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Star-Field Photography and Laser Ranging Techniques for Satellite-Based Geodetic Measurements

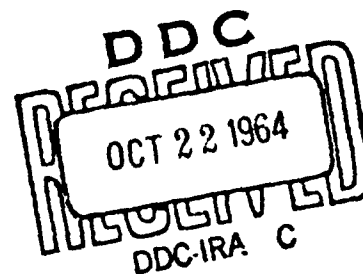
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Prepared for COMMANDER SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California



LABORATORY OPERATIONS

• AEROSPAC CORPORATION
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STAR-FIELD PHOTOGRAPHY AND LASER RANGING TECHNIQUES
FOR SATELLITE-BASED GEODETIC MEASUREMENTS

Prepared by
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This technical documentary report has been reviewed and is approved for publication and dissemination. The conclusions and findings contained herein do not necessarily represent an official Air Force position.

For Space Systems Division
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FOREWORD

This report was prepared by Space Physics Laboratory at the request of the Technical Development Program Office in support of the Exploratory Development Program Element -- Aerospace Environment.

ABSTRACT

A method is described for obtaining cartographic and geodetic data from a manned orbital satellite. The techniques utilized are a boresight camera, which simultaneously photographs a particular point on the ground and the coaxial star field, and a laser for obtaining slant range. These, together with an accurate spacecraft ephemeris, will obtain data on angle coordinates and elevation of particular points along the orbital trace of the spacecraft with respect to a primary control station. Particular instrumental requirements are given for the star-field camera and the laser ranging device.

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I. INTRODUCTION

At the present time, uncertainties in the location of geographic positions at certain places on the earth are estimated to be as large as 10,000 ft. The uncertainty in the primary datums which relate the separation of the continental land masses are estimated at about 100 m between the United States and Europe and about 300 m between the United States and Asia.

These uncertainties are reducible by several techniques, such as the ANNA satellite which has been operating successfully for about two years. The ANNA satellite is limited, however, to cooperative measurements made from two or more sites on the ground. This severely limits the areas that can be surveyed and mapped. Alternatively, one can utilize a satellite that overflies portions of the earth's surface and maps in great detail the surface between its orbital trace. The uncertainties in this method can be reduced to the level of the major limiting error which is the uncertainty in the spacecraft ephemeris. The ephemeris uncertainty is due primarily to errors introduced by variations in the earth's atmosphere for low-orbit spacecraft and to tracking uncertainties for the ground-based radars that determine the ephemeris. With adequate care, however, these errors can be reduced significantly below the present uncertainty in the primary datums, and will permit an extensive mapping of the region overflown by the spacecraft.

One approach being considered for the Manned Orbital Laboratory to accomplish this geodetic survey is described in Appendix A. The purpose of this report is to describe the techniques and equipment necessary to accomplish the mapping experiment described. Other approaches will be examined for the MOL experiment.

II. EXPERIMENTAL METHOD

The experiment is intended to determine accurately the location of a series of selected landmarks, such as established geodetic control points, rivers, lakes, or unique terrain, and to establish very accurately location and elevation with respect to a primary control station. In order to do this, it is necessary to establish an accurate ephemeris for the spacecraft which can be used with equipment in the spacecraft to determine the angle to the identified point and its elevation with respect to the spacecraft orbit.

Figure 1 is a simplified representation of the method. In this figure, the spacecraft is located at S and the particular point to be identified is located at C. The radius from the center of coordinates to the spacecraft is known, as is the angle ϕ with respect to the control point A. In order to

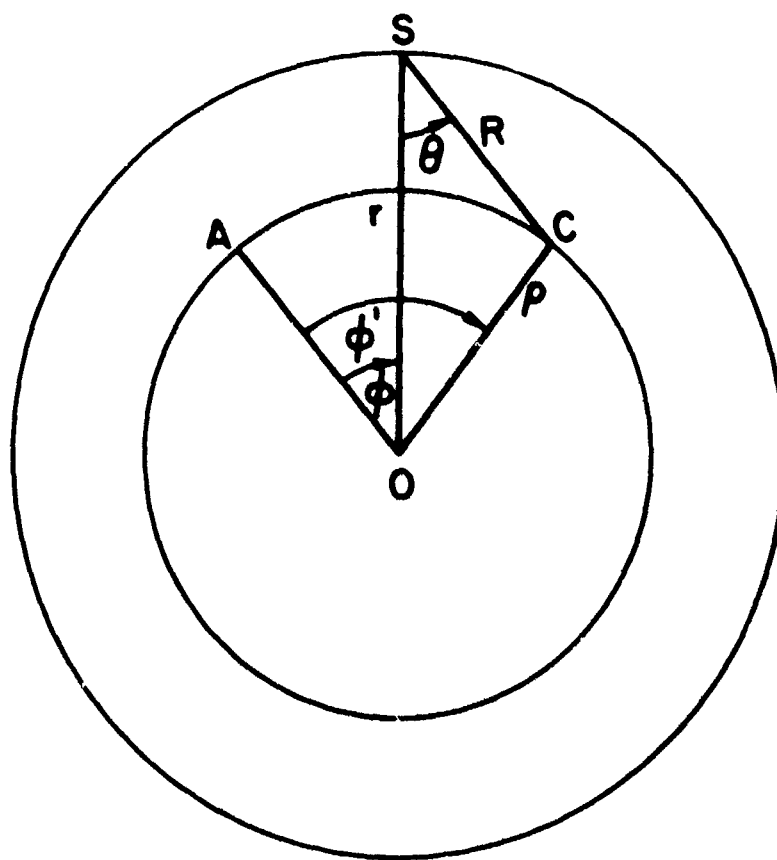


Fig. 1. Representation of method of determining position of point from satellite.

accurately determine the coordinates for C, it is necessary to establish accurately the angle θ between the spacecraft radius and the point to be determined at C as well as the range, R, from S to C. Since the ephemeris is not capable of determining the aspect of the spacecraft with respect to the radius, it is necessary to determine θ , as well as R, from independent measurements. This determination is made by means of a camera on the satellite that simultaneously and coaxially photographs the star-field and the point C on the ground; this measurement determines θ . The range, R, is determined by a laser ranging device that measures the transit time from S to C and back.

A series of points to be identified are observed on the orbital trace, and star-field photographs and ranging data are obtained. In addition, an accurate time of transit between points is determined to establish the distance between the points.

At a spacecraft altitude of 200 n mi, the estimated errors for locating the spacecraft can be reduced to approximately a few hundred feet. The error depends primarily on the number of tracking stations employed that determine the interpolation of the ephemeris between stations, which is the major contributing error. Considerable study is required to establish this error accurately. However, the data can be carefully analyzed after the flight to further refine the ephemeris.

The methods of obtaining the photographs of the star-field and the requirements for the laser ranging device represent the presently available capability and present no difficulty in obtaining accurate photographs and ranging information. These methods are described in detail below.

III. SHORT-DURATION STAR PHOTOGRAPHY

In lieu of experimental data, it is possible to make some reasonably good calculations of the exposure times required to photograph stars from above the atmosphere. The exposure time, τ , can be expressed as:

$$\tau \text{ (sec)} = A \text{ (cm}^2\text{)} / S \text{ (cm}^2\text{/erg)} P \text{ (erg/sec)}$$

where P is the stellar power collected by the camera objective and focused on the film, A is the area of the stellar image, and S is the sensitivity of the film.

The area of the stellar image, A , depends upon the focal length and angular resolution of the camera and upon the linear resolution of the film. For example, consider a camera with a 6-in. -diam objective and a focal length of 80 in. Such an instrument can be made to have resolution that approaches the diffraction limit. The widely used Rayleigh expression for maximum theoretical resolution is:

$$\theta_0 = 1.22 \frac{\lambda}{D}$$

For $\lambda = 5000 \text{ \AA}$ and $D = 15.25 \text{ cm}$, one obtains $\theta_0 = 4.00 \times 10^{-6} \text{ rad}$. Therefore, let us assume a resolution of $4.85 \times 10^{-6} \text{ rad}$ for this camera, i. e., an angular resolution of 1 sec of arc. The diameter of the stellar image is then $(4.85 \times 10^{-6}) \times (\text{focal length of the camera}) = (0.985 \times 10^{-3} \text{ cm}) \approx 10 \mu$. Then,

$$A = \frac{\pi}{4} (0.985 \times 10^{-3})^2 = 0.76 \times 10^{-6} \text{ cm}^2$$

It is clear now that a film with a resolution of 100 lines/mm is required in order to match the resolution of the camera. This resolution is typical of films referred to as fine-grain, high-resolution film. As an example, consider

even on clear nights. Finally, there will always be some sky glow to fog the film. In brief, then, photographs taken from below the atmosphere require an increase in exposure time over those taken above the atmosphere. The amount of this increase is variable, and is expected to range from a factor of two to a factor of 40 on clear nights.

Now recall the above calculations based on a 6-in. -aperture camera. For an average zeroth-magnitude star, an exposure time of 3.3×10^{-5} sec was required. This means an exposure time of 3.3×10^{-4} sec for a second- to third-magnitude star. These calculations were made for photographs taken above the atmosphere. These calculations can be partially confirmed by considering the ANNA satellite, which is presently being photographed from the ground through the earth's atmosphere. It has been shown that the exposure must be increased two to 40 times when photographs are taken from below the atmosphere. This means a range of exposure times from 6.6×10^{-4} to 1.3×10^{-2} sec to photograph second- to third-magnitude stars. ANNA looks like such a star for about 1×10^{-3} sec. Therefore, our calculations say that ANNA would be photographed with our supposed system under the best atmospheric conditions, but that the system would fail under average or poor conditions. Another way of expressing these calculations is to say that a 5-in. aperture would be required to photograph ANNA under optimum conditions, and about a 20-in. aperture to consistently obtain good pictures.

These calculations are well verified by the results obtained by various aperture cameras that attempted to photograph ANNA. The smallest instrument to successfully photograph ANNA was the BC-4 (4.5-in. aperture), and it required very good conditions. Much greater success was obtained with the PC-1000 (8-in. aperture), and the satellite has been consistently photographed by the Baker-Nunn camera (20-in. aperture).

IV. LASER RANGING

The proposed ranging system will use a ruby laser in the giant pulse mode. Present capability for this laser indicates that approximately 0.5 J can be radiated during a 100 nsec pulse with an angular divergence of 3×10^{-4} rad. If this capability can be improved it is desirable to do so; however, the calculations are based on these values. For this pulse duration and power, the capacitor energy needed is about 400 J, assuming an efficiency of 0.12 percent, which is typical. The capacitor size when operating at 10,000 V will be

$$C = \frac{2E}{V^2} = \frac{800}{1 \times 10^8} = 8 \mu F \quad (1)$$

The small efficiency of 1.2×10^{-3} for the capacitor energy is based on typical laboratory performance for lasers.

For high energy-to-weight capacitors such as the Cornell-Dubilier type NRG-121, one can get about 11 J/lb; thus, for 400 J the capacitor will weigh 36 lb. The NRG-121 has a volume of $3.29 \times 10^3 \text{ cm}^3$ so that the energy density is $4.7 \times 10^{-2} \text{ J/cm}^3$. This gives a volume of $8.4 \times 10^3 \text{ cm}^3$ for 4000 J, or a cube approximately 8 in. per side.

To determine the irradiance at the earth due to the laser, a 200-mi range is assumed. With an angular divergence of 3×10^{-4} rad, the spot diameter is 0.06 mi and the illuminated area $2.8 \times 10^{-3} \text{ mi}^2$, which gives an irradiance of

$$H_\lambda = \frac{5.0 \times 10^6}{7.52 \times 10^7 \text{ cm}^2} = \frac{6.7 \times 10^{-2} \text{ W}}{\text{cm}^2 \cdot \Delta\lambda} \quad (2)$$

where $\Delta\lambda$ is the spectral bandpass of the ruby laser line which will be much narrower than the spectral bandpass of any filter that can be obtained for the

detector in the spacecraft. The laser irradiance is considerably greater than the solar irradiance in a typical bandwidth for an interference filter. Near the ruby red line at 6943 Å, the solar irradiance is approximately 1.5×10^{-5} W/cm²-Å, and for a 10 Å bandpass interference filter the solar flux will be much less. The sunlight however is easily rejected by a high pass electronic filter in the detector circuit since it is essentially constant.

The spectral radiance due to the laser is calculated by assuming diffuse reflection for the earth, and an average albedo of 0.25 reported by Nordberg et al.¹ for Tiros. These values give

$$N_{\lambda} = \frac{0.25 H_{\lambda}}{\pi} = \frac{5.4 \times 10^{-3} \text{ W}}{\text{cm}^2 \cdot \text{sr} \cdot \Delta\lambda} \quad (3)$$

Since the illuminated spot on the ground is nearly that desired for a precise measurement of position, the angular field of view of the detector will be about the angular subtense of the spot and it will thus be an extended source for the detector. The illuminated area will be about 330 ft, and the angular field of the detector will be

$$\Omega = \frac{1 \times 10^5}{(2 \times 5.28 \times 10^5)^2} = 8.98 \times 10^{-8} \text{ sr} \cong 10^{-7} \text{ sr} \quad (4)$$

For such a small angular field it will be necessary to use a long focal-length lens and a small aperture with the detector, e. g., a 2×10^3 mm focal length and 0.6-mm-diam aperture. This gives an irradiance at the spacecraft due to the laser of

$$H_{s\lambda} = \frac{5 \times 10^{-10} \text{ W}}{\text{cm}^2 \cdot \Delta\lambda} \quad (5)$$

To observe the return pulse, a photomultiplier, an interference filter, and a 12-in. -diam telescope will provide the detection. Although the detector

will be used in a pulse mode, it is useful to calculate the expected signal to noise ratio for a dc mode to estimate pulse rate for the dark current. Flight qualified photomultipliers are available with a cathode quantum efficiency of about 10 percent, a current gain of 1×10^6 , and dark current of approximately 1×10^{-10} A. At 6943 Å, this corresponds to a noise equivalent power of

$$W_{\min} = \frac{I_d h\nu}{Qgq} = 1.8 \times 10^{-15} \text{ W} \quad (6)$$

where I_d is the dark current, h is Planck's constant, ν is the ruby red line frequency, Q is the photocathode quantum efficiency, g is the tube gain, and q is the electron charge. For the expected spacecraft irradiance and collector area of about 720 cm^2 , the signal power level will be approximately 3.6×10^{-7} W neglecting losses in the optics. With available filters and reflecting optics, the transmission will be about 10 percent and the signal power to the tube will be of the order of 3.6×10^{-8} W. This is many orders of magnitude above noise, which should be adequate for positive detection. However, the signal may be too small to detect during the 1×10^{-7} sec pulse and it is necessary to determine this.

Since the above calculation assumes dc operation and integration times of the order of 1 sec, one must estimate the magnitude of the return pulse from calculations of the photon flux. The irradiance at the spacecraft is $H_{s\lambda} = 5 \times 10^{-10} \text{ W/cm}^2\text{-}\Delta\lambda$ and the collector area is 720 cm^2 , so that $W_{s\lambda} = 3.6 \times 10^{-7} \text{ W}$. At 6943 Å, $h\nu = 2.85 \times 10^{-19} \text{ J}$ per photon and the flux of photons is

$$F = \frac{W_{s\lambda}}{h\nu} = \frac{3.6 \times 10^{-7}}{2.85 \times 10^{-19}} = 1.26 \times 10^{12} \text{ photons/sec} \quad (7)$$

For the assumed pulse width of 1×10^{-7} sec, the total number of photons received will be 1.26×10^5 , of which approximately 1.3×10^3 will be converted into photocathode electrons per pulse. Such a pulse of current can be

readily detected and accurately timed by methods that are standard practice in high-energy physics. The above calculations show that dark current noise pulses are unlikely to be troublesome; however, if it is necessary, the effect of this noise can easily be eliminated by using coincidence techniques.

V. CONCLUSIONS

On the basis of these calculations, it is concluded that star-field photographs can be obtained to determine the spacecraft aspect angle, θ , and that a laser ranging device can be used to determine the altitude of the particular point with respect to the orbit. All of the assumptions inherent in the calculations are based on presently available equipment and standard laboratory practice and do not represent excessive requirements or new developments of components. By resorting to techniques that are presently in use in high-energy physics, one can obtain considerable improvement with respect to the laser ranging device. However, it is not expected that this improvement will be required. It is presumed that in the conduct of the experiment, actual flight tests from airplanes can be conducted to field test the apparatus and that these tests, rather than the simple calculations included here, will be the basis for instrumental design. These calculations provide only an approximate answer but justify continuing the development of the experiment along the lines previously proposed.

REFERENCE

1. W. Nordberg, et al., J. Atmospheric Scis. 19, 20 (1962).

APPENDIX A
MAPPING AND GEODETIC SURVEY FOR IDENTIFIED POINTS

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February 14, 1964

ABSTRACT

Uncertainties in identified points in the Soviet Union and China are typically 1000 to 5000 ft. For special cases the uncertainties may be as great as 10,000 ft. A photographic and laser radar mapping from a manned orbital laboratory will provide maps and identified points related to major geodetic datums which will have uncertainties of a few hundred feet. A strong contribution will be provided by the man who will carefully select permanent objects such as large lakes, rivers, cities, mountains, and other distinguished terrain for establishing a network of identified points which can be used for cartographic and geodetic mapping.

I. Test Objective

This experiment will achieve a great improvement in the knowledge of the ties between the various major continental datums. The results will contribute directly to a more precise knowledge of the location of positions on the earth's surface.

II. Importance of the Test

Present estimates of the uncertainty of positional errors of some of the unmapped areas of the earth's surface are as large as 2000 to 5000 ft. In some special cases the errors noted are as large as 10,000 ft. These errors are greater than acceptable for intermediate range ballistic missiles and constitute a problem for intercontinental range ballistic missiles. Because of the difficulty of flying over portions of the earth's surface in an airplane or balloon, only a satellite is acceptable for accurately mapping these unknown regions. The ANNA satellite, which was successful in mapping areas with an extensive cooperative ground-based observing system, considerably improved geodetic knowledge. However, in large areas, such as the Soviet Union and China, where cooperation is not probable, good positional accuracy has not been realized.

For a manned spacecraft, such as MOL, whose ephemeris is accurately known and where the principal errors contributing to a mapping operation are of the order of a few hundred feet, one can conduct a complete mapping of any region. The uncertainty in such a map will be the uncertainties in the spacecraft ephemeris and the ability of a man to accurately point a camera and laser radar at a well-identified point on the ground. The experiment described here will satisfy an immediate military requirement of locating positions on the earth to within a few hundred feet. It will provide a secondary scientific purpose by accurately relating major datums of the continents and improving the present knowledge of geodesy. It will greatly assist in assessing man's capability of performing an experiment in space.

III. Description of the Experiment

The experiment will determine the position of permanent landmarks such as rivers, lakes, continental boundaries, and distinguishing terrain, by measuring their absolute position and the separation distance between bench marks. These measurements are obtained from an accurately determined ephemeris of the spacecraft and from devices for measuring the range from the spacecraft to the point of interest and the angle of the spacecraft with the radius from the center of coordinates. This will determine the angle and radius of the point with respect to a primary datum that is already established. The uncertainties in the ephemeris and in the range- and angle-measuring devices are such that the positional accuracy can be made as low as several hundred feet.

The experiment consists of a special camera which photographs a point on the ground and, simultaneously, the star field along the line of sight. The range from the spacecraft to the point is determined by means of a giant pulse ruby laser and counter. This determines the absolute position of a point with respect to the spacecraft ephemeris. Points of separation between two objects can be determined with the camera and a crystal clock which determines the transit time between the two points. This will permit an extensive mapping of a region with high internal precision and with accurate reference to an external datum point. The most significant problem that is expected to be encountered in this measurement is that of identifying the targets on the ground with sufficient accuracy for mapping purposes. However, with the aid of an auxiliary optical system that will be a part of the spacecraft, it is expected that this problem will be resolved.

a. Configuration of Test Items

The principal items of test equipment to be used for the geodetic experiment are: (1) a camera, Fig. A-1, which will simultaneously photograph a position on the ground with sufficient resolution to identify the object photographed on which is superimposed the star field on the optical axis.

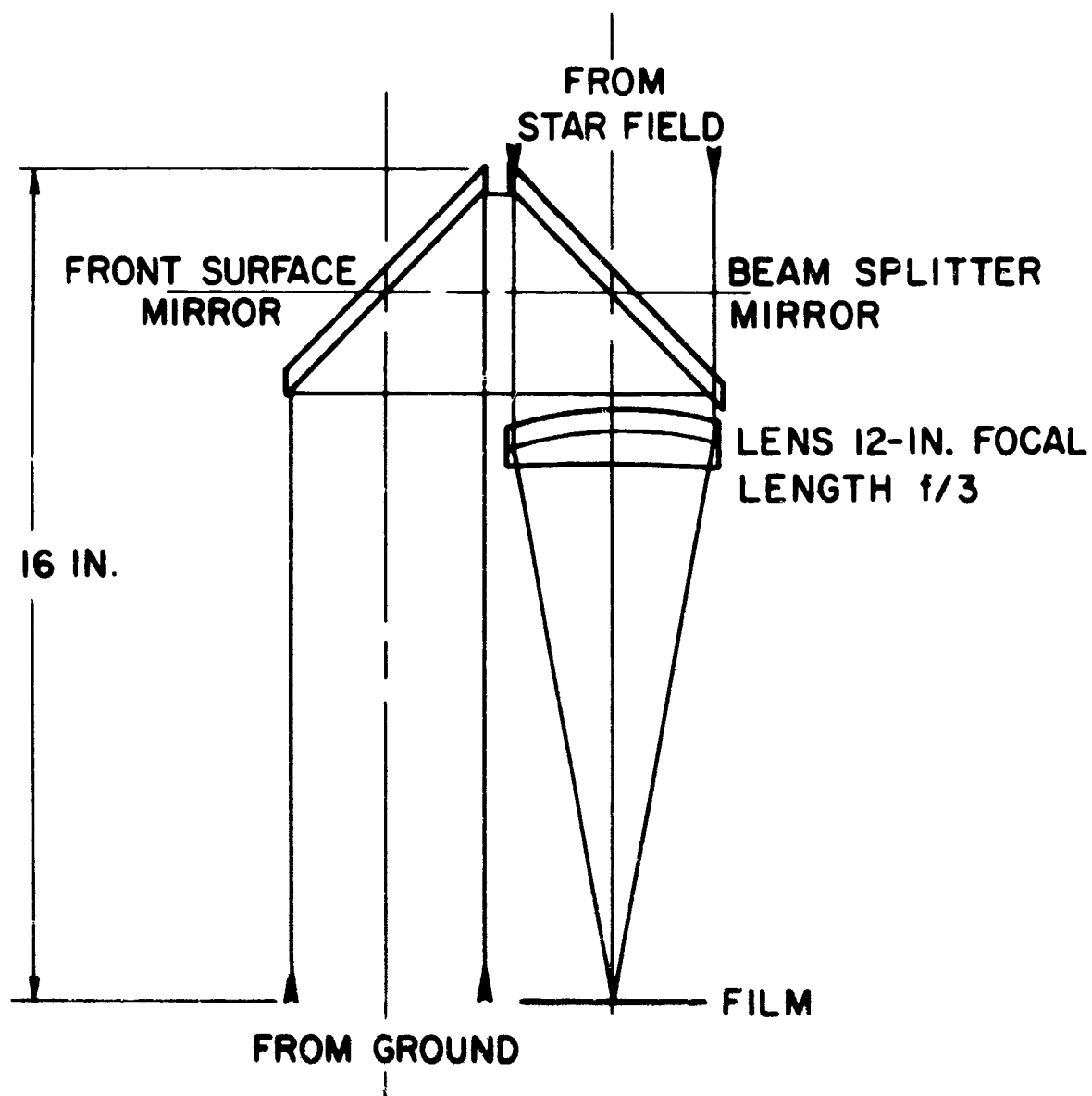


Fig. A-1. Boresighted camera for simultaneous photography of star field and ground.

Additional instruments are rectangular boxes whose dimensions are given on the following page. These instruments can be made to conform with available racks.

(2) a laser range device, consisting of a capacitor, high-voltage power supply, electronic circuitry, and ruby laser, which will determine the range from the spacecraft to the ground, and (3) a 50 Mc counter to measure the transit time of the light pulse from the spacecraft to the ground and back. In addition, the separation distance between two points on the ground can be accurately determined by using the camera and a precision crystal clock to determine the transit time between the points. Since the camera is required to observe the earth, it will be necessary to locate this item and the laser head on the MOL in such a fashion as to permit it to view simultaneously the ground and the star field. Attachment I gives the design characteristic details.

Physical dimensions of the equipment are as follows:

<u>Item</u>	<u>Dimensions (in.)</u>	<u>Weight (lb)</u>	<u>Power (W)</u>	<u>Volume (ft³)</u>
Camera	6 × 12 × 12	25	1	0.5
Capacitor	8 × 8 × 8	36	0	0.3
Power supply & electronics	2 × 4 × 6	2	2	0.03
Laser head & mirror	4 × 4 × 5	1	0	0.05
Counter & clock	5 × 17 × 19	43	100	0.93

These items may be placed at any convenient spot on the vehicle where the camera and laser head have a view of the ground.

b. Test Support Equipment Required

(1) Spacecraft

In addition to the equipment described, the support of an auxiliary optical system to identify objects on the ground and to point the camera and laser at the same point is required.

(2) AGE

Range support to accurately establish an ephemeris for the vehicle and checks on the crystal clock on board to maintain time accuracies to 1 msec are required. Attachment II describes the test support equipment in detail.

c. Test Procedure

It is planned to observe a large network of identified objects on the ground to establish a map which is internally accurate from the clock measurements and to relate one or more points of the map to one of the major datums in the United States. To accomplish this, the astronaut will have to identify major and minor landmarks which are permanent, such as large lakes, rivers, cities, or other distinguishing terrain. Attachment III describes the test operating factors. Man's contribution to the experiment is in the identification and selection of significant areas and objects to be mapped. He will be utilized to the maximum extent possible in making decisions on the importance of the objects he identifies for mapping and the care with which he makes the measurement. His contribution will be measured by the quality of the map he produces.

d. Category of Experiment

The geodesy experiment will be part of the primary experiment on autonomous navigation and geodesy.

*f. Schedule

(1) Hardware and Software Available for Test

Prototype hardware will be constructed during FY65 and available for test during FY66.

*The numbering system conforms with Air Force format instructions for preparation of the appendix; missing numbers do not apply.

(2) Hardware and Software Flight Readiness Date

Flight ready equipment will be available beginning with FY67, tested and flight qualified.

V. Additional Requirements

a. Special Security

Special processing of the data will be required in view of this importance to identification of possible target areas in the Soviet Union and China land areas.

b. Logistics

No special requirements.

c. Facilities

Existing facilities can be used for the experiment integration. Coordination with the national range and SSD satellite network will be required to obtain an accurate ephemeris. It is expected that training of the astronaut will require use of a flight simulator, but only for the purpose of instructing the astronaut in the use of the equipment.

d. Simulation and Training

(1) Astronaut

The astronaut must be trained to the level of a technician in order that full effectiveness is achieved in this experiment. It is expected that a few weeks training in photo-reconnaissance work and in astronomical observation techniques will be adequate to develop a capability necessary for the experiment.

(2) Ground Personnel

No requirement.

(3) Equipment

The equipment to be used in the experiment will be utilized in training the astronaut.

VI. General

a. Communications

Communications will be limited to discussions with specially informed ground-based personnel on particular areas to be observed. This will involve someone with knowledge of the land mass expected to be surveyed. Data will be recorded on film and magnetic tape and will be required to be recovered with the re-entry vehicle. Attachment VI describes the data recording requirements.

b. Development Characteristics

No additional requirements. The development time is specified in Attachment VII.

ATTACHMENT I

1. LASER RADAR AND GEODETIC CAMERA

2. WEIGHT

107 lb

3. VOLUME

Stored, 1.81 cu ft; in use, 1.81 cu ft

4. CRITICAL DIMENSIONS

<u>Item</u>	<u>Dimensions (in.)</u>
Camera	6 × 12 × 12
Capacitor	8 × 8 × 8
Power supply & electronics	2 × 4 × 6
Laser head & mirror	4 × 4 × 5
Counter & clock	5 × 17 × 19

5. SPARES

Volume: 3.62 cu ft

Quantity: 2

Weight: 200 lb

6. TOOLS

No requirement

7. HEAT OUTPUT

100 W with 1/10 duty cycle

8. STABILITY

No requirement

9. VIBRATION LIMITS

20 g

ATTACHMENT I (Cont.)

10. SHOCK LIMITS

30 g

11. HAZARDS

Electrical, 10 kV power supply

12. TEMPERATURE LIMITATIONS

No requirement

13. TYPE AND RANGE OF MEASUREMENT

Ground-based photography and laser radar ranging

14. SPECIAL ENVIRONMENTAL REQUIREMENTS

No requirements

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS

Accurate ephemeris and accurate time evaluation

16. EQUIPMENT OPERATING CYCLE

Several times daily; time duration: 15 min

17. EQUIPMENT LOCATION REQUIREMENTS

Camera requires access to ground and stellar background

18. SPECIAL MOUNTING REQUIREMENTS

Apertures: Clear view of ground and stars

Pulse: None

Windows: None

Antennas: None

Bracketry: Mountings for camera, laser, and power supply

ATTACHMENT I (Cont.)

19. PRESSURE VESSELS

No requirements

20. ELECTROMAGNETIC INTERFERENCE

No requirement

21. MAINTENANCE REQUIREMENTS

No requirement

ATTACHMENT II

1. RECORDING MEDIA

Tape recorder required to store laser range data

Film required to obtain ground and stellar photographs

2. HANDLING

No requirement

3. PACKAGING

No requirement

4. CALIBRATION

Accurate crystal clock with comparison with ground clock

5. JIGS AND FIXTURES

Mounting jig for camera and telescope

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION

None

7. SENSORS

One photomultiplier for laser radar

8. TRAINERS/SIMULATORS

Flight training program for astronaut on airplane or balloon

9. INSTRUMENTATION

Telescope for guiding camera and identifying ground based objects;
may be time shared with other experiments

10. RELATED SUPPORT EQUIPMENT

Simulated ground based target

Communication with specialists on ground

ATTACHMENT II (Cont.)

Accurate tracking to establish very good ephemeris
Film recovery and processing required

11. AGE

Time calibration and position-indicating equipment

12. ENVIRONMENTAL TEST EQUIPMENT

No requirement

13. FACILITIES

No requirement

ATTACHMENT III

1. ORBITAL PARAMETERS

Altitude: 200 mi

Inclination: Polar desired

Epoch: No requirement

Ellipticity: Circular preferred

2. PLANE CHANGE

No requirement

3. ALTITUDE CHANGE

No requirement

4. TIME ON ORBIT

30 days desired

5. TEST DURATION

3 days

6. TOTAL NUMBER OF TESTS

100

7. TEST FREQUENCY

Daily

8. INTERVAL BETWEEN TESTS

When orbit permits survey of area to be mapped

9. CREW TASK LOADS

0.3 of a man month

10. CREW TASK FREQUENCY

Daily

ATTACHMENT III (Cont.)

11. FIELD OF VIEW REQUIREMENTS

2 deg view of earth and stars

12. GROUND CONTROL LIAISON DURATION

10 min

13. GROUND CONTROL LIAISON FREQUENCY

Each orbit

14. EXTERNAL TEST ITEMS

No requirement

15. QUALIFICATION TESTS

Shock and vibration for launch; life test for laser and power supply;
shock and vibration qualification of 30 g or less

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT

Photographs taken of terrain during passage over territory to be mapped

Check of clock and ephemeris on each orbit to maintain precise ephemeris

Removal and return of film at conclusion of flight

17. HANDLING PROCEDURES

Recovery of film and magnetic tape record and special processing

ATTACHMENT VI

1. DATA RATE

Ten photographs recorded each orbit

Transit time between 10 points recorded each orbit

2. FUNCTIONS TO BE MEASURED

Time, position, and aspect angles

3. TYPE OF ANALYSIS REQUIRED

Photographs of geographic terrain

4. PICTORIAL DATA REQUIRED

Reconnaissance photographs of geographic terrain

5. REALTIME MONITORING REQUIREMENT

Crystal clock and ephemeris monitoring required

6. DATA EDITING OR COMPRESSION

Data edited to correlate ephemeris, photographs, and stellar aspects

7. READOUT TIME

Data readout on passage over ground support station

8. REQUIREMENTS FOR PERMANENT DATA RECORDS

Photograph and aspect records permanently recorded

9. MANUAL AND/OR AUTOMATIC CONTROL

Manual control of camera; automatic control of time

10. SIMULTANEITY

All events require correlation in time

11. GROUND COMMANDS REQUIRED

Identification of proper targets to be photographed; correlated with ground

ATTACHMENT VII

1. DEVELOPMENT TIME

Development time required to design and build camera and laser radar: approximately two years

2. FINAL DEFINITIVE TEST DESIGN TIME

One year required for final flight model

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED

Several ground and flight tests to familiarize astronaut with operation of equipment

4. TYPE OF DEVELOPMENT TEST ITEMS

Vacuum test required if camera operates outside of spacecraft

Shock and vibration test for booster-induced environment

Thermal cycling dependent on location of camera on spacecraft

Normal vibration during boost to orbit

Star-field and terrain radiance simulation for ground-based training of astronaut

Aircraft flights to familiarize astronaut with equipment and flight condition.

5. SUPPORT EQUIPMENT DEVELOPMENT TIME

One year to develop stellar/terrain simulator

6. NUMBER OF TEST ARTICLES REQUIRED

One ground test instrument required

One instrument for aircraft test

Four instruments required for flight qualification, prototype installation, flight instrument and back-up.

7. DATE AVAILABLE FOR TESTS

FY67

8. CURRENT DEVELOPMENT STATUS

Proposed only

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