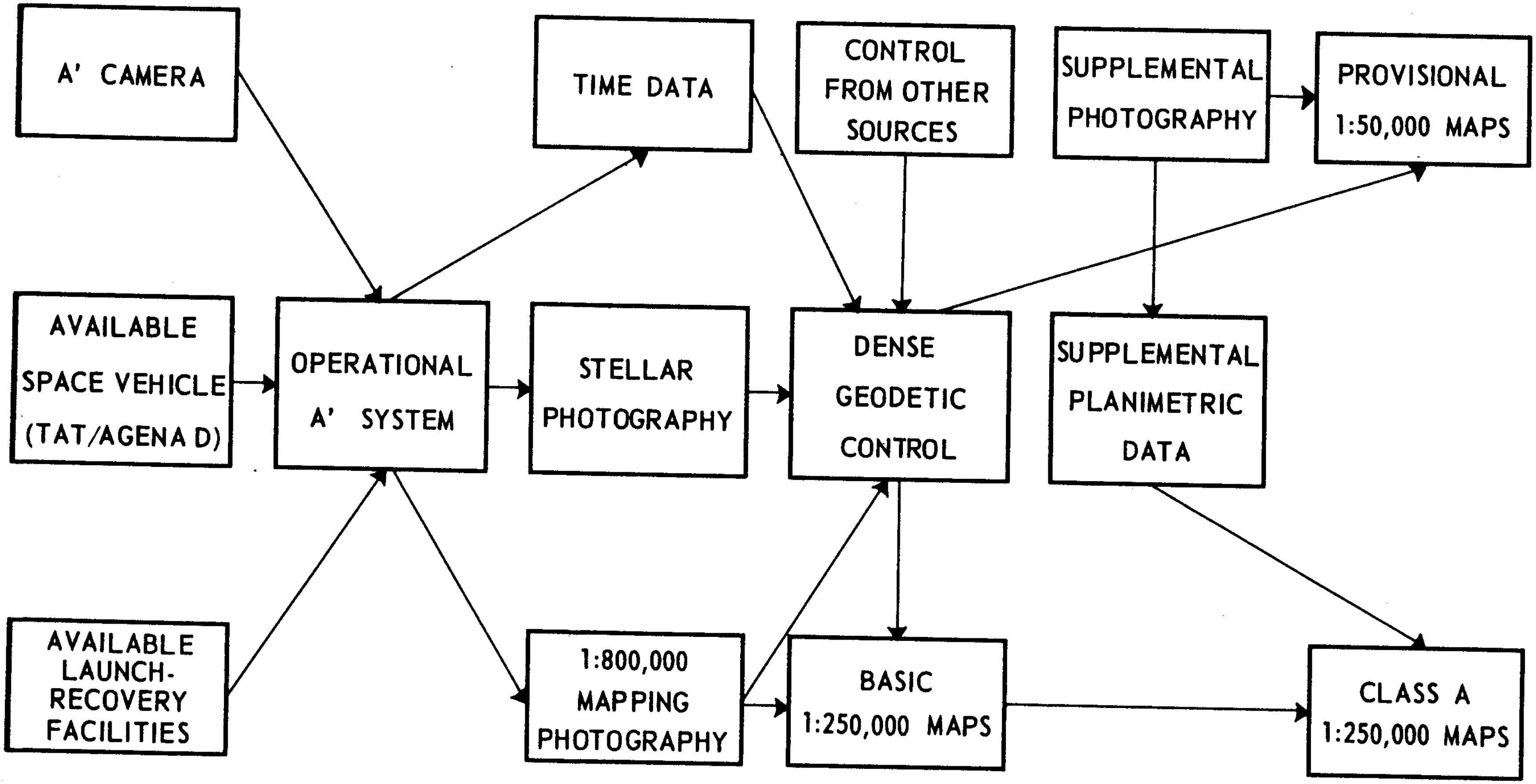


FIGURE VII

APPENDIX

SUMMARY OF UNIVERSAL AUTOMATIC DATA REDUCTION SYSTEM

1. GENERAL

Map Compilation with the A' materials may be carried out with the Universal Automatic Data Reduction System now under development by the Corps of Engineers. This system will be installed in an Army Precision Photogrammetric Laboratory soon to be constructed at the Army Map Service. Although the system is not a part of the A' program, a brief description (making no distinction between 1:250,000 and 1:50,000 compilation) is included below to illustrate the general features of the system.

2. INPUT MATERIALS

The input materials suitable for production of standard 1:250,000 and provisional 1:50,000 scale topographic maps are:

a. A' program precision 9 x 14¼ inch format, 12 inch focal length, mapping photography;

b. A' program precision stellar photography;

c. A' program precision time data;

d. Existing geodetic control and maps;

e. Additional geodetic control obtained from photographic observations on passive satellites;

f. High resolution photography from other programs.

3. SYSTEM OPERATION

The system comsists of all equipment and operations necessary to produce completed topographic maps from the input materials. It consists of five basic functional phases. These are: materials preparation, materials evaluation and selection, triangulation-mensuration, compilation, and general computer operations. The following is a brief description of these five phases, including information on the more important and/or highly advanced items of equipment. No attempt is made to describe all items of equipment. Many of the operations described will be carried out under "White Room" conditions to ensure maximum utilization of the information content of the photographic materials.

a. Materials Preparation Phase

This phase includes all film duplication, photographic processing, enlarging rectifying and glass plate preparation. Equipment will be especially designed and fabricated to ensure maximum retention of photo detail and geometric fidelity. The more sophisticated items of equipment will include advanced film processors and electronic Universal Rectifier.

b. Materials Evaluation and Selection Phase

This phase includes the evaluation of all photography, abstraction of auxiliary data and selection of materials to be used in subsequent operations. An Evaluation Viewer Instrument will permit a technician to evaluate the film and to enter the evaluation data into a card punch for subsequent storage and processing of the data by the central computer complex. In addition, an Auxiliary Data Reader will be used to abstract binary data recorded on the film.

c. Triangulation-Mensuration Phase

This phase will produce all photographic coordinate information necessary for computation of geodetic and exposure orientation data required for independent compilation of single stereomodels in the Compilation Phase. Included are identification control points, selection of pass points, transfer and marking of control and pass points, and measurement of coordinates of photographic images. This phase is highly automated; two major items of equipment used will be almost completely automatic in operation. The first of these is an Automatic Point Transfer and Marking Instrument. This will provide a capability for automatic correlation of images on stereoscopic photographic coverage for triangulation pass point and/or control point transfer, automatic marking of transferred points on the photographic plates, semi-automatic matching of map and photographic coverage to produce "substitute control" in areas lacking control, and automatic marking of the selected substitute control points on the photographic plates. The second major item is a Coordinate Reader. This instrument will provide a means for measurement of stellar, reseau, fiducial, and marked control and pass points on either film or glass plates. It will be capable of utilizing pre-programmed approximate coordinates to bring the measuring system to the vicinity of each marked point whose coordinates are to be determined. An automatic centering device will then be activated to electronically scan and center on the marked point. The coordinates of the point will be read into a card punch for subsequent introduction into the central computer.

d. Compilation Phase

In this phase automation will produce extensive savings in time and manpower. Conventional photogrammetric plotters will be replaced by Universal Automatic Map Compilation Equipment now under development. This equipment will automatically produce orthographically corrected photographs (orthophotos) and topographic contour manuscripts from stereoscopic photographic coverage. To produce this output, pairs of photographs, on glass photographic plates, will be scanned electronically and the conjugate images correlated. The correct ground positions of these conjugate images will be computed by an integral digital computer and the outputs will be photographically produced as orthophotographs and contours. The planimetric manuscript of the map will be compiled from the orthophotos using a Planimetric Compiler to abstract the basic detail from the orthophoto and to add planimetric detail, not visible on the orthophoto, from high resolution supplemental photography. It is expected that Automated Cartographic Equipment will be used to prepare final reproduction materials from the contour and planimetry manuscripts. Extensive investigations have recently been initiated in this area.

e. General Computer Operations

A central computer will perform all computer operations for the system except the computations associated with two items of equipment, the Universal Rectifier and the Universal

Automatic Map Compilation Equipment, which will have their own specialized computer components. The most complex computations performed will be the determination of orientation data for each mapping exposure used in the Universal Automatic Map Compilation Equipment. All available data and techniques which will contribute to the accuracy of the determination will be used. Both photogrammetric triangulation and orbit determination will be used to compute the position of each exposure station, with the triangulation and orbit data assigned weights compatible with the quality and quantity of the input data. In some areas, photogrammetric triangulation may not be possible because of water areas, cloud coverage, or other reasons and complete reliance will have to be placed on orbit positions.

The central computer will perform such other functions as determination of exposure attitude information from the stellar photo coordinates, computation of corrections for lens distortion and film shrinkage, and general data storage and retrieval.