FACILITY FORM 602
N64-27802
(ACCESSION NUMBER)
37
(PAGES)
TMX-51878
(NASA CR OR TMX OR AD NUMBER)
(THRU)
1
(CODE)
15
(CATEGORY)

# SPACE AND THE MOON - PHOTOGRAPHY'S CHALLENGE FOR TOMORROW

37 p.

By

code 1

cat.

John M. Eggleston
John R. Brinkman
NASA Manned Spacecraft Center
Houston, Texas

To Be Presented at
The Society of Photographic Instrumentation Engineers
9th Annual Technical Symposium
Miami Beach, Florida
August 25, 1964

OTS PRICE

XEROX $ 3.60 ph.
MICROFILM $ ______

## REQUIREMENTS FOR MANNED SPACEFLIGHT AND LUNAR PHOTOGRAPHY

### Introduction

Man's expansion into the realm of space has opened new horizons and posed new challenges to the photographic industry. Part of the challenge has already been answered with the camera requirements for the Mercury program. In the Gemini program, two new cameras are being developed to increase man's capability to take photographs from spacecraft. Project Apollo, the manned lunar landing program, will require a technical advancement in cameras, film, and developing processes.

The interest and active participation of the photographic industry is essential in developing usable cameras for lunar photography. This paper will describe some of the research programs under development and the requirements for the future, particularly in hand-held lunar surface cameras.

### History

Starting with the orbital flights, a variety of hand-held cameras have been used. John Glenn carried a 35mm Ansco Autoset, Carpenter shot with a 35mm Robot Recorder, and both Schirra and Cooper used the 70mm Hasselblad.

The results produced by these cameras are interesting since it marked the start of a series of camera improvements for manned space flight. Glenn noted that the color fidelity of his photographs did not exactly match his memory of the sunrises, sunsets, and space fireflies that he had seen and photographed. It emphasized the fact that color film was not being made to give a "true" representation of what the eye sees. Engineers became conscious of the difficulties involved in using existing cameras with space suit gloves and helmets. The size of knobs, shutter releases, film packs, and additional lenses for serial photography created a handling problem with heavy gloves in a small crew compartment. Spacecraft project office and operations personnel had to consider the safety aspects of a camera which could explode if sudden depressurization occurred. It became necessary to flight qualify all cameras, both for the launch and the space flight environment.

### Gemini Cameras

The interval between the Mercury and Gemini flights has given time to survey Mercury experiences and prepare for both Gemini and Apollo.

Gemini photographic requirements promise to be heavy. Table I lists Gemini photographic experiments. The expression "GT" refers to the Gemini-Titan launch number, GT-4 is the second manned orbiting flight, with a launch date of 1965. Only photographic experiments are outlined here, although other types of experiments will be flown.

To provide this photography, a number of new cameras are being developed. Some are being developed by the individual experimenter. For several experiments, J. A. Maurer Company is under contract to the Manned Spacecraft Center to construct a general purpose still camera. Its features are described in Table II.

In addition to the still camera, a time sequence or motion camera is also being developed for operational photography in the Gemini mission. This contract, also won by J. A. Maurer Company under open bid, will provide sequence pictures of such activities as rendezvous, docking, astronaut extra-vehicular excursions and earth reentry. Table III lists the characteristics of this camera.

## Apollo Cameras

There will probably be four cameras involved in the Apollo lunar landing missions. These are:

(1) A hand held still camera for scientific photography on the lunar surface and in cislunar space. Camera and film must be qualified for extra-vehicular activity. The requirements for this camera are the principal subject of the second half of this paper. A study of the development of this camera was recently released for industry bids.

(2) A time sequence (motion picture) camera to record operational activities such as spacecraft transposition during rendezvous and docking and astronaut movements and mobility on the lunar surface. The camera and film are designed for internal use, but will be vacuum qualified. This camera will probably be identical to the Gemini sequence camera described in Table III.

(3) A television camera for use on the lunar surface to provide live television images of the surface and monitor some astronaut activity. It will operate in lunar day or night conditions, using an 80-ft extension cable. Frame rate is 10 fps, and the image is a 320 line rasters per scan. It uses both fixed and zoom lenses, with a 20-80mm extension. The field of view is 70 degrees.

(4) A large format, high resolution camera to be used in the command module for reconnaissance photographs of the lunar surface. The camera and film will be designed for internal use only but will

be vacuum qualified. It will probably be an off-the-shelf aerial camera such as the KC-4 and still be required to meet the flight qualification tests for Apollo. The desirable characteristics of this type of camera are its 6-inch focal length GEOCON 1 lens capable of using its full F/5.6, its format size of 9 inches by 9 inches, and its shutter speed range of $\frac{1}{25}$ to $\frac{1}{400}$th sec. Other features include a magazine of 390 feet of $9\frac{1}{2}$-inch film, its resolution of 30 lines/mm, a package size of 2 cubic feet or less, and a ground resolution of approximately 93 feet from 80 nautical miles altitude.

## Mission Profile

A typical Apollo mission profile will use the four onboard cameras as follows:

(An illustration of the various modules referred to in the mission profile is shown in fig. 1.)

After full flight qualification and reliability tests on identical models, flight cameras and film will be placed onboard the command module as early as six weeks prior to flight, depending on the capability of the film to withstand the pre-launch environment. The environment before and during launch may be hot and humid (up to 140° F and 100 percent humidity).

Following launch from Cape Kennedy, the command module, the service module, the lunar excursion module, (LEM), the adapter and S-IVB booster stage will be in earth orbit for 2 to 4 hours before injection into the translunar orbit. Shortly after injection into the translunar trajectory, the command and service module will detach from the rest of the booster, turn around (transposition), dock with the LEM and drop off the adapter and S-IVB booster.

About 70 hours after launch, the Apollo spacecraft will arrive at the moon and inject into lunar orbit by firing the service module engine as a braking rocket. While in lunar orbit, two of the astronauts will transfer into the LEM, taking the hand held camera, film, time sequence camera and accessories with them. After two orbits of the moon for orbit determination, the LEM will separate and descend to the lunar surface. The astronaut who remains in orbit will photograph the lunar surface with his survey camera. The astronauts in the LEM, one at a time, go out on the lunar surface to explore and conduct scientific experiments.

The first astronaut out will set up a telemetry antenna and then plug the TV camera into the LEM S-band link by means of the 80-foot extension cable. Once the TV camera is in operation, he will pan the lunar surface and set the camera on the LEM to cover his lunar surface activities. This camera will continue to operate for about 1 hour. Then the astronaut will survey the surrounding terrain using a hand held still camera to photograph the general surface and individual rock samples prior to collecting these specimens and setting up passive experiments. During these activities, the astronaut in the LEM cockpit will be photographing the astronaut on the lunar surface with the time sequence camera to record his mobility and activities. All conversation between the two will be recorded on tape along with a digital recording of time. This correlation of activity with time is particularly important as well as the photographic history of each sample before its removal from its natural surroundings. This relation and orientation of the sample to its surroundings and to the lunar north pole (or the ecliptic) is important to the geologists. Since the appearance of the sample may change upon return to earth, original appearance must be carefully recorded on film. Distant terrain will be photographed for relationship to landmarks (if any) and for general information.

During the approximately 35-hour lunar surface staytime, four to six excursions of 3 hours duration each will be made onto the lunar surface. Sleep requirements will be accommodated between excursions such that one astronaut is always on duty in the LEM during periods when the other is on the surface. At the conclusion of the planned surface activities, launch will occur. The TV camera will be left inoperative on the lunar surface. One hour later, the LEM will rendezvous in lunar orbit with the command module. The sequence camera is used to photograph this rendezvous. Film, tape, and rock samples will be transferred from the LEM to the command module while excess equipment will be put into the LEM and left in lunar orbit. Depending on the weight of the rock samples and the weight allowance for earth return, it may or may not be possible to return one or more of the cameras to earth. They will be returned only if they are desired for photography during the transearth and reentry phases of the mission.

After transfer of excess equipment to the LEM, the command module and service module detach from the LEM. About 2 hours after rendezvous, the service module engine is ignited and injection into the transearth trajectory takes place. About 90 hours later, entry into the earth's atmosphere takes place. During this phase of the mission, high accelerations (8 to 10g), high temperatures (up to 140° F in the cockpit equipment section), and high landing loads (up to 72g for earth impact) may be experienced. All scientific equipment carried during this phase of the mission must be designed and tested to survive these conditions. Following recovery (probably from the Pacific Ocean) the film tape and scientific samples and data will be dispatched to MSC, Houston for processing and distribution to authorized sources.

## Lunar Environment

To produce a clear usable record of the mission, lunar surface cameras must be able to operate under a number of adverse conditions which may exist at a lunar landing site. First, there is the operating environment itself. The moon has an atmosphere with a pressure of less than $10^{-10}$ mm Hg and with temperatures ranging from 114° C at the lunar high noon down to -186° C just before lunar dawn. Just after dawn, the temperature rises at a maximum rate of 11° C per hour. Since there is no convection of heat, any heat generated must be carried away by conduction or radiated to a cooler surface.

Due to the lack of any significant lunar atmosphere, the lunar surface is completely exposed to external sources of energy such as cosmic rays, ultraviolet radiation, and meteoritic particles. Their energy is unattenuated or unabsorbed as it is by the earth's atmosphere. The moon has no detectable (less than $10^{-3}$ gauss) magnetic field and no trapped (Van Allen) radiation belt to absorb the proton and alpha particles that are released by occasional solar flares. Each of these factors can significantly affect the ability to use a camera and bring back acceptable film. Fortunately, most of these undesirable factors can be offset by careful design.

However, implications of this environment as it affects photography on the moon must be considered carefully. The lack of an atmosphere is most significant. Ordinary lubricants cannot be used to reduce friction, mechanical parts will bind, very small components may be welded by Van der Waal attractions, and electrical arcing will find no atmospheric resistances. (In fact, flash or light bulbs no longer need a globe to hold a near vacuum for the electrical filaments to glow). These problems (or advantages) are not unique to the photographic industry, and most of them have been or are being solved.

There is one characteristic associated with the near vacuum on the lunar surface which may be extremely important to photography. There will be virtually no diffusion of light. Since the lunar surface itself is a poor reflector, the subject material for photography will be either in full light or in full and complete shadows. It might appear to offer photographic subjects with very high contrast. The results may be very drab since the moon appears to be homogeneously dark (low albedo) and shows very little contrast between visible areas. Furthermore, the reflectivity of the lunar surface indicates that for a person standing on the surface, reflected light intensity (luminosity) falls off very rapidly with increasing distance from the sub-light point. To illustrate this phenomenon, certain terms must be defined and related: luminance reflectivity, albedo and contrast. Luminance is regarded as reflected light from a surface; the latter three are generally lumped together by photographers and called "texture". The luminance of the lunar surface under all conditions of illumination and viewing can be expressed in terms of the normal albedo, the luminance for normal illumination, and by introducing the factor $\phi$. Thus

$$B = \frac{E}{\pi} \rho \phi$$

Where B = luminance of the observed lunar surface in candles/ft$^2$

E = solar constant = 12,450 lumens/ft$^2$

$\rho$ = the normal albedo of the lunar surface = 0.073 out of a theoretical maximum of 1.0

$\phi$ = proportionality factor, known as the "photometric function" which depends on the variation of the angle of incidences and the angle of emittance.

If measurements are made of the light reflected by a typical area at the center of the moon during a lunar day (about 29 earth days) there is found a variation in luminosity (B) shown in figure 2. At lunar high noon, the brightness of the lunar surface is about equal to the measured luminance of average subjects here on earth on a clear bright summer day. Photography, even in full earth-shine (light reflected by the earth) may be possible at about 0.027 candles per square foot (note the change in scale). For comparison, moonlight reflected off the earth produces only 0.0017 candles per square foot. Because of its cloud cover, the large water areas, and its size, the earth is a better reflector of light than the moon by a factor of about 70.

The observed photometric model ($\phi$) of the moon is quite unusual. Figure 3 presents a schematic drawing of the intensity of light reflected with normal illumination on the lunar surface and on a Lambert surface. Such a variation would be obtained by first illuminating a small section of the moon from an infinite distance and then walking around it with a photometer and plotting the relative illumination at each position. The process is then repeated for a material which reflects as a Lambert surface. (The lunar photometric model as observed from earth is actually three dimensional, but is illustrated here in two dimensions for simplicity.)

This diagram reveals that the light reflected from the lunar surface falls off quite rapidly as the phase angle (the angle between the incident and reflected rays) increases. This unusual reflecting property of the lunar surface is one of the many perplexing characteristics of the moon yet to be fully understood. On earth, most surfaces such as typing paper, sand, wood, grass, etc., reflect light diffusely like a Lambert surface. For a Lambert surface, light does not fall off with increasing phase angle.

The practical effect of the lunar reflecting properties on the visibility of man and the possibility of photography is illustrated in figure 4. Taking the simplest case of normal illumination to the surface, the percentage of reflected light is given as a function of distance from the astronaut. Lunar surface material about 28 feet away from an average astronaut would have a reflected brightness only 25 percent as great as the same material directly at his feet. This phenomena is observed only in lunar material and is not a magic transition which occurs when foreign objects are taken to the moon. They will still reflect as Lambert surface or near-Lambert surfaces.

An artist's rendition of how the photometric model on the moon will appear under earth-shine illumination is shown in figure 5. The scientific instrument package is in the foreground and the lunar excursion module is in the background. When the astronaut is taking photographs, the area in the foreground will require an exposure different from the area near the horizon by a factor of 2. If the film used in the camera should not have a broad exposure latitude, then large area photographs may create a problem.

There are many other environment factors such as radiation which may affect photographic quality and may require special provisions such as onboard processing. Full discussion of these aspects cannot be included within this paper.

## DESIGN OF LUNAR SURFACE CAMERA

### Mission Criteria

The hand held camera for lunar operations is a prime consideration for development. A number of mission and camera functions for design of lunar surface camera have been listed in a recent request for proposals to the photographic industry. They take into consideration the environmental and mission characteristics mentioned earlier. The camera design should permit the astronaut to obtain many types of photographs with a stabilizing support where required. The scientific requirements of the mission demand the following qualities:

(1) Color photographs of objects as small as 0.1mm in linear dimension with sufficient resolution and image size to make positive identification of the object's shape.

(2) Stereo pairs should be used to record physical relief conditions of the surface near the LEM, and to establish the LEM's location with respect to the surrounding surface features.

(3) Color photographs should distinguish surface features 6 feet in linear dimension at a distance of 1 mile.

(4) The ability to take photographs of the lunar surface near the LEM in ultraviolet, between 2000 and 4000A°, and in infrared, between 7000 and 10000 A°.

(5) Photographs of various celestial bodies including the Earth in µV, visible, and IR portions of the spectrum with an angular resolution of 1 second of arc.

## Environmental Test Criteria

To be useful on the lunar surface, the camera must go through a series of environmental test conditions covering the period from launch of the Saturn booster to touchdown of the lunar excursion module on the lunar surface. They include:

(1) Acceleration as much as plus or minus 20 g's for 3 minutes in three mutually perpendicular directions.

(2) Shock, 30 g's for a period of 11 milliseconds.

(3) Air pressure which varies from sea level to less than $10^{-10}$ mm of Mercury.

(4) A temperature range from minus 186° C to plus 114° C.

(5) Solar flare radiation of 600 rads.

(6) The possibility of 100 percent relative humidity including condensation for five days in a temperature range of 80 to 160 degrees Fahrenheit.

## Operational Criteria

Taking all these factors into consideration, the camera requires the following operational features:

(1) It should have three lenses: one telephoto, one special purpose lens to pass UV, and one normal focal length lens for general purpose photography.

(2) All of the lenses must be matched pairs for the stereo requirement.

(3) The lenses must have a resolution of from 150 to 200 lines/mm.

(4) The entire camera may be enclosed in a pressurized container.

(5) All adjusting knobs, levers, et cetera must be actuated from outside the pressurized container and easily manipulated.

(6) The entire camera or at least the film chamber should be protected from solar radiation and extensive variations in temperature.

(7) Film format should be either 35 or 70mm.

(8) The overall requirements suggest either a single color film with extended spectral range and one, or possibly two, black and white films.

These qualities meet the photographic requirements but lunar surface operations demand another set of features which will influence the final design. The lunar camera must:

(1) Provide a maximum of 300 different stereo pairs.

(2) Afford a minimum eye relief of 3 inches.

(3) Be operated by a suited astronaut who possesses the dexterity of a man wearing a medium weight mitten over a rubber glove (fig. 6).

(4) Be capable of being held to the face plate for periods up to 30 seconds.

(5) Endure the lunar environment for several excursions of up to 4 hours each.

(6) Have a reflex viewing system to minimize paralax.

(7) Weigh no more than 7 pounds with film and accessories and take up no more volume than $\frac{1}{4}$ cubic foot.

In an operational sense, the ability of the suited astronaut to use the camera is vital.

A fully pressurized suit will be necessary in extravehicular activities in space and on the surface of the moon. Holding any object in the same position for any period of time requires a constant exertion against the rigidity of the suit. The mobility of the astronaut under these conditions is illustrated in figure 6. Grasping small objects will be difficult; therefore, oversized or simplified operational design must be stressed in a lunar camera. Face plate support will enable the astronaut to provide a tripod-type support without undue exertion from bending the arms or wrists.

## Film

The features of the lunar camera define in some respects the type of film to be used. Consideration must be given to both the practical approach, that is, using existing films, and the most desirable approach, which is using a new, single film.

Preliminary experiments were conducted with films under earth-shine conditions in the Lunar Surface Test Chamber at MSC, Houston. These tests indicate that earth-shine illumination is so low that an extremely fast film will be needed. Color temperature simulation tests were also made and they revealed that heavy filtration will be required to obtain any degree of fidelity using present day color emulsions. It is becoming apparent that a new color film with extended spectral sensitivity, having an ASA from 10,000 to 12,000, may be needed to accomplish the mission.

Similar tests were made with combinations of existing black and white films with little more success than when color was used. It is obvious then, that if a new film design program is initiated, it should encompass the development of new accurately recording color emulsions rather than black and white emulsions.

Existing color emulsions are designed to produce pleasing color renditions of a subject to satisfy the average user rather than accurate color reproduction needed by the scientific community.

It is suggested, therefore, when a program for new color films is undertaken, that color emulsion studies be included for a film which will satisfy technical and engineering requirements as well as those of the average consumer.

The desirable qualities for lunar surface film are:

(1) A color film (negative or reversal) is needed which will reproduce colors with at least 95 percent accuracy.

(2) It should have an ASA of 10,000 or higher for photography under the worst conditions of earth-shine.

(3) It must resolve at least 200 lines/mm.

(4) The emulsion must be coated on a $2\frac{1}{2}$ mil stable base with readily removable backing.

(5) It must not out-gas or produce any toxic fumes.

(6) It must have a spectral sensitivity range of from 2,000 to 10,000 angstroms.

## On-Board Processing

On-board color processing may be necessary during the lunar mission and consideration is being given to the design of necessary equipment. Radiation levels in space may cause fogging if the film is left in the undeveloped state for the entire mission. Until the problem of radiation and its effect on photographic emulsions is more clearly defined, the development of a compact, simple-to-operate color processor should parallel the effort expended on new cameras and films.

The processor could use the viscose processing technique with enough chemicals to process the film exposed by the astronaut. The system must meet the same environmental conditions and restrictions as the camera and film. Chemical out-gassing is a major problem, making a pressurized container mandatory. The allowable volume for the processor is 2 cubic feet.

## Evolution of A Lunar Camera

Building cameras for space will be a demonstration of the photographic industry's ability to take standard parts and adapt them for a new use. Following the guidelines outlined, a lunar camera can be constructed by using individual features from existing cameras. The models mentioned are for the purpose of example only and do not necessarily imply the model's feature is the best for use in lunar camera design.

For the first step (figs. 7(a) and 7(b)), the Graphic stereo is used for stereo pairs. Since the camera must have three lenses, the turret principle from a Bell and Howell Model 70 is added (figs. 8(a) and 8(b)).

The next step is a built-in strobe and magnifier for the lenses, and the Nikon provides this feature (figs. 9(a) and 9(b)). A timing device is necessary from a flight research camera (figs. 10(a) and 10(b)). There are cameras on the market now with waterproof housings, such as the Myoflex. It is necessary to adapt this housing to produce a pressurized container which will resist the effects of vacuum and radiation (figs. 11(a) and 11(b)).

From the J28A Model of Chicago Aerial, a reflex viewer is used (figs. 12(a) and 12(b)). Added to the lunar camera, it provides built-in reflex viewing which can be used by the astronaut in his pressure suit. The Kodak Instamatic contributes an automatic light meter to the design which is also built into the new lunar camera (figs. 13(a) and 13(b)).

The final step is compression of these details into a compact $\frac{1}{4}$ cubic foot resulting in a streamlined lunar surface camera (fig. 14). The handles can be pulled out to different lengths to engage gears which can change film or filters, or lenses. The headpiece on the rear allows the astronaut to bring his face plate close to the reflex viewer and provide stability and support. The light meter and viewer are reduced in size and repositioned. It is a true space age concept – a camera to take pictures on the moon.

## Conclusion

Figure 14 is only a design concept based on mission, environmental, and operational considerations. It should not be interpreted as the final design for the lunar camera. Subsequent knowledge of the lunar surface and improvements in camera mechanical operation will refine the concept of the working model. It does provide a basis for engineering personnel in government and industry to develop a suitable camera and film to cope with conditions existing in space.

The primary mission of the lunar camera is to bring back the maximum amount of scientific information from space. The design and development of this specialized piece of equipment is the challenge for tomorrow for the photographic industry.

## TABLE I.- GEMINI PHOTOGRAPHIC EXPERIMENTS

| | | |
|---|---|---|
| Zodiacal Light<br>Special Camera - 50° × 120° field of view<br>f/1.0 - 28 mm focal length lens<br>35 mm color film | University of Minnesota | GT-5, 8, 9 |
| Synoptic Terrain<br>Hasselblad (GT-4), MSC General Purpose<br>f/2.8 - 80 mm focal length<br>70 mm, color and IR film | NASA GSFC | GT-4 thru 9<br>GT-5 thru 9 |
| Synoptic Weather<br>Hasselblad (GT-4), MSC General Purpose<br>f/2.8 - 80 mm focal length<br>70 mm, color film | U. S. Weather Bureau | GT-4 thru 9<br>GT-5 thru 9 |
| Cloud Top Spectroscopy<br>Special Spectrography - Dispersion 20A°/mm<br>Spectral Range: 7200 - 7600A°<br>35 mm, IR film | U. S. Weather Bureau | GT-5 |
| Horizon Airglow<br>MSC General Purpose - 30° field of view<br>f/0.95 - 50 mm focal length<br>70 mm, high speed B and W | Naval Research Laboratory | GT-5, 9 |
| UV Reflection from Lunar Surface<br>MSC General Purpose<br>f/3.3 - 70 mm focal length<br>B and W, UV sensitized | NASA MSC | GT- ? |
| Earth Limb Definition<br>Hasselblad<br>f/2.8 - 80 mm<br>70 mm, B and W with red and blue focal plane filters | MIT | GT-4 |
| Color Patch<br>MSC General Purpose<br>f/.95 - 50 mm focal length<br>70 mm, color film | NASA MSC | GT-10, 12 |
| Visual Acuity | NASA MSC | GT-5 |
| Visual Definition<br>Zeiss Contarex Special<br>f/16 64 in. focal length Questar<br>f/4 200 mm focal length Kikkor<br>50 mm focal length<br>35 mm, B and W, color, IR | DOD | GT-4, 5, 6 |

GT - Gemini-Titan flight number

TABLE II. - GEMINI GENERAL PURPOSE STILL CAMERA

| | | | |
|---|---|---|---|
| Film | 70 mm | Type II | Perforations |
| Lens | f/2.80 | 80 mm | Visible and IR |
| | f/0.95 | 50 mm | Visible |
| | f/3.30 | 70 mm | UV |
| Weight | Camera ~ 2.0 lbs | | |
| | Magazine ~ 1.75 lbs | | |
| | Lenses ~ 1.0 lbs | | |
| | Timer ~ 0.5 lbs | | |
| Size | Camera 4 × 7 × 2.2 in. | | |
| | Magazine 4 × 7 × 2.0 in. | | |

Camera will put time-correlation on flight tape

Contractor: J. A. Maurer, Inc.

TABLE III.- GEMINI TIME SEQUENCE CAMERA

| | | |
|---|---|---|
| Film: | 16 mm, 120 ft/magazine | |
| Lens: | 75 mm, 35 mm, 25 mm, 2 mm focal length | |
| Speed: | 6 frames/sec, 1 frame/sec<br>Single frame manual, time exposure | |
| Weight: | Camera ~ 2.0 lbs<br>Magazine ~ 0.75 lbs<br>Lenses ~ 3.0 lbs | |
| Size: | Camera | $1\frac{5}{8} \times 3\frac{1}{2} \times 5\frac{5}{8}$ in. |
| | Magazine | $\frac{3}{4} \times 3\frac{1}{4} \times 4\frac{3}{4}$ in. |

Camera will put time correlation on flight tape

Contractor: J. A. Maurer, Inc.

NASA-S-64-4052

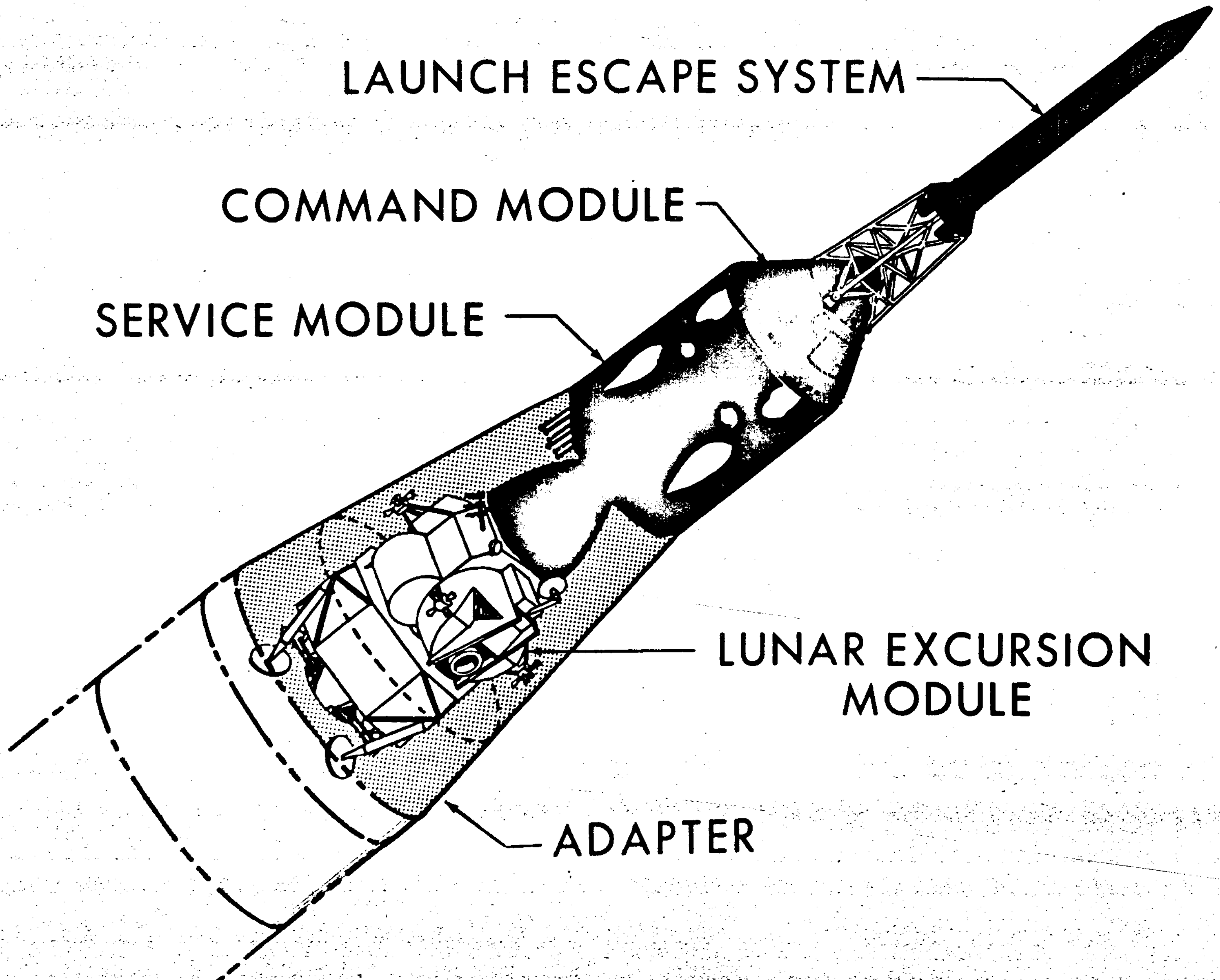


Figure 1. Spacecraft launch configuration

NASA
S-63-17031

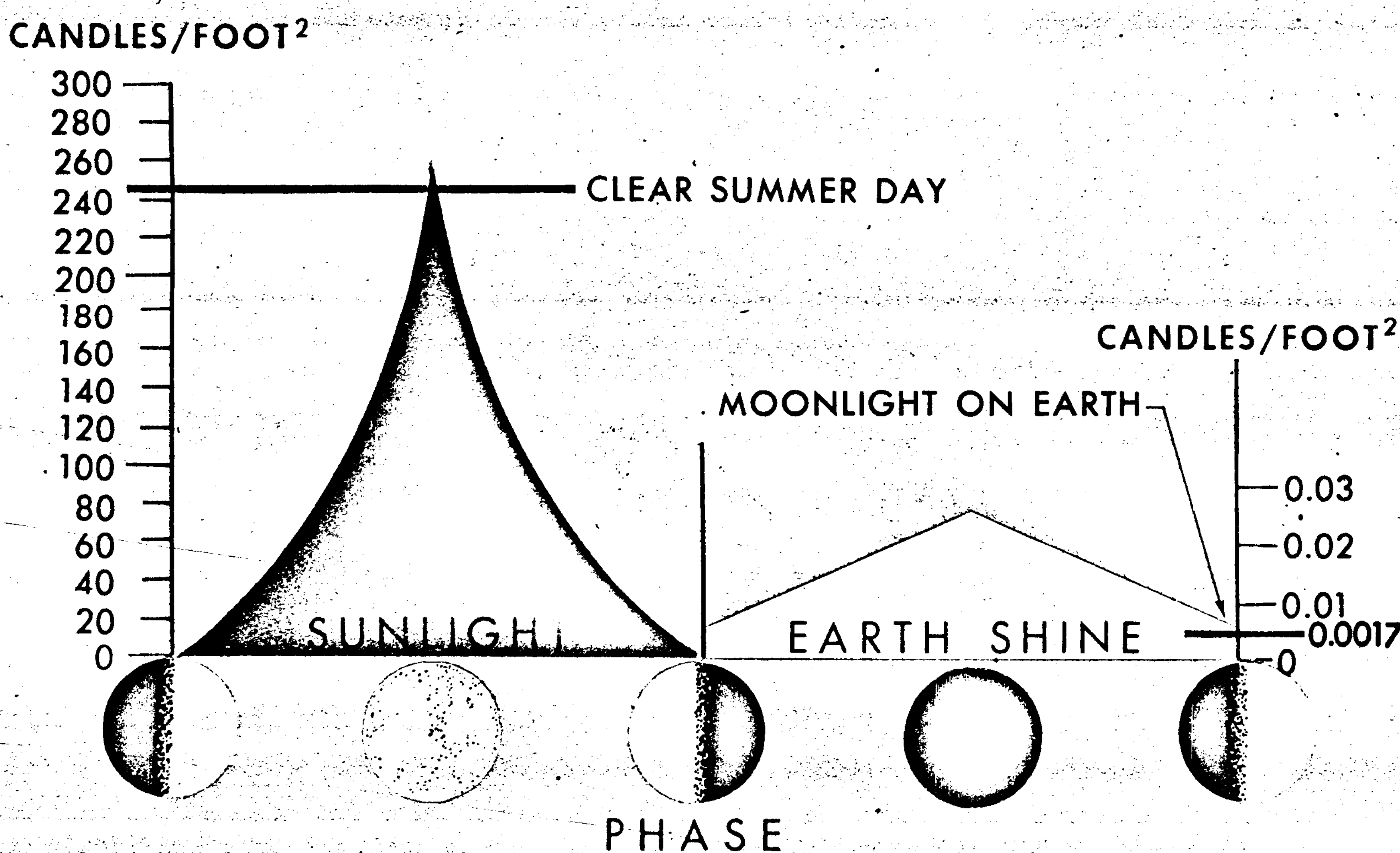


Figure 2. Lunar surface brightness

NASA-S-64-4732

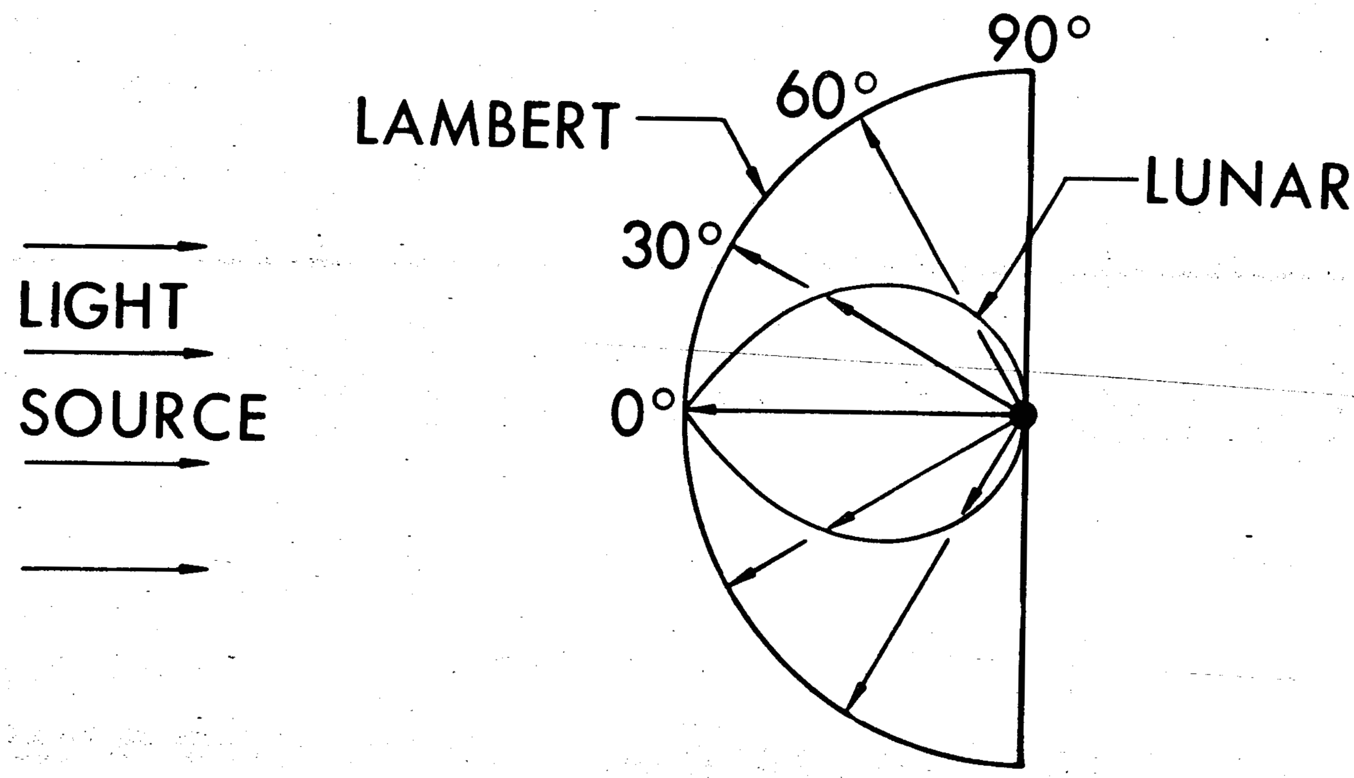


Figure 3. Comparison of lunar and Lambert photometric model

NASA-S-64-98

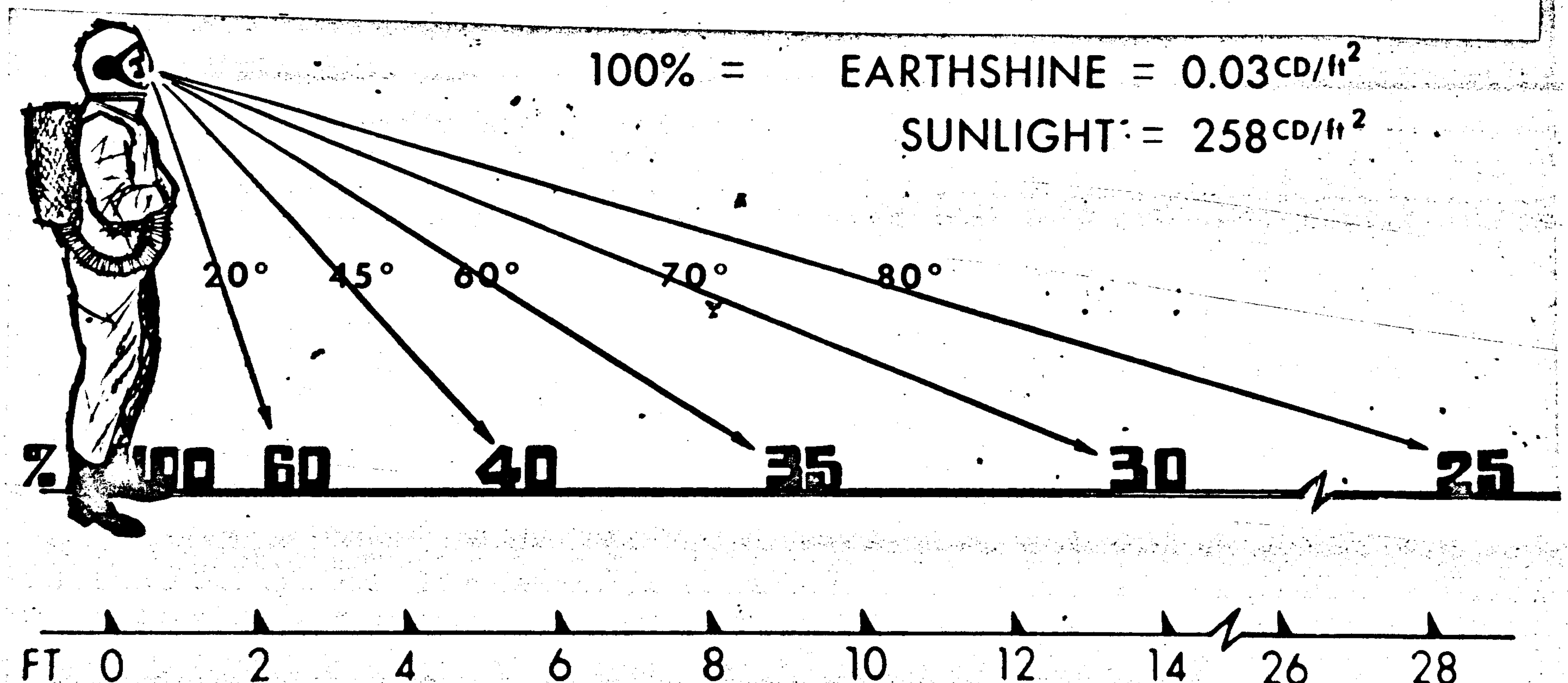


Figure 4. Observed brightness on lunar surface

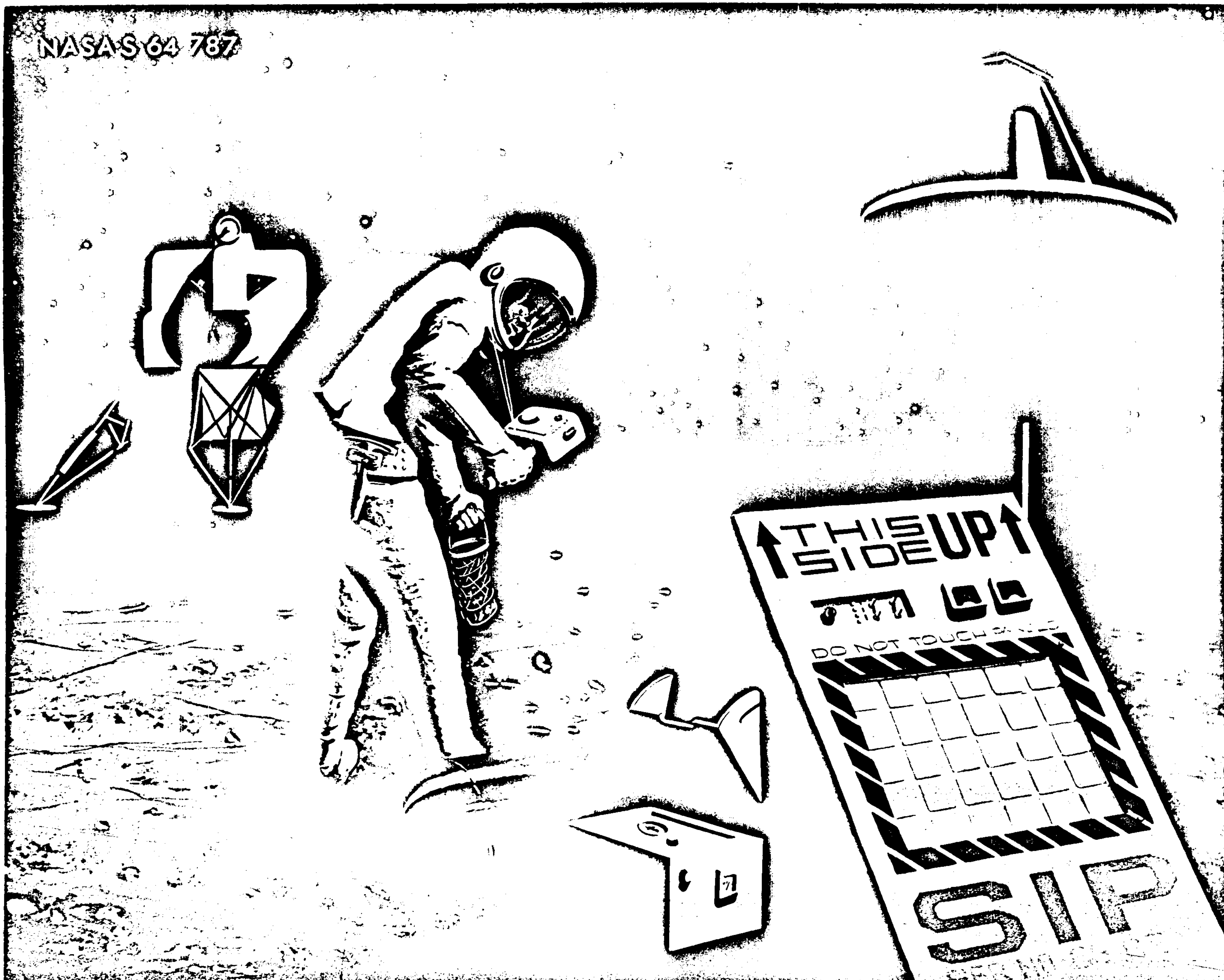


Figure 5. Lunar surface under earth-shine illumination

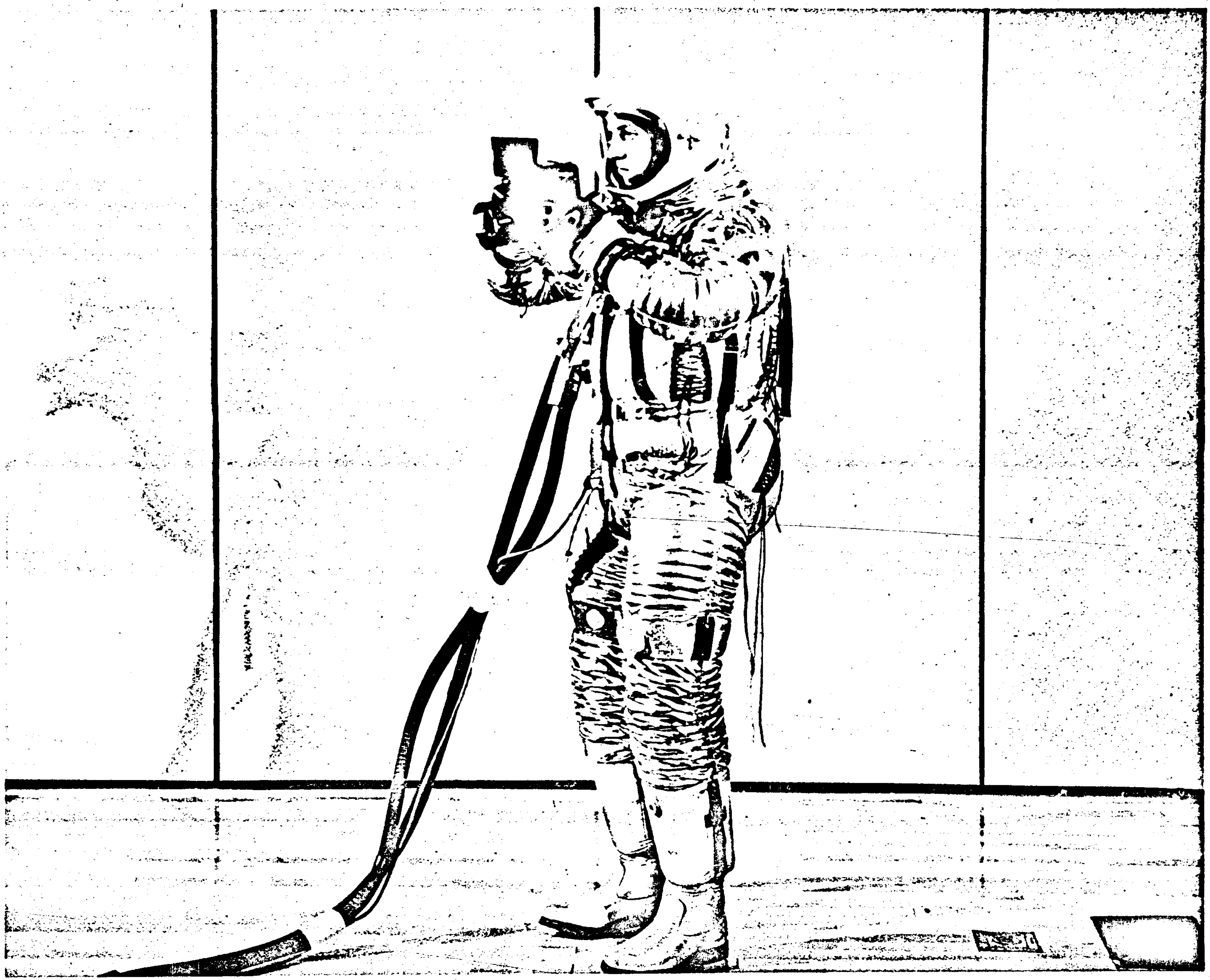

Figure 6. Suited astronaut holding camera

NASA
S-64-25714

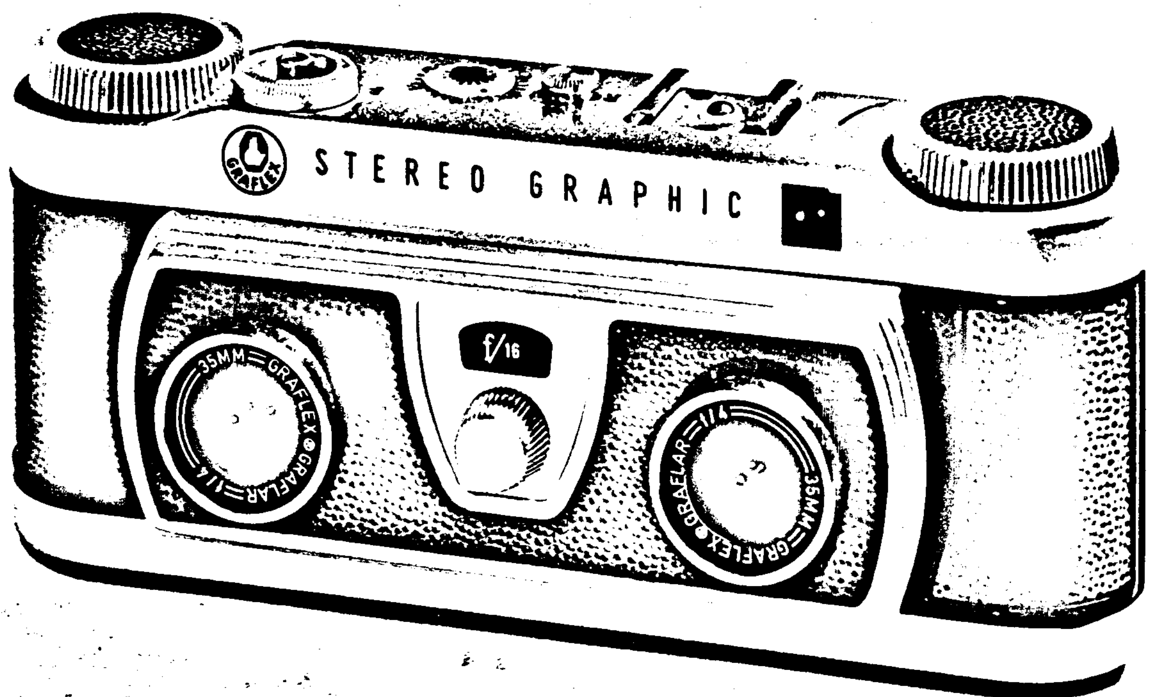


Figure 7.(a) Stereo graphic camera with stereo pairs

NASA-S-64-4476

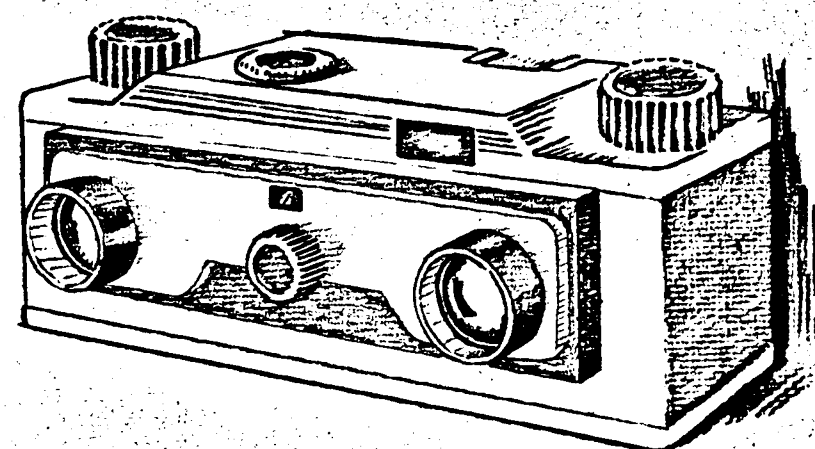

Figure 7.(b) Lunar camera model with stereopairs added

NASA
S-64-25709

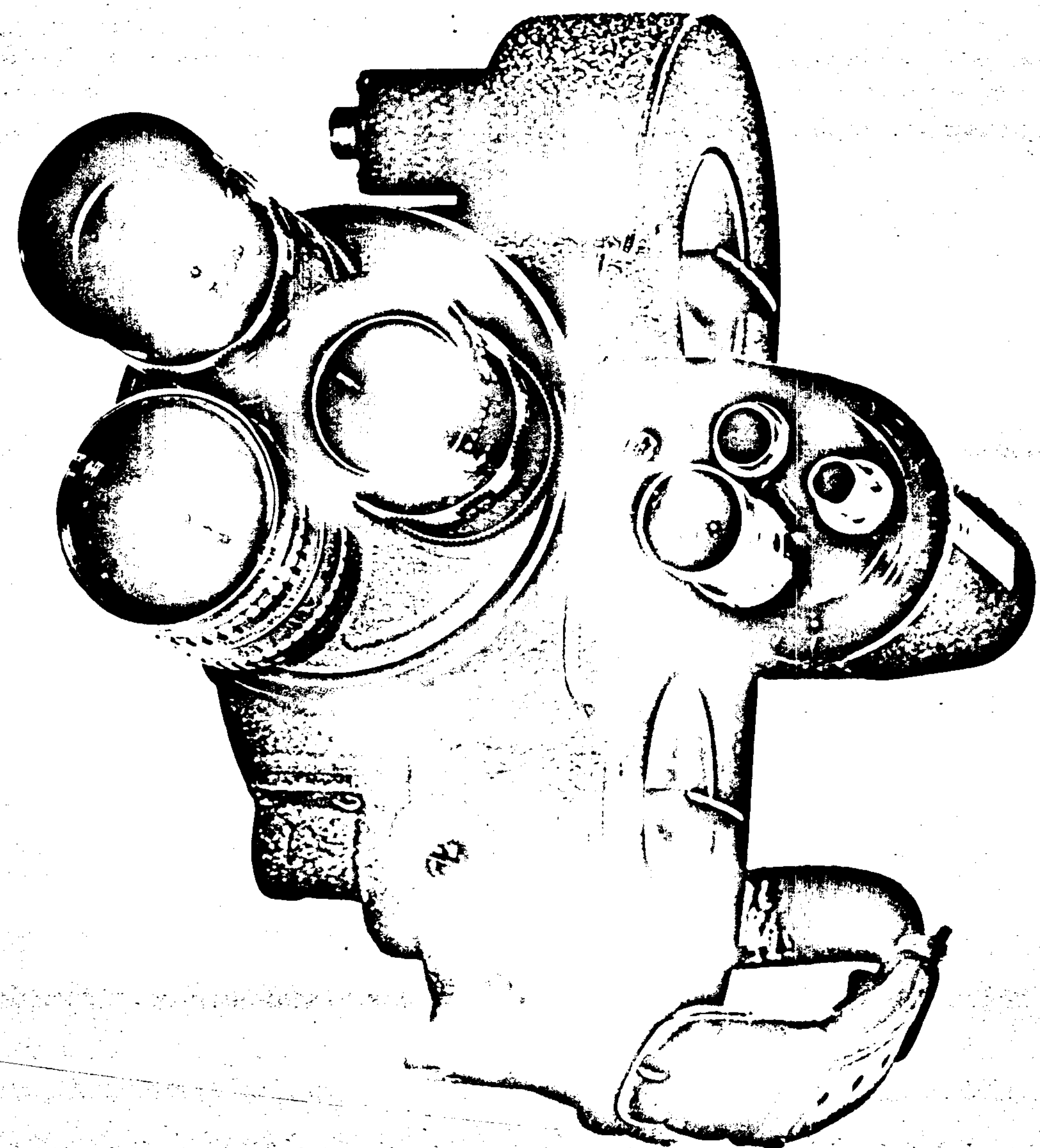

Figure 8.(a) Bell and Howell model 70 with 3 lens turret

NASA-S-64-4477

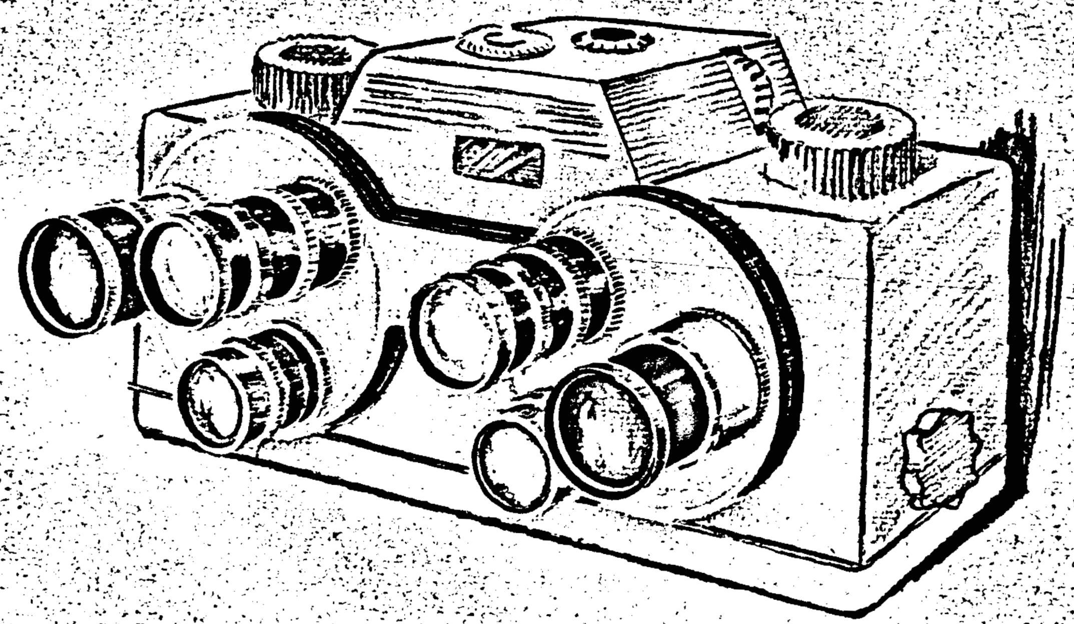

Figure 8.(b) Lunar camera model with lens turrets added

NASA
S-64-25776

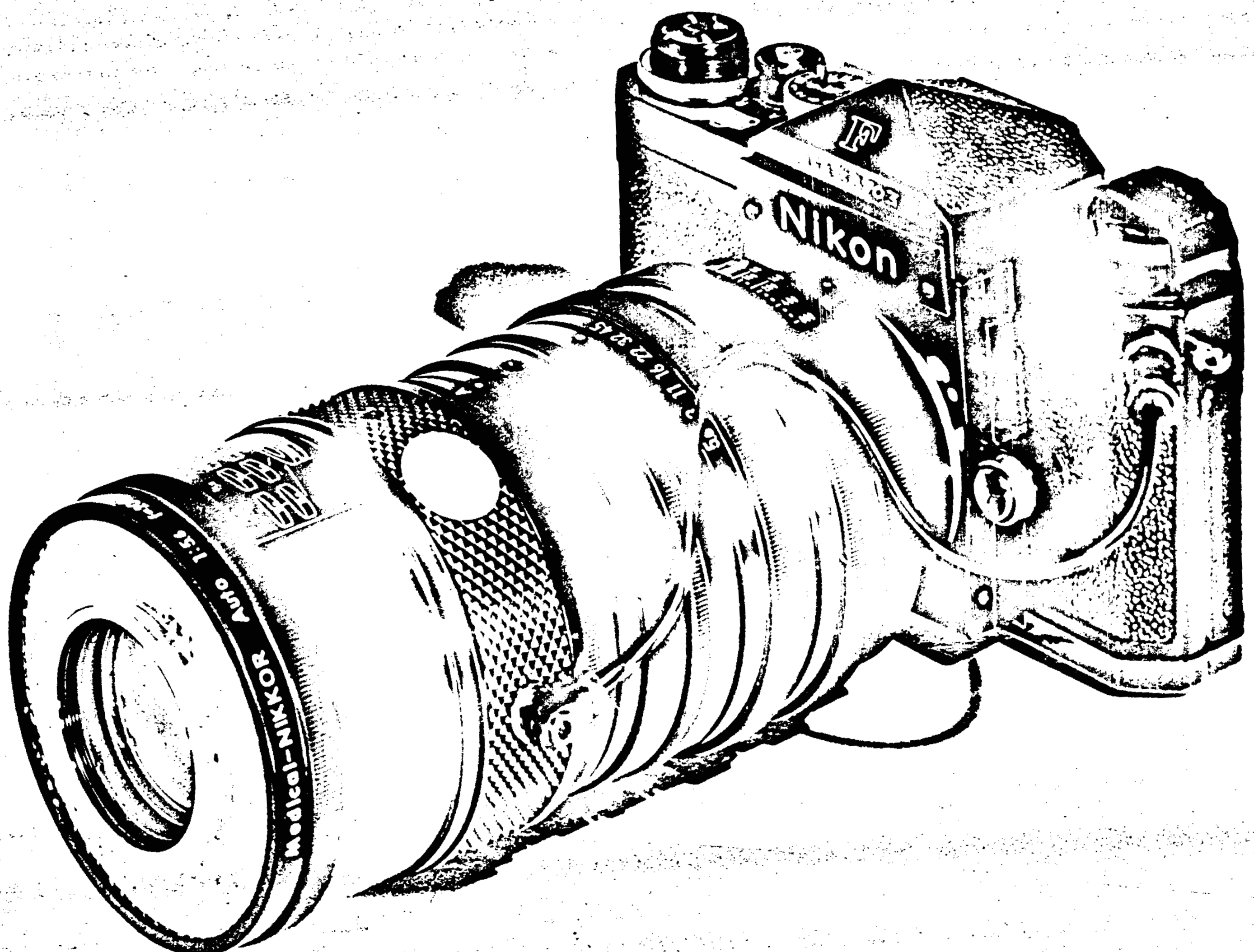


Figure 9.(a) Nikon camera with built-in strobe and magnifier

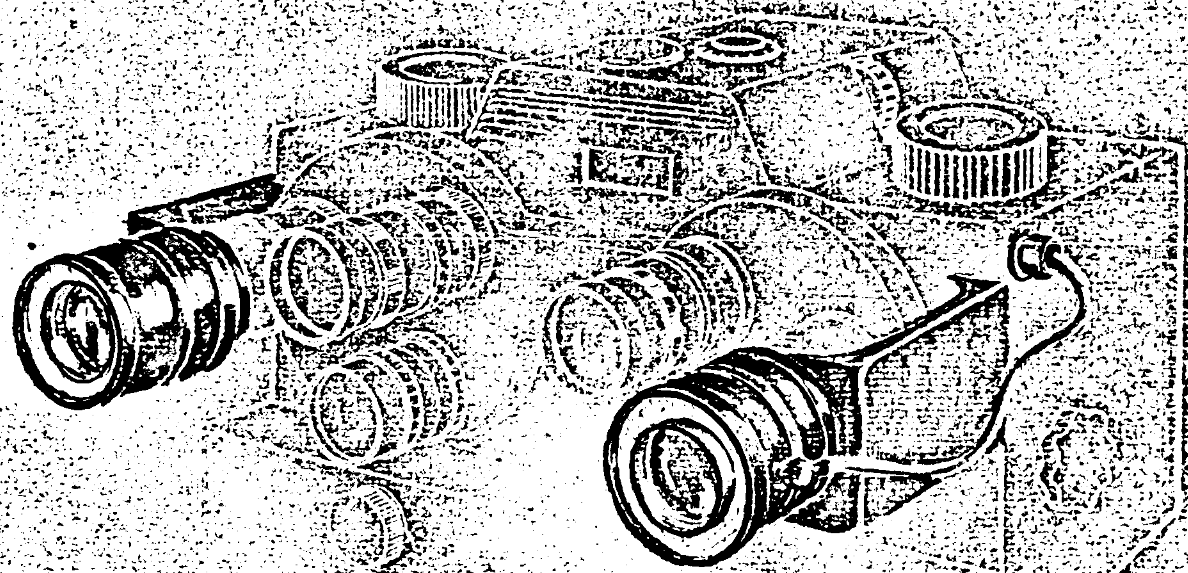

Figure 9.(b) Lunar camera model with strobe and magnifier added

NASA
S-64-25720

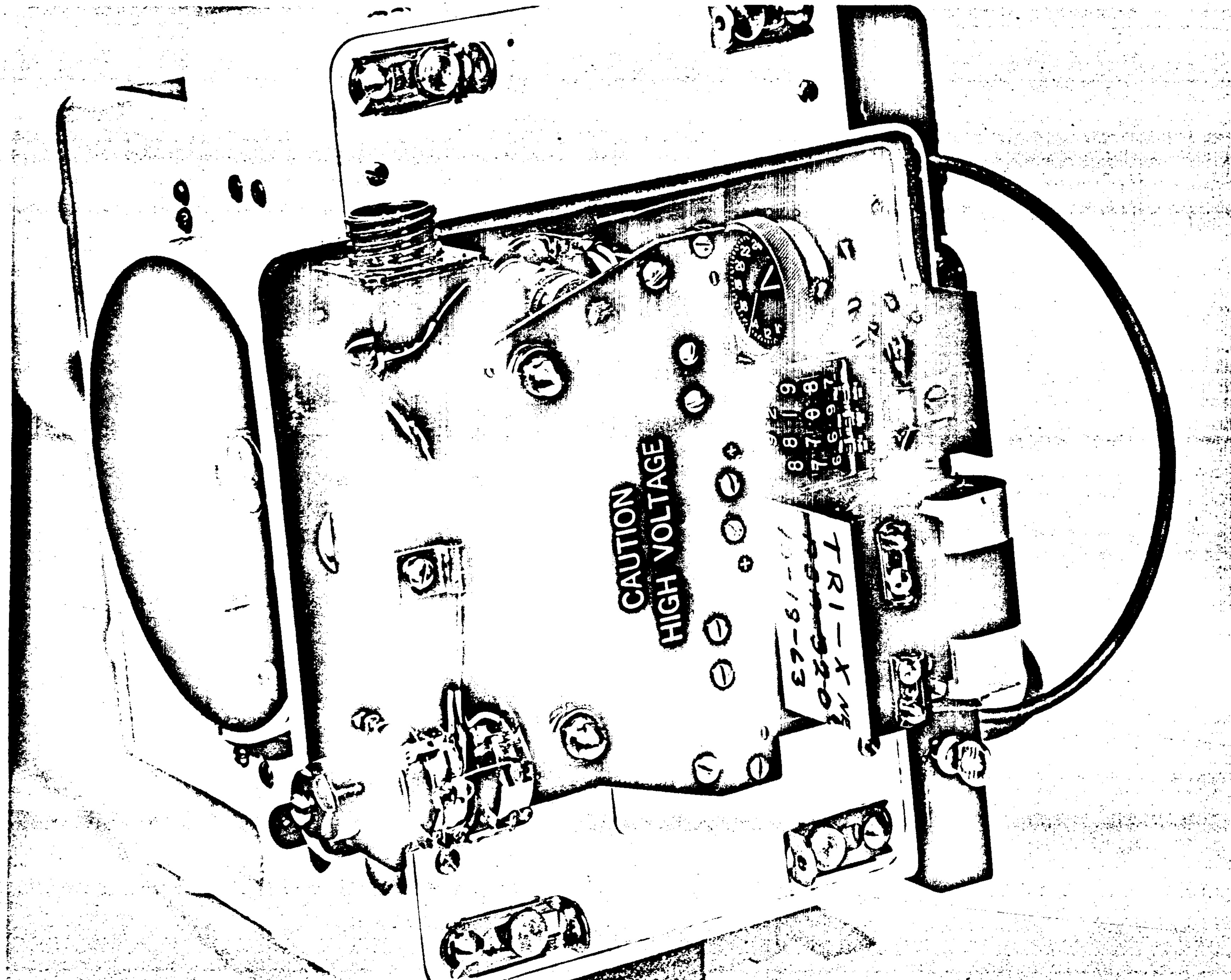


Figure 10.(a) Flight research camera with timing device

NASA-S-64-4479

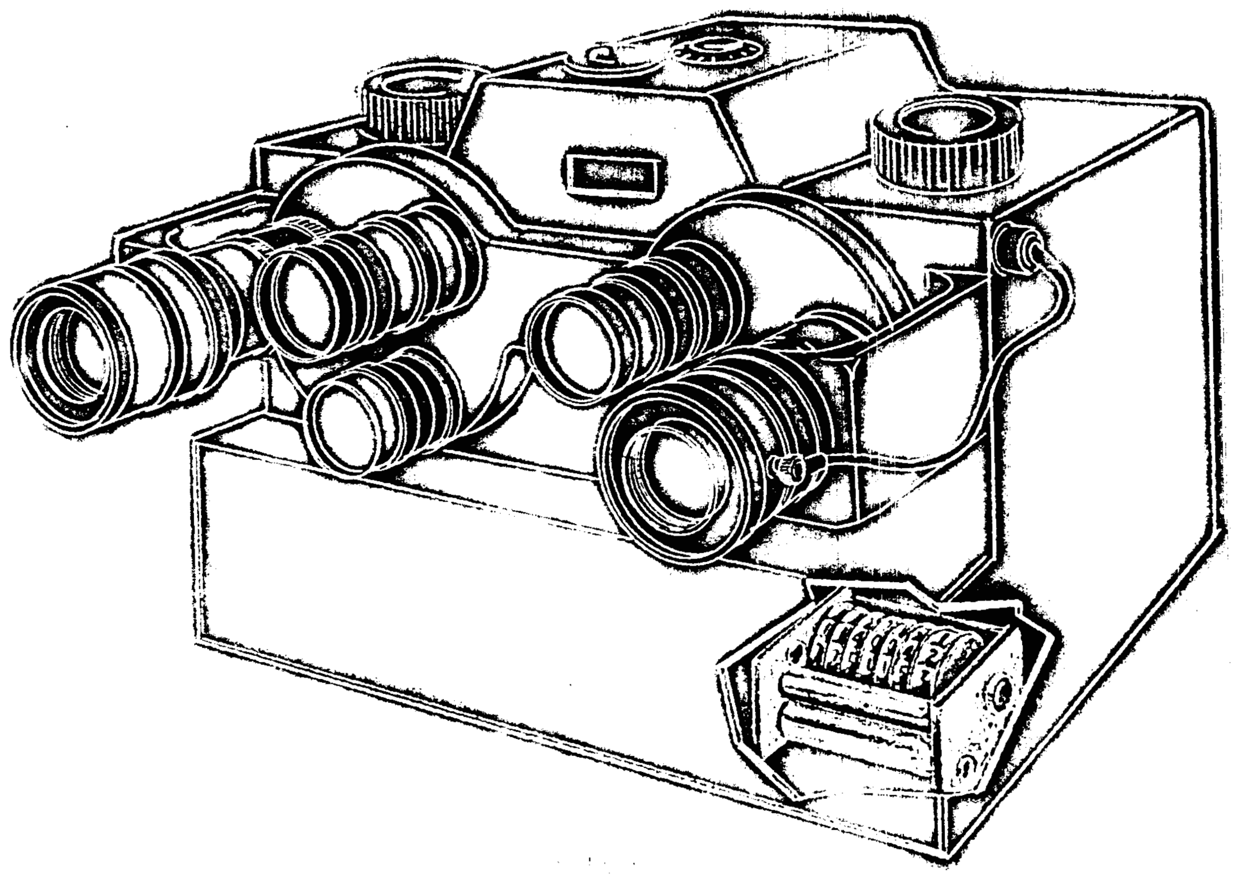

Figure 10. (b) Lunar camera model with timing device added

NASA
S-64-25713

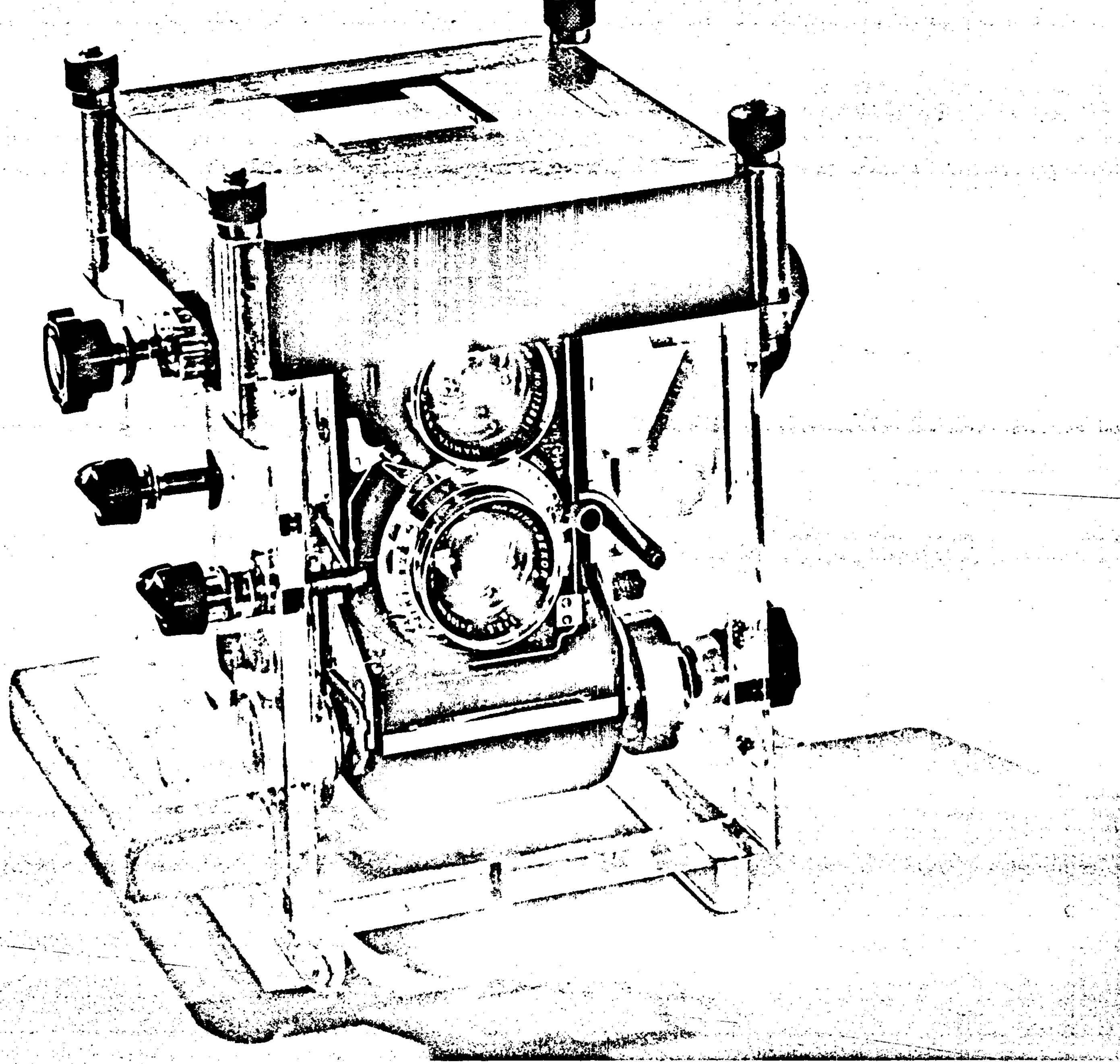

Figure 11. (a) Myoflex camera with waterproof housing

NASA-S-64-4480

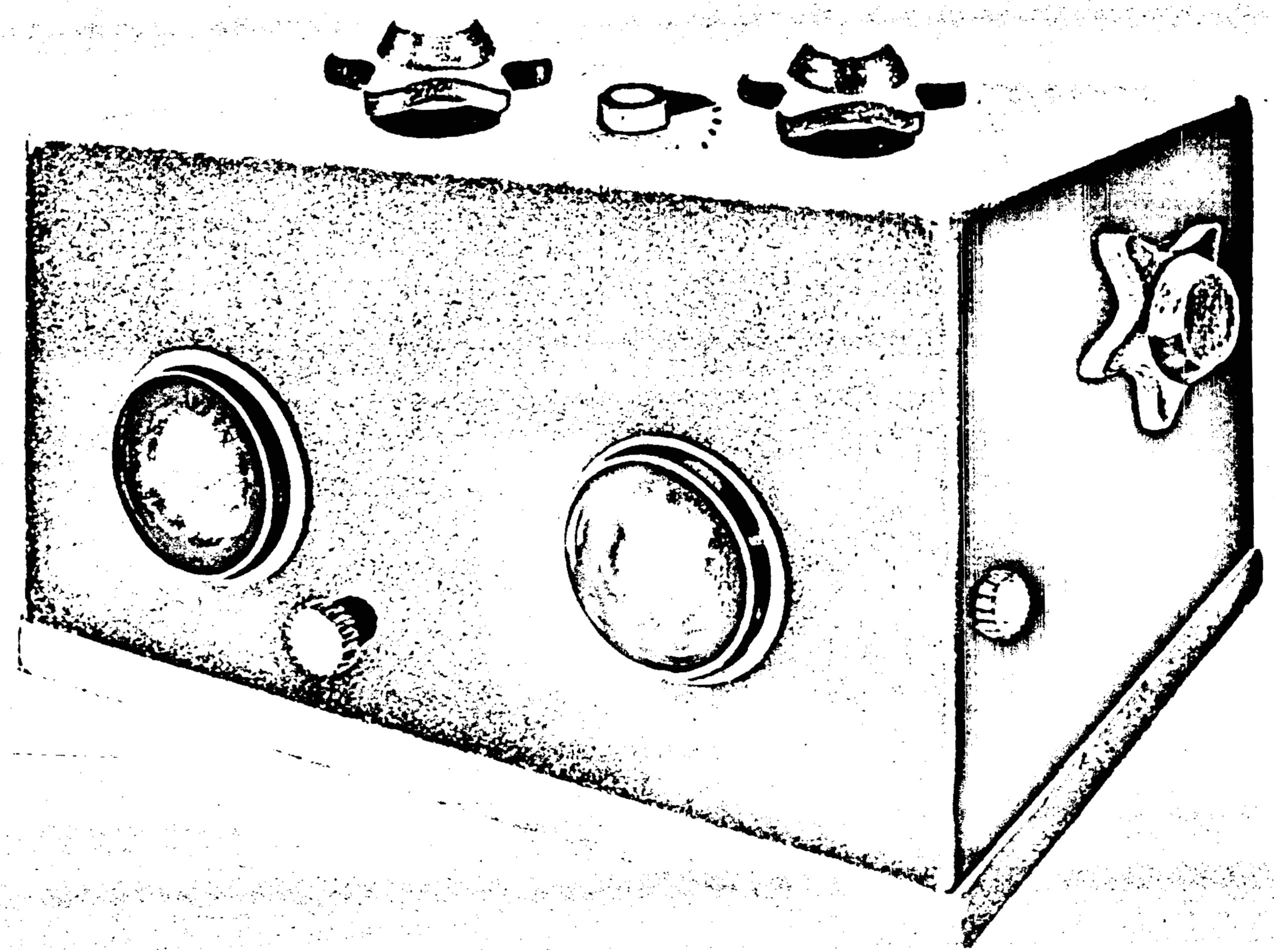

Figure 11.(b) Lunar camera model with housing added

NASA
S-64-25707

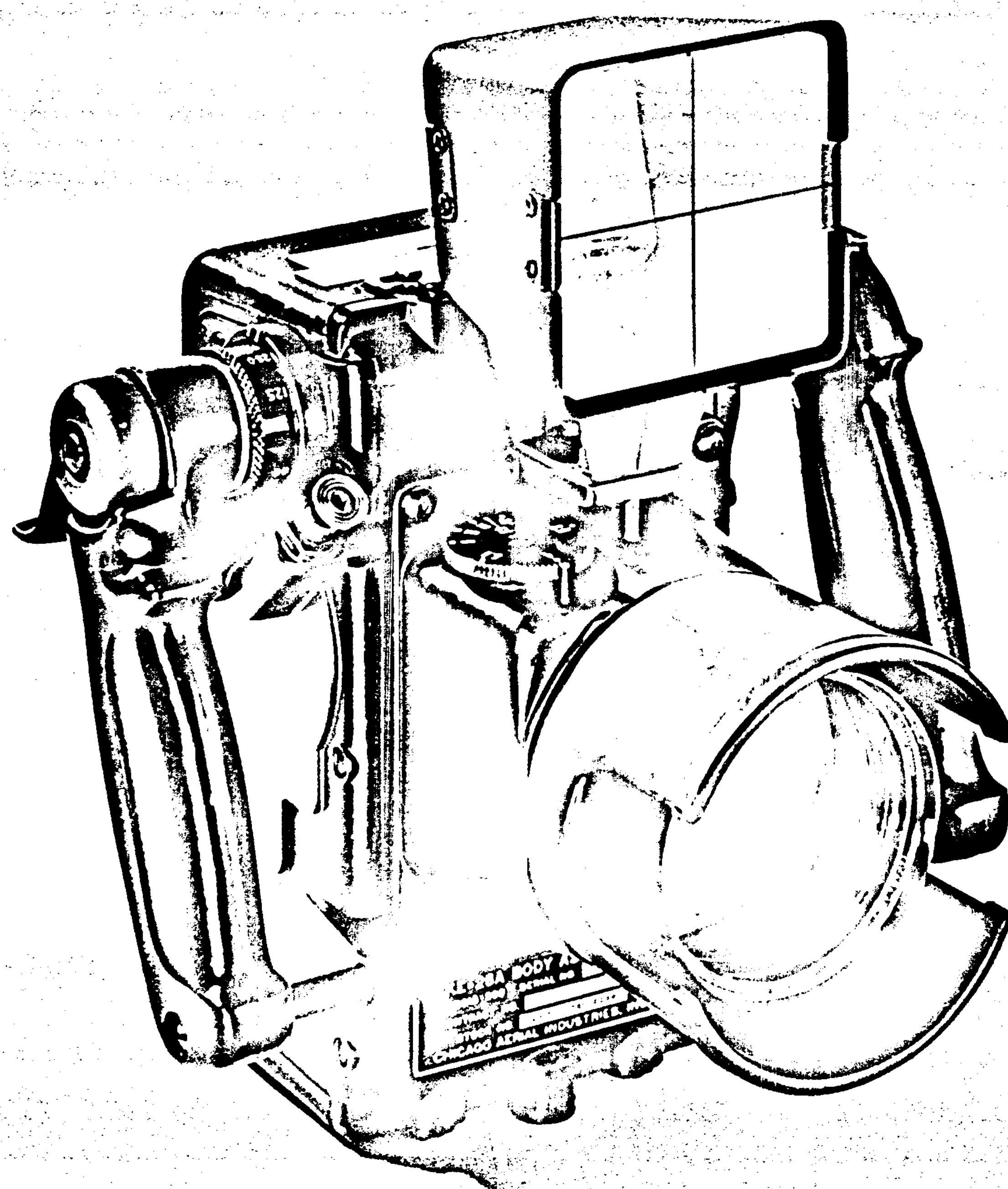

Figure 12. (a) J28A model of Chicago Aerial with reflex viewer

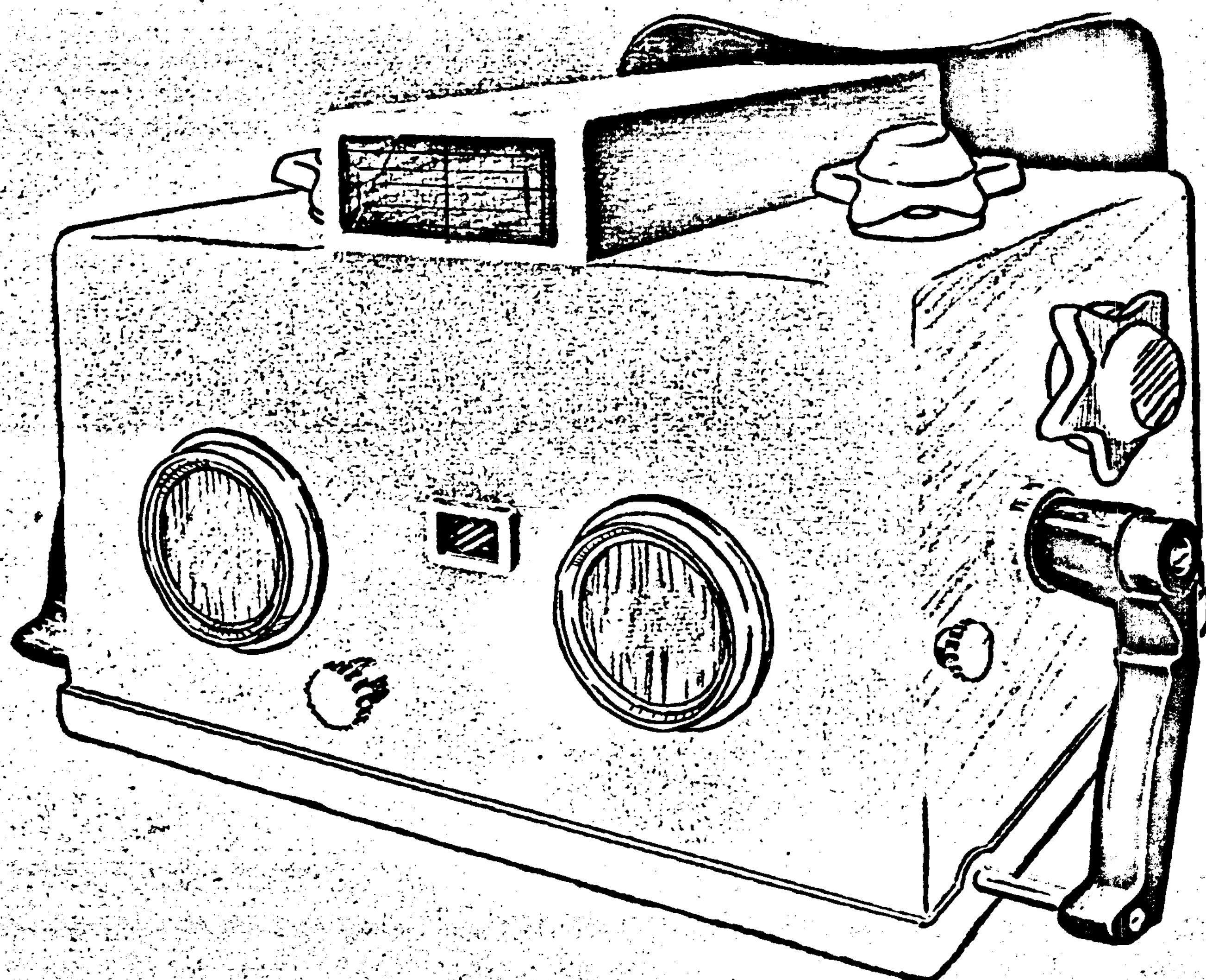

Figure 12.(b) Lunar camera model with reflex viewer added

NASA
S-64-26712

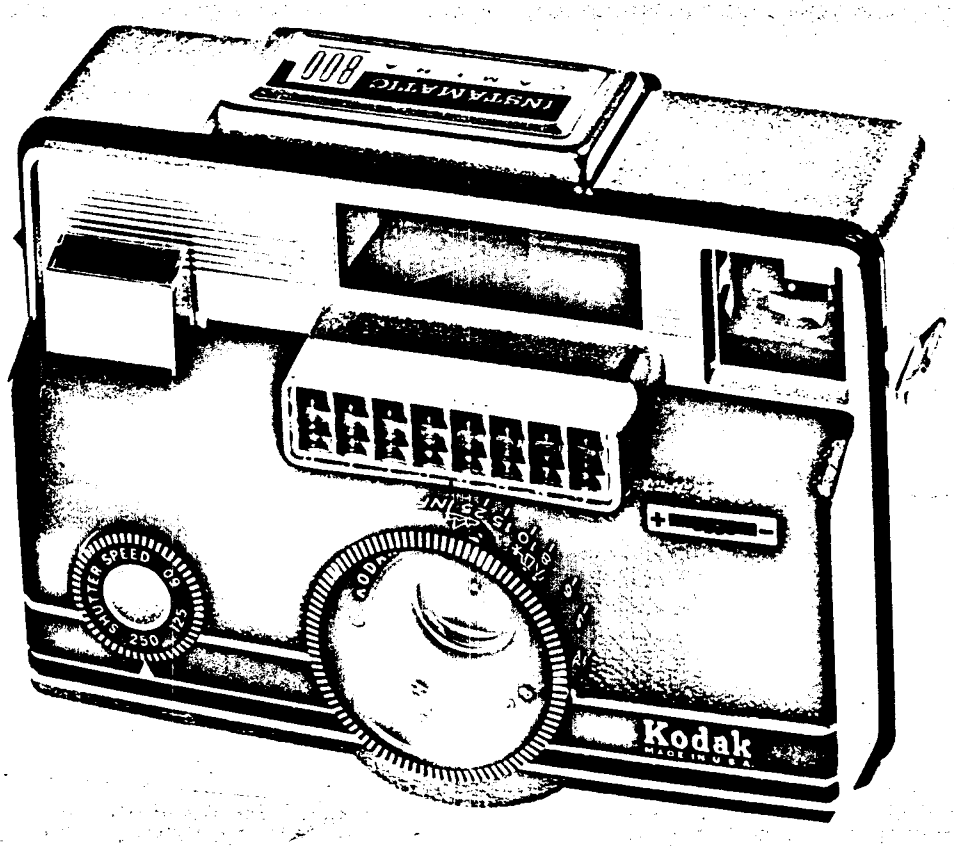


Figure 13.(a) Kodak Instomatic with automatic light meter

NASA-S-64-4482

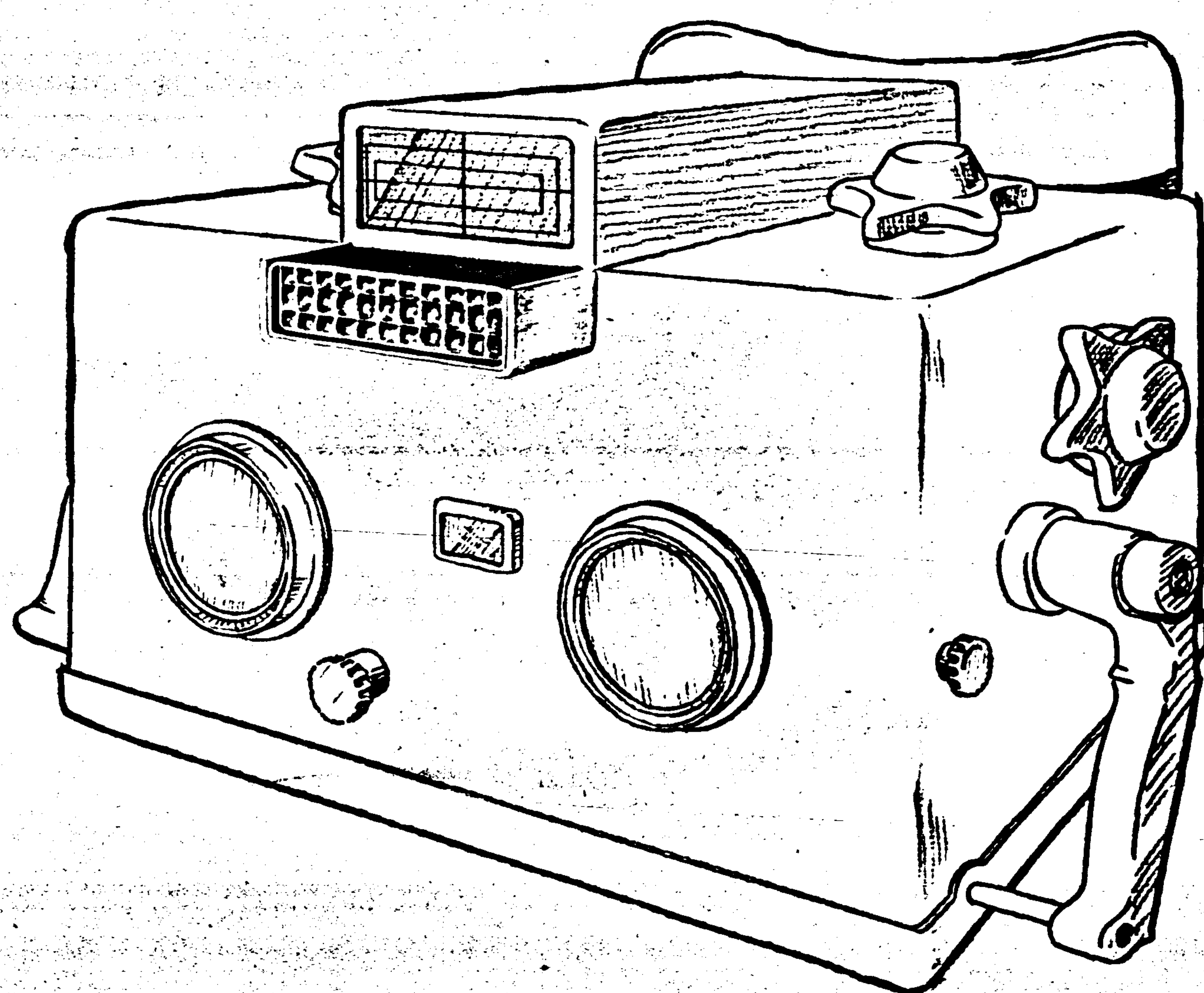

Figure 13.(b) Lunar camera model with automatic light meter added

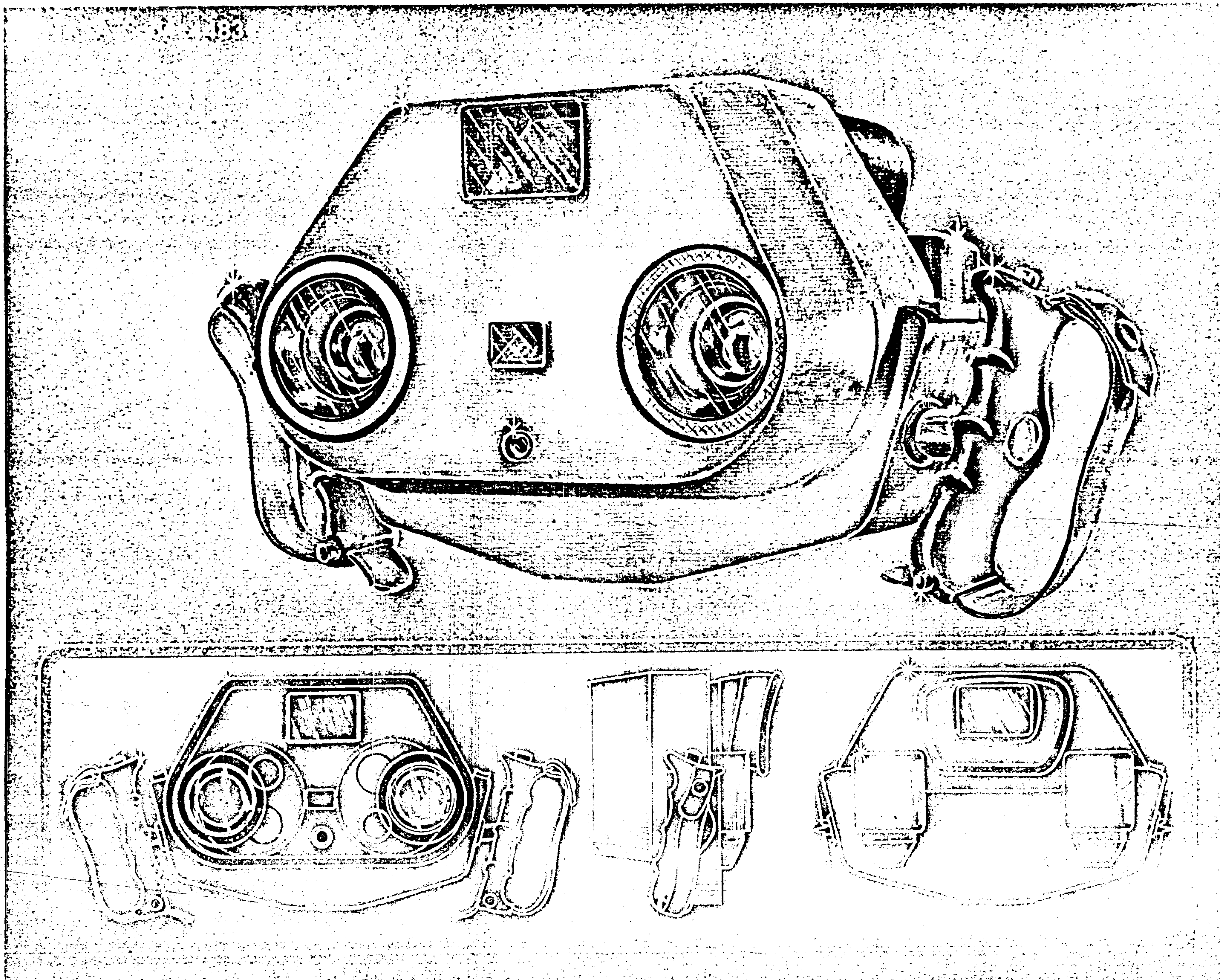

Figure 14. Design concept of streamlined lunar surface camera