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PHOTOGRAPHY EQUIPMENT AND TECHNIQUES

A Survey of NASA Developments

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in association with
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The Franklin Institute Research Laboratories

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Foreword

The Apollo program has been the most complex exploration ever attempted by man, requiring extensive research, development, and engineering in most of the sciences before the leap through space could begin. Photography has been used at each step of the way—to document the efforts and activities, isolate mistakes, reveal new phenomena, and to record much that cannot be seen by the human eye. At the same time, the capabilities of photography were extended because of the need of meeting space requirements. The results of this work have been applied to community planning and ecology, for example, as well as to space and engineering.

The National Aeronautics and Space Administration has established a program by which the results of aerospace research and development from a wide variety of sources are collected, evaluated, and disseminated widely for the benefit of the industrial, educational, and professional communities in the nation. This new technology is announced in appropriate documents, or by other means, by the Technology Utilization Office of NASA. Materials, processes, products, management systems, and design techniques are among the topic areas in which aerospace research has led to significant contributions.

This document describes special uses of standard equipment, modifications and new designs, as well as film combinations that indicate actual or potential ecological problems. It is hoped that the information contained will not only be of general interest, but that the text will also suggest potential solutions to problems for society, the various governmental groups, and many fields of technology.

Director
Technology Utilization Office

Preface

For more than a century, photography has given us a unique and significant record of historical events. Who would be so bold as to assess the value of the information that was recorded by Matthew Brady and his coworkers during the Civil War? When the National Aeronautics and Space Administration began space exploration, it was only natural that these events be recorded for future generations.

Certainly, most of the measurements and physical events could have been, and actually were, recorded by direct-sensing transducers and electronic-analysis equipment. A transducer is a device which, when applied to the surface of an object, measures its temperature, pressure, vibration, or any one of a number of physical parameters, and generates an electrical signal, the magnitude of which is related to the magnitude of the parameter being measured. But few, if any, of these methods communicate information for the scientist or the layman as effectively as photography.

Photographic recording uses the visible and invisible light energy of the environment to produce a signal which is recorded on a photographic emulsion or film. In many cases, such photographic records provide information not only directly but also more efficiently than any of the other information measuring and recording techniques. A piece of film gives a direct visual picture of the phenomenon to the scientific investigator for immediate examination and analysis, and techniques for automatically reducing photographic images to mathematical forms for computer input are now available.

By certain criteria, photography may be said to be the most widely used technique or technology in the space program. Six general areas of photographic applications are identifiable:

(1.) Pictorial photography is used both for providing a permanent documentary record and for detailed technical recording and measuring purposes. This covers the range of applications from the hand-held "tourist" photography of Astronaut Aldrin, through the technical resolution of the measurement detail from the same photographs, to the technical measurements of launch-vehicle tracking provided by tracking cameras and phototheodolites. It also includes various techniques of aerial photography in which pictures of both the Earth and lunar surfaces are identified and charted. The largest volume of actual photography is used in various phases of engineering photography for the recording and analysis of many phenomena in research and development.

(2.) Photography for research investigations includes special techniques for picture formation and manipulation, such as Schlieren and shadowgraphy, holography, photomicrography, and electron microscopy.

(3.) Photosensitive materials are used for the direct recording of energy of the various wavelength bands of the electromagnetic spectrum for such scientific and technical purposes as radiography, spectrography, diffraction studies, and similar laboratory applications.

(4.) Photography is used for direct recording of electronic signals, whether they be image forming or coded information data signals. This includes both direct recording of electron energy and the use of optical conversion through cathode-ray-tube reconstruction.

(5.) Through the techniques of microphotography, such as microfilming and its derivatives, photographic systems are the basis of modern document-storage, retrieval, and distribution systems.

(6.) Graphic arts techniques such as process camera work, photoengraving, and photo-offset printing have resulted from extensions of photographic systems. The most recent active growth in photography has been its application in the preparation of microelectronic devices.

The first application is historically known as photography. This survey stresses only those applications which fall within this category. It includes photographic systems and techniques that have been used by NASA and developed either directly by NASA, or through contracts with outside organizations. Many advances in the state of the art have been accomplished by industry under its own initiative to meet the needs of the space program.

In the development of photographic equipment, many new ideas and suggestions for new equipment are generated. While many would promote small improvements, at times there must be a rational engineering tradeoff for the sake of simplicity, uniform quality, flexibility, and the amount of time that is involved in interfacing a new technique or camera into the system. Therefore, there has been a great tendency to standardize certain well-proven photographic cameras and systems. This makes it possible to interchange cameras and camera parts, and increases economical backup capability. This survey is organized according to general applications. An attempt will be made to direct the reader's attention to the photographic systems used in each application. Since the films are generally common to several of the applications, their characteristics are discussed in a separate chapter.

In chapter I, NASA-sponsored advances in hand-held photography for lunar exploration are described. The task of providing the astronauts with effective tools to document scenes that man would be seeing for the first time led to the development of a fully automatic hand-held camera system with high reliability. It also led to the development of a unique technique for photogrammetric data analysis from hand-held photography, a significant achievement.

Chapter II reviews the use of cameras mounted in spacecraft and aircraft for direct recording of the Earth, the Moon, and other astronomical phenomena. Chapter III discusses one segment of engineering photography as applied to space-vehicle launch operation. Chapter IV surveys the application of engineering photography to a diversity of research programs and demonstrates the flexibility of photographic systems for the recording and display of technical information.

In chapter V a brief discussion of multispectral photography as a technical tool is presented, and chapter VI reviews photographic Earth resources investigations. At the Kennedy Space Center, the author found that:

> The Photographic Branch Staff is of the opinion that the most significant photographic technological event will be realized in the utilization of multispectral space photography once a camera platform for that purpose is established in space. The Skylab program will permit opportunity for preliminary research for this utilization. The benefits to be derived from this utilization are far-reaching and will impact all mankind.

A survey of film characteristics and the typical films used in NASA operations is given in chapter VII. This is followed by some notes on special film-handling techniques in chapter VIII.

Acknowledgments

Photography is so widely used in NASA programs that the author received helpful suggestions and information from many more persons than can be listed. Specialists in airborne science, optics, data control, Earth observations, camera repairs, propulsion research, and various other fields provided much of the information summarized in this survey.

Technology Utilization Officers at NASA Headquarters and their colleagues at Ames Research Center, Goddard Space Flight Center, John F. Kennedy Space Center, Langley Research Center, Lewis Research Center, and Manned Spacecraft Center were extremely helpful. So, too, were the chiefs and staffs of the photographic technology divisions and branches at those NASA centers, and representatives of companies assisting those centers contractually. Helpful contacts also were made with personnel of the Smithsonian Institution, Paillard, Inc., GAF Corp., and Eastman Kodak Co., in the course of the survey.

Review consultants were Professors William Shoemaker, Hollis M. Todd, and Albert D. Rickmers of the Rochester Institute of Technology School of Photographic Arts and Sciences.

Contents

CHAPTER I

Hand-Held Systems

When the United States was about to send some of its most adventurous citizens on journeys that man had never before taken, it was evident that these adventurers should be given the necessary equipment to make a clear pictorial photographic record of what they saw—a record unmarred by the vagaries of memory and not confused by the many essential technical facts and functions important to the safe operation of spacecraft.

The concept of taking photographs as a permanent record from space is a silent tribute to the pioneers of a century before who (on October 13, 1860) had taken photographs from a height which, at that time, men had seldom achieved—1200 feet in a balloon (fig. 1).

Photography was not given high priority in the first two suborbital flights of American astronauts because it was essential that they concentrate on operating the spacecraft. It was not until Mercury-Atlas 6, when John Glenn made the first orbital flight, that a hand-held camera was included in the spacecraft equipment. The camera was the commercially available 35-mm Ansco Autoset (fig. 2).

All commercially available cameras present operating problems for an astronaut. His heavy gloves do not allow him to use the hand controls normally designed for such a camera. In addition, viewfinders on commercial cameras are designed to be placed next to the operator's eye. In fact, many viewfinders are difficult for people wearing ordinary glasses to use. In the environment within the early spacecraft, the astronaut was required to take pictures without removing his helmet. The camera, therefore, was equipped with a new viewfinder that made it possible for the astronaut to work with his eye farther from the camera than is normal for conventional photography. The camera was fitted by its manufacturer with a pistol grip and an oversized film advance. Fortunately, this camera was fully automatic so there was no need to adjust shutter speed or lens-diaphragm setting.

It was recognized that there would be a need to duplicate the photographs acquired and also to accommodate the high dynamic

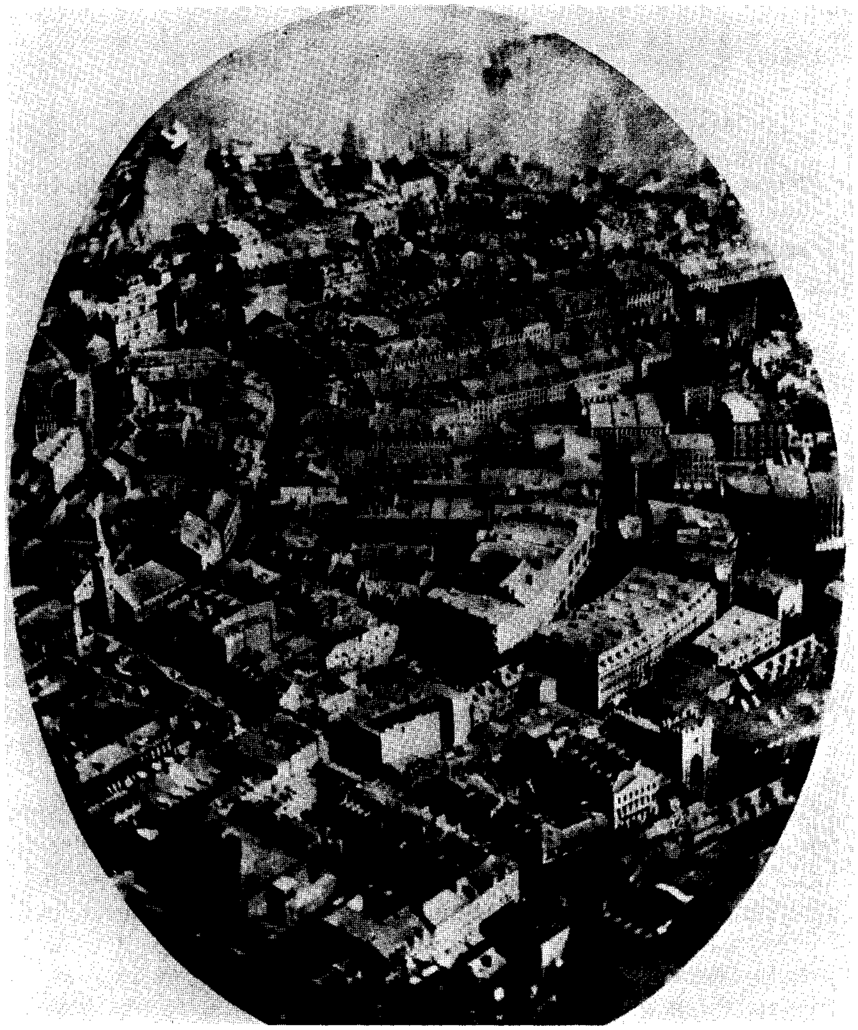

FIGURE 1.—This picture was taken from a balloon October 13, 1860, by C. W. Black, while 1,200 feet above the waterfront area in downtown Boston. (Courtesy of GAF Corp.)

range of scene luminance ratios that would be encountered in the outer atmosphere. Scene luminance range is the ratio of the light level that comes from the bright areas of a scene to that from the shadows. On an overcast day, the general scattering of light adds light to shadows and increases their luminance level; at the same time, it decreases the maximum light level of the bright areas, thus the range is reduced. In the outer atmosphere, and on the lunar surface, there is no light scattering to reduce the total scene

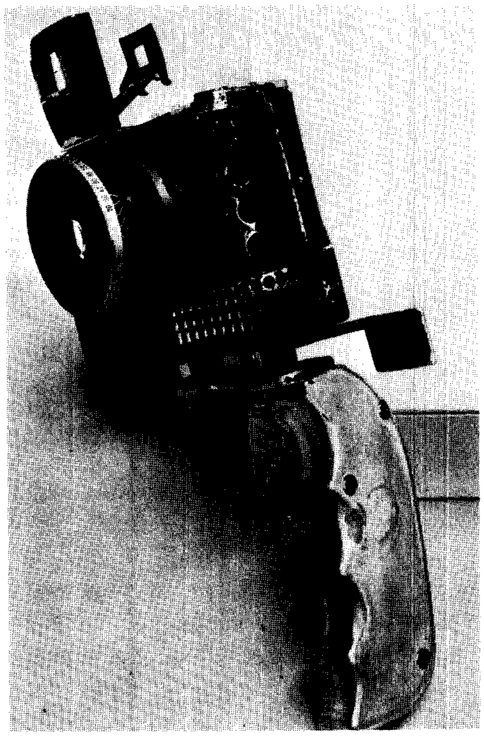

FIGURE 2.—The first hand-held camera taken into space was this modified commercial 35-mm camera used by John Glenn on the Mercury-Atlas 6 flight. It required only film advance by the astronaut.

luminance. It was anticipated, therefore, that a wide range of light levels might be encountered. The film selected for the first mission to include photographic experiments was a color negative film which provides maximum accommodation of the dynamic range, and is also an effective means for duplicating the pictures with reasonable retention of image quality. The result of this selection is illustrated by the picture which was taken by Astronaut John Glenn. (Color Plate 1(*a*)).

For the next flight, Mercury-Atlas 7, the decision was made to continue using a 35-mm camera. A Robot Recorder with well-developed automatic film advance features had been modified for easier use by the astronauts working in their spacesuits. This Robot camera was also used on the Mercury-Atlas 9 flight, where it was modified for dim-light photographic experiments to investigate the zodiacal light and the night airglow. The camera (fig. 3) had a fixed lens with a large aperture (*f*/0.95) to provide maximum efficiency in recording low-light phenomena. Exposures were timed manually. Three small supports or "feet" were provided to aid the pilot in positioning the camera against the window for aiming.

FIGURE 3.—A modified Robot Recorder was used on the Mercury-Atlas 9 flight by Gordon Cooper for experiments in dim-light photography.

A significant contribution to space photography was made during the Mercury-Atlas 8 flight. It was recognized that the optics of modern high-performance photographic systems for hand-held photography are essentially film limited in their capability; that is, the amount of information that can be recorded is determined by the ultimate performance of the film rather than by the lens. Thus, improvement in total information content within the capability of the camera mechanics may be achieved by simply increasing the size of the film used to record the image. It was also realized that a high-quality system for space photography should have interchangeable lenses to produce the optimum size image within the film-size format. It should also have interchangeable magazines to permit the choice of color films or black-and-white films and of several sensitivity levels in either film without requiring additional camera bodies and lenses. Basically, a camera body that could accommodate interchangeable lenses on the front and interchangeable magazines on the rear was needed. Such a system was commercially available in the Hasselblad camera. Early modifications were made by NASA technicians to insure ease of operation by a gloved astronaut (ref. 1).

The Hasselblad is basically a single-lens reflex camera. The reflex mirror arrangements were removed, however, since they could not be conveniently used in the spacecraft. They were replaced by a straight eye-level finder with a suitable base length, so that an astronaut could use it while wearing his spacesuit helmet.

The modifications by NASA technicians for ease of operation were further improved by the manufacturer of the camera and incorporated in new models. The commercially available magazines for the camera were designed to accommodate 12 exposures on roll film. Realizing that the bulk and weight of the backing paper are detrimental to the efficient operation of the camera system, a NASA contractor modified one of these magazines to accommodate 70-mm film (figs. 4 and 5). The camera manufacturer, having started on the development of a suitable magazine for 70-mm film, put additional emphasis on the program to make the magazine available in time for the space explorations. The commercial 70-mm magazine was designed to take approximately 18 feet of film, permitting 70 exposures on the 70-mm film that was then available. In the earlier magazines NASA had demonstrated the advantages of obtaining a large number of exposures on a relatively small volume of film and thus stimulated photographic manufacturers to expand development of thin polyester base for application to conventional color emulsions. By using this thin-based film with a magazine film gate modified to accommodate it, and eliminating the cartridge used in the commercial version, the same magazine could hold 38 to 42 feet of film for approximately 200 exposures. The first modified camera (fig. 6) had an auxiliary hand crank that was used for rapid film advance by a gloved hand. An electric advance system was used on later models (fig. 7) to allow an increased number of exposures without taking valuable time from the astronaut's other duties. Thus, NASA was shaping the system of the future for hand-held photography for its lunar exploration mission. Meanwhile, other considerations dictated additional developments for the hand-held photographic system.

The 6- x 6-cm format with general-purpose lenses was rather limited in its available angles of view. A model known as the "superwide" (fig. 8) was investigated and was found to give more satisfactory results. The superwide model was used with the hand advance, but a parallax-free viewfinder was designed for framing by the astronauts through their spacesuit helmets. The superwide gave a broad angle of view to pictures taken on orbital flights (Color Plate 2), maximizing the amount of picture coverage and minimizing errors of pointing. It was also more suitable for pictures taken inside small spacecraft.

Many significant developments were associated with making the camera convenient and easy to handle by astronauts in their various spacesuits and under space conditions. Typical of these

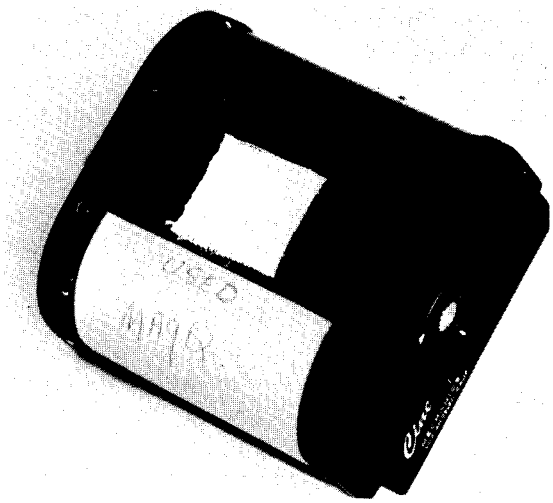

FIGURE 4.—This basic 70-mm magazine was developed under contract by Cine Mechanics for NASA for use with the Hasselblad camera. The magazine is shown as originally intended for the Mercury Program with a patch of Velcro for holding the dark slide. (Magazine Courtesy of Smithsonian Institution)

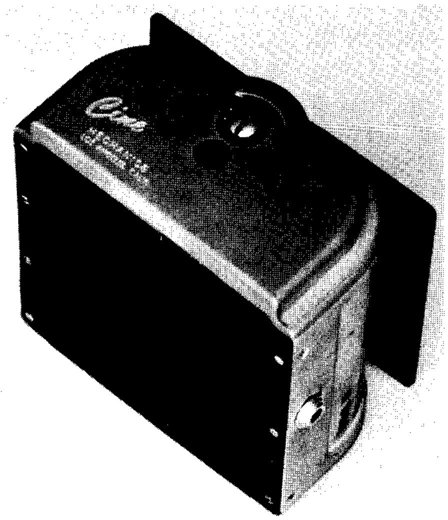

FIGURE 5.—A variation of the device shown in figure 4 was developed for the Gemini program, with a plate attached for storing the magazines. After experimenting with a silver finish, the decision was made to continue with a black finish until the lunar landing.

FIGURE 6.—The first version of the Hasselblad camera, as modified by NASA for use in the Mercury Program. The body is shown without lens and magazine. The magazine used is that of figure 4. (Camera courtesy Smithsonian Institution.)

FIGURE 7.—The improved, modified electric Hasselblad was developed by the manufacturer under the stimulation of the space program and is now available for commercial and industrial applications. (Paillard, Inc.)

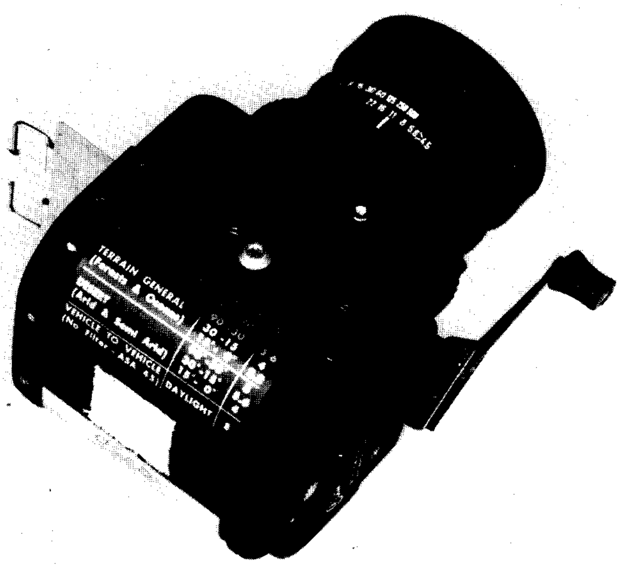

FIGURE 8.—The Hasselblad superwide camera was utilized in Gemini missions GT–9 through –12 to permit photography of broad areas of the Earth's surface with minimum effort. A later version had a Wireframe Viewfinder and improved shutter-release actuator. (Camera courtesy of Smithsonian Institution.)

developments was the chest pack used to support the Lunar Data Camera in operating position on an astronaut's chest while he worked on the lunar surface. An initial application of this principle took place on Gemini-Titan IV, when Edward H. White III was the first man to work outside the vehicle in space. The camera was incorporated as part of the extravehicular propulsion unit (fig. 9). A stock Contarex 35-mm camera, modified for White's operation with his suit and helmet, was used. It was incorporated as part of the propulsion unit for convenience, ease of use, and maximum safety.

A general program was initiated after the disastrous Apollo fire to insure high reliability and maximum safety in all spacecraft equipment. Electrically driven cameras were required to be capable of operating in a high oxygen environment without any significant danger of fire or explosion. To meet these standards, the camera system components were redesigned. Hermetically sealed switches were selected to minimize heat generated in the various components. Much attention was also paid to reliability of the system for continuous duty over a long period of time to insure a low probability of failure.

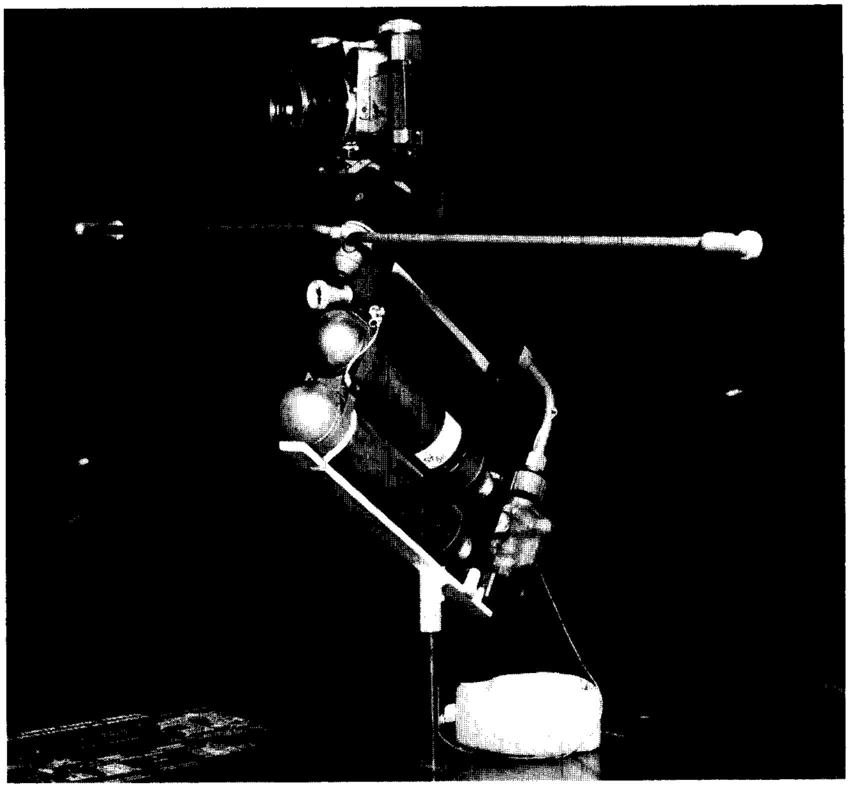

FIGURE 9.—The camera used by Edward H. White II on the Gemini IV mission, where he became the first man to work outside a vehicle in space, is shown here on the extravehicular propulsion unit. (Smithsonian Institution.)

Some of the parameters for the lunar exploration camera are given in reference 2. A hand-held lunar photographic system would be required to meet the following environmental criteria: (1) an acceleration up to ±20 G's for 3 minutes in any direction; (2) a shock of 30 G's for a period of 11 milliseconds; (3) air pressure variations from sea level to less than 10^{-10} millimeter of mercury; (4) a temperature range from −186° centigrade to +114° centigrade; (5) solar flare radiation of 600 rads; and (6) the possibility of 100 percent relative humidity, including condensation for 5 days in a temperature range of 80° to 160° F.

Looking forward to the lunar landing, NASA technicians investigated methods of optimizing the information to be recovered from pictures which would be taken by hand-held systems. Richard Thompson and others developed a technique for orthoscopic rectification or geometrical correction of the two-dimensional scene, provided that the image fields were flat with sufficient accuracy. The Zeiss 60-mm Distagon lens had such capability. Under the stimulation of Thompson's technique, this lens was redesigned to accommodate a glass plate with fiducial marks (small hairline crosses) which is known as a reseau plate (fig. 10). This technique provides accurate locations in the film plane from which information about distances in the lunar scenes can be derived by means of calibration of the plate. The camera system, with the reseau plate installed, is known as the Lunar Data Camera (fig. 11). The calibration of the Lunar Data Camera system for photogrammetric purposes is detailed in reference 3.

The still photographs taken by the astronauts making the early lunar-surface excursions yielded additional scientific data because of the metric feature of the lunar-data camera with the glass reseau plate. The film format is small in comparison to the usual photogrammetric system, and compromises have been made to maintain lens 'focusing and interchangeability. However, the camera has many advantages over other cameras for lunar-surface photography, particularly in its ability to be hand held. Many potential applications of this technology outside the space

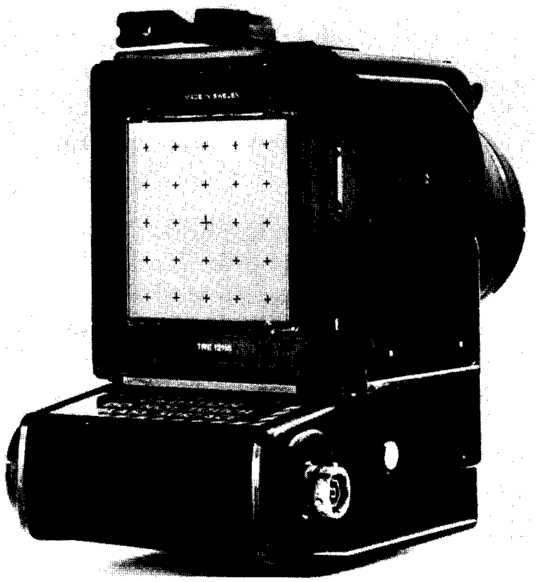

FIGURE 10.—A photograph of the Lunar Data Camera showing the reseau grid plate at the focal plane of the camera body. (Paillard, Inc.)

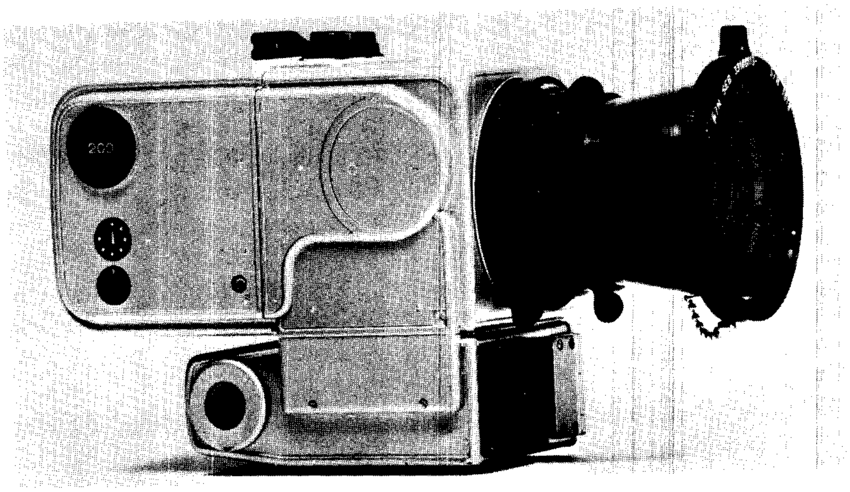

FIGURE 11.—A completely assembled Lunar Data Camera. Note particularly the silvered surfaces, a contrast to the all-black surface formerly used. The silver is intended to reflect radiation and heat energy, thus minimizing temperature variations within the camera and obviating the necessity for expensive control equipment. (Paillard, Inc.)

program should be anticipated. This camera system has the advantage of small size and moderate price, along with the necessary flexibility of film, lenses, and filters. A group of cameras can be combined easily for multispectral investigations (chap. V) to provide more precise scene measurement. A configuration of these cameras is small enough for easy handling and installation. A two-camera arrangement could easily be used as a stereometric system for accurate three-dimensional measurements of objects at close range. Its use in earthbound colorimetric analysis and experimental investigation is also indicated. The development of a wide spectral range lens, which was investigated as a possibility to be used on the lunar data camera, is discussed in reference 4.

All of the early cameras were painted completely black to minimize disturbances caused by the reflection of polished surfaces in the high solar intensity of outer space. The only exception to this rule is the Lunar Data Camera, which was painted matte silver to minimize the absorption of thermal radiation and to assist in maintaining a reasonably constant temperature environment within the camera.

One of the most unusual hand-held cameras specifically designed for the space program was the stereoscopic camera cane, officially designated the Apollo Lunar Surface Close-up Camera (ALSCC) (ref. 5). It was designed to record lunar-surface microstructure in its undisturbed state. The photographs provide scientific information on the size and cohesion of particles making up the undisturbed and freshly disturbed lunar surface. This camera provides closeup photography in stereo pairs. The image is approximately one-third the actual size of the object. Designed to be operated through the telescoping handle by an astronaut wearing a pressure suit and standing erect, the camera gives the impression of a cane camera. The exposed film is contained in a cassette, which is the only portion of the unit returned to Earth. This is the one camera for lunar-surface use which carries its own electronic flash-unit illuminating system. (See Color Plates 3 and 4.)

Representative hand-held and vehicle equipment (chap. II) that was used in the various missions is listed in table 1.

Among future applications of hand-held photographic instruments is the photographic sextant (ref. 6). The sextant is a navigational instrument that measures the angle above the horizon of a known star or the sun's limb on Earth, or the angle from a planetary body to a stellar reference for measuring a planet's subtense in space navigation. A sextant is a visual viewing and measuring instrument. The development of a photographic recording sextant suitable for use through the small windows of a spacecraft that would produce records for positive target star identification has been suggested. Techniques for immediate development of the film are expected to be similar to those used for unmanned vehicles where film is processed on board.

In addition to hand-held systems for space photography by the astronauts, a large volume of hand-held photography is utilized at all the NASA centers. The equipment used for such photography is straightforward. The standard Hasselblad has been widely used because of its versatility.

Typical of the significant applications are those performed at Kennedy Space Center in conjunction with the launch program. In these activities, photographic technicians work closely with the engineering people, documenting each item of work for review purposes in case of a critical malfunction. For example, before each connector is attached to the launch vehicle or the space capsule from the umbilical tower, a photograph is made of the connector and its receptacle. Another photograph is made immediately after it is connected. Every physical operation of this type is recorded as part of the engineering photographic program. Other photographs are even made of camera installations, particularly those that are remotely operated, to insure that a record exists of the installation prior to the event which it is to photograph.

Other hand-held photography utilized for public affairs purposes generally relies on acceptable techniques used by the professional and industrial photographic community. The films used in these operations are also the types used in projects described in the other chapters.

TABLE 1.—*Some Typical Camera Assignments for Space Missions*

(a) Mercury Program

Mission, date, and astronauts	Vehicle cameras 16 mm						Hand-held cameras		
	Milliken DBM-4	Milliken DBM-7 instrument observation	Milliken DBM-8 pilot observer	Milliken DBM-8 periscope	Maurer 220G Earth and sky	McDonnell pilot observer	Robot 35 modified	Ansco Autoset 35 modified	Hasselblad 500C modified
MA-1; 7/29/60; unmanned	2-BW	----------	----------	----------	----------	----------	----------	----------	----------
MR-1A; 12/20/60; unmanned	----------	BW	----------	----------	BW	----------	----------	----------	----------
MR-2; 1/31/61; unmanned (Ham)	----------	BW	BW	----------	CR	----------	----------	----------	----------
MA-2; 2/21/61; unmanned	----------	----------	----------	----------	CR	----------	----------	----------	----------
MA-3; 4/25/61; unmanned	----------	BW	----------	CR	CR	----------	----------	----------	----------
MR-4; 5/5/61; Shepard	----------	BW	CR	----------	CR	----------	CR	----------	----------
MR-4; 7/21/61; Grissom	----------	CR	CR	----------	----------	----------	----------	----------	----------
MA-4; 9/13/61; unmanned	----------	BW	----------	CR	CR	----------	----------	----------	----------
MA-5; 11/29/61; unmanned (Enos)	----------	BW	CR	CR	CR	----------	----------	----------	----------

MA-6; 2/20/62; Glenn	----------	BW	CR	----------	----------	----------	----------	----------	----------
MA-7; 5/24/62; Carpenter	----------	----------	CR	----------	----------	----------	----------	CN	----------
MA-8; 10/3/62; Schirra	----------	----------	CR	----------	----------	----------	----------	----------	CR
MA-9; 5/16/63; Cooper	----------	----------	----------	----------	----------	BW/CR	----------	----------	M
GT-I; 4/18/64; unmanned		----------	----------	----------	----------	----------	----------	----------	----------
GT-II; 1/19/65; unmanned		3-BW	CR	----------	----------	----------	----------	----------	----------
GT-III; 3/24/65; Grissom and Young		----------	----------	----------	----------	CR	----------	CR	----------
GT-IV; 6/3/65; McDivitt and White		----------	CR	----------	----------	CR	CR	----------	----------
GT-V; 8/21-29/65; Cooper and Conrad		----------	CR	----------	----------	CR	CR/CIR	----------	----------
GT-VI-A; 12/14-16/65; Schirra and Stafford (GT-VI was unmanned)		----------	----------	2CR	----------	M	----------	----------	----------