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APOLLO EXPERIENCE REPORT — PHOTOGRAPHIC EQUIPMENT AND OPERATIONS DURING MANNED SPACE-FLIGHT PROGRAMS

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16. Abstract

The evolution of crew-operated photographic equipment and the procedures for manned space-flight photographic operations are reviewed. The establishment of program requirements is described. Photographic operations are discussed, including preflight testing and inflight operations.

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SUMMARY

Photographic equipment has been carried on board manned spacecraft from the first orbital flight to the present time. The photographic requirements have increased with mission complexity. The photography obtained has become an important part of the technical data for each manned space flight and has been a major source of information to the world on the progress and accomplishments of the U.S. manned space-flight program.

INTRODUCTION

The evolution of photographic equipment and the procedures for manned space-flight photographic operations are reviewed in this report. This report shows how and why the equipment and procedures were developed from one program to the next. The status of photographic equipment at the major milestones in the manned space-flight program is summarized.

ESTABLISHMENT OF PROGRAM REQUIREMENTS

Photographic Requirements

From the time of the first manned orbital flight in Project Mercury to the present, space-flight photographic equipment and photographic operations have greatly matured. The photographic equipment, the photographic procedures, and the accompanying operations have developed in keeping with the requirements of the various space-flight programs. During Project Mercury, the consumables (for maneuvering), allowable weight, time, and space for photographic equipment were very limited. Therefore, many worthwhile photographic requirements could not be fulfilled. However, on the first Mercury orbital mission, a hand-held camera was carried, and interesting documentary and scientific photography was obtained. During Project Mercury, no formal procedures existed for the acceptance, evaluation, and incorporation of photographic requirements. Suggestions were made (informally) directly to the training and flight planning organizations by personnel both within and outside of the space task group. These suggestions were incorporated as well as possible into the inflight activities. During the latter part of Project Mercury, however, the photographic experiments were somewhat more formalized; the accomplishment of photographic objectives was primarily a function of how much photographic activity could be incorporated into the flight plan.

After the Mercury 6 mission, which proved that man can operate in space and that he can accomplish at least some photography from his crowded spacecraft with all the existing restrictions, the number of photographic requirements was increased, and consideration was given to expanding the photographic capability. On the Mercury 7 and 9 missions, horizon-definition photography was obtained in support of navigational-systems studies; and, on the Mercury 9 mission, dim-light-phenomena photography was obtained. These experiments are noted as the first examples of organized scientifically oriented photography in the manned space-flight program. The most extensive photographic experiments, however, consisted of the weather and terrain photography started informally on the Mercury 6 mission and formally on the Mercury 8 and 9 missions. This photography started a catalog of synoptic-weather and synoptic-terrain photography that was continued during the Gemini Program. The results of these experiments are summarized in references 1 to 4.

Throughout the Gemini Program, photographic requirements of two types were established: (1) the operational and documented photography and (2) scientific photography. The evolution of experiment-requirements organizations is summarized in reference 5.

From the beginning of the Gemini Program through the Gemini VIII mission, the photographic requirements were stated in the flight plan in general terms. As the interest in and demands for photography increased, it was deemed necessary to delineate the photographic plan more specifically; consequently, a documented photographic plan was introduced with the Gemini IX mission. The purposes of this plan were to define the photographic requirements of the mission and to specify the photographic equipment to be used. The photographic plan served as the formal documentation for mission photography.

A significant increase in the photographic-equipment capability was required in the Gemini Program to make permanent records of maneuvers during extravehicular activity (EVA), docking dynamics, docked-vehicle dynamics, and tethered-spacecraft dynamics. Experiment photographic requirements are summarized in references 5 and 6. The operational photographic requirements were dictated by the mission requirements and objectives, as stated in references 5 and 6. Photographic requirements in support of mission requirements will be discussed later in more detail, along with photographic equipment.

The Apollo Program increased the demand for broader photographic requirements. Photographic requirements became more formal, and the photographic plan was made a control document. The plan was retitled the photographic and television procedures document. Again, as in the Gemini Program, the operational photographic requirements were dictated by the mission requirements. However, an entirely new science (lunar mapping from orbit and lunar surface geology) became a part of the photographic requirements in the Apollo Program. The photographic requirements are usually routed through the mission requirements document to the photographic and television procedures document. Photographic requirements and procedures are controlled by the photographic and television procedures document, which in turn furnishes inputs to the mission flight plan and onboard data.

The additional requirements placed on photography in support of the Apollo Program include detailed vehicle inspection, crewman mobility inside the vehicle, lunar surface and specific-area mapping to support landing-site selection and determination, lunar surface crew-operational studies, lunar-traverse and sample-collection documentation, inspection of vehicles on the lunar surface, and many other engineering- and science-related photographic documentation tasks. Details of these photographic requirements are listed in the photographic and television procedures documents for each mission. (Selected portions of the Apollo 12 photographic and television procedures document are presented in the appendix to illustrate the mission documentation and degree of detail required to conduct a successful photographic mission.) The photographic and television procedures document is an operational document that presents the photographic objectives, crew procedures, camera use and exposure settings, time-line integration and equipment, and spacecraft stowage descriptions.

Photographic-Equipment Requirements

Photographic equipment has evolved during the manned space-flight program in accordance with the photographic requirements or objectives. The major photographic equipment used on each manned space flight from Mercury 6 to Apollo 13 is shown in table I, as are film types and equipment applications. During Project Mercury, the photographic-equipment requirements were conservative. On the first two Mercury orbital flights, 35-millimeter cameras modified by NASA to be crew compatible were used for mission documentation and for recording phenomena of interest or of an unusual nature at crew discretion. The potential for orbital photography was recognized in reviewing the photography obtained on the Mercury 6 and 7 missions. More extensive requirements were established for synoptic-terrain, synoptic-weather, and horizon-definition photography. Therefore, a 70-millimeter-format professional-quality camera was needed. The Hasselblad 500c camera was chosen as the basic camera. Modifications by NASA included removing the reflex viewing system and dechroming the commercial unit. Synoptic-terrain, synoptic-weather, and horizon-definition photography was required on the Mercury 8 and 9 missions to support future navigational system studies. In addition, dim-light phenomena were studied on the Mercury 9 mission; therefore, a specially equipped 35-millimeter camera with high-speed lens was provided for that requirement.

A 16-millimeter camera was carried on the Mercury missions to photograph the crewman's reactions to the new environment and to observe the instrument panel. The pilot-observer camera yielded particularly significant data on the crewman's reaction to launch accelerations and zero gravity and also on the crewman's position in the restraint system. The photographic data were useful in the design of restraint systems for following missions. Further information on the Mercury photographic operations and results is contained in references 1 to 4.

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Mercury 6				
Ansco Autoset	35	55	Eastman color negative, stock number 5250	Terrain, weather, sunset phenomena
Mercury 7				
Robot Recorder	35	55	Eastman color negative, stock number 5250	Terrain, weather, horizon definition, sunset phenomena
Mercury 8				
Hasselblad	70	80	Super Anscochrome D-200	Terrain, weather, sunset phenomena
Mercury 9				
Hasselblad	70	80	Ultraspeed Anscochrome, FDC 289, D-200	Terrain, weather, horizon definition
Robot f/0.95	35	--	--	Dim light
Gemini III				
Hasselblad	70	80	Special order (SO-217)	Terrain, weather
McDonnell motion picture camera	16	5	SO-217	Crew activity (for evaluation)
		25	SO-217	Earth strip
Gemini IV				
Hasselblad	70	80	SO-217 (black and white with red-blue filter)	Terrain, weather, stereoscopic coverage, EVA (for documentation and analysis), earth-limb definition
McDonnell motion picture camera	16	5, 18, 75, and 25	SO-217	EVA and maneuvering unit (for evaluation)
Gemini V				
Hasselblad	70	80	SO-217	Terrain, weather
			Ansco color reversal (D-50)	Zodiacal light, airglow, spectrophotography
McDonnell motion picture camera	16	5, 18, 75, and 25		Crew activity (for evaluation)
Spotmeter	NA[a]	NA	NA	Exposure value upgrading
Gemini VII				
Hasselblad	70	80	SO-217	Terrain, weather
		250	Ektachrome infrared (IR) 8443	Visual-acuity site documentation
			Panatomic-X 3400	Dim light
			Kodak 2475	Dim light

[a]Not applicable.

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION - Continued

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Gemini VII - Concluded				
McDonnell motion picture camera	16	5, 18, 75, and 25	SO-217	Crew activity (for evaluation), rendezvous (for documentation and analysis), stationkeeping (for dynamics evaluation)
Spotmeter	NA[a]	NA	NA	Exposure value upgrading
Gemini VI-A				
Hasselblad	70	80	Kodak 2475	Terrain, weather
		250	SO-217	Rendezvous (documentation), vehicle (inspection), dim light
Maurer sequence camera	16	5, 18, and 75	SO-217	Rendezvous (relative-motion analysis), vehicle (inspection)
Spotmeter	NA	NA	NA	Exposure value upgrading
Gemini VIII				
Hasselblad	70	80	SO-217	Agena docking (engineering and evaluation), terrain, weather
Maurer sequence camera	16	5, 18, and 75	--	Rendezvous and docking, separation, vehicle (dynamics analysis)
Spotmeter	NA	NA	NA	Exposure value upgrading
Gemini IX-A				
Hasselblad	70	80	SO-217	Terrain, weather (Agena, EVA)
Hasselblad Super Wide Angle (SWA)	70	38	SO-217	Agena, EVA
Maurer	70	80 and 50	SO-217	Terrain, weather, zodiacal light, airglow
Maurer sequence camera	16	75	SO-217	Rendezvous to 50 feet
	16	18	SO-217	Agena, EVA, rendezvous from 50 feet
		5	SO-217	EVA
Gemini X				
Maurer	70	73 (ultraviolet (uv)) with uv objective grating and 50	Kodak I-O	S-13 (uv astronomical photography), zodiacal light, airglow
Hasselblad SWA	70	38	SO-217	EVA, terrain, weather, Agena service propulsion system (SPS), Agena stationkeeping

[a]Not applicable.

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION - Continued

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Gemini X - Concluded				
Maurer	70	80	SO-217	Terrain, weather, Agena SPS thruster plumes, Agena primary propulsion system (PPS) burn
Maurer sequence camera	16	75	SO-217	Rendezvous, final separation, MSC-12 landmark contrast
Maurer sequence camera	16	18	SO-217	Rendezvous (50 feet to docking), bending-mode check, PPS burn, EVA
			Kodak 2475	S-26 (Agena ion-wake measurement)
Maurer sequence	16	5	SO-217	EVA
Gemini XI				
Hasselblad SWA	70	38	SO-368	Terrain, weather, EVA, terrain from high altitude, Agena operations
Maurer	70	80	SO-368	Terrain, weather
Maurer	70	73 uv (uv grating, uv prism)	Kodak I-O	S-13 (uv astronomical photography)
Maurer	70	80	Kodak 103 (1 magazine)	S-11 (airglow photography)
			SO-166 (Kodak 0-85)	S-29 (libration-region photography) - planned but not performed
Maurer sequence camera	16	75	SO-36	Rendezvous
		18	SO-368	Rendezvous and docking, S-26 (ion-wake measurement), Agena PPS burn, docking practice, EVA, tether evaluation
			Ektachrome 2475 (2 magazines)	S-26 (ion-wake measurement)
		5	SO-368	EVA (camera mounted outside spacecraft)
McDonnell motion picture camera	16	5	SO-368	Apollo sump-tank
Gemini XII				
Hasselblad	70	80	SO-368	S-5 (terrain), S-6 (weather), Agena operations
Maurer	70	80	SO-368	S-5 (terrain), S-6 (weather)
		50	Ektachrome 103D	S-11 (horizon airglow)
			SO-166	S-29 (libration regions), S-51 (sodium cloud) - no data return

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION - Continued

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Gemini XII - Concluded				
Maurer		73 uv	Spectroscopic I-O	S-13 (astronomical uv spectroscopy)
Maurer sequence camera	16	75	SO-368	Rendezvous and formation flying, S-51 support data
		18	SO-368	Docking, undocking, formation flying, tether operations, entry
		5	SO-368	EVA (camera mounted outside)
Apollo 7				
Hasselblad	70	80	SO-121 (6 magazines)	Simulated docking, spacecraft-LM adapter (SLA), window coating, terrain, weather
			Panatomic X (1 magazine)	S-5 (terrain), S-6 (weather)
Maurer sequence camera	16	18 and 75	SO-121 (5 magazines)	Simulated docking, SLA, rendezvous and SLA, window coating, terrain, weather
		5	Kodak EF (7 magazines)	Intravehicular activity (IVA)
Television	NA[a]	--	NA	Crew and spacecraft interior, earth
Apollo 8				
Hasselblad electric (EL)	70	80	SO-368 (2 magazines)	Earth (long distance), moon (long distance), lunar surface targets, stereoscopic strip
			SO-121 (1 magazine)	Earth (long distance), moon (long distance), lunar surface
			Kodak 3400 (3 magazines)	Lunar stereoscopic strip, lunar landmarks, earth (long distance), moon (long distance), solar corona, lunar surface targets, lunar surface (red-blue surface study)
			Kodak 2485 (1 magazine)	Spacecraft exterior atmosphere, lunar surface in earthshine, transient luminescent phenomena, gegenschein, zodiacal light
		250 (medium telephoto)	SO-368	Lunar surface targets, moon (long distance)
			SO-121	Moon (long distance)
			Kodak 3400	Lunar terminator, image-motion-compensation (IMC) training, moon (long distance), lunar surface targets, zero phase angle

[a]Not applicable.

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION - Continued

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Apollo 8 - Concluded				
Data-acquisition camera (DAC)	16	200	SO-368 (9 magazines)	IMC training, earth and moon (long distance)
		75	SO-368	Earth and moon (long distance), lunar surface
		18	SO-368	Separation and Saturn IVB (S-IVB) inspection, lunar surface, earth and moon (long distance)
		5	SO-368	Exhaust effects on command module (CM) windows
			SO-168 (2 magazines)	Crew activities
Television	NA[a]	--	NA	Crew and spacecraft interior, earth and moon from lunar orbit
Apollo 9				
Hasselblad	70	80	SO-368	S-IVB/SLA/LM (inspection), docking, EVA (from CM), LM (from CM), LM landing gear, LM from CM and CM from LM during docking, terrain
Hasselblad SWA	70	38	SO-368	Drogue-impact damage, EVA from LM porch, docking, weather
			SO-168	Interior crew activities
DAC	16	75	SO-368	Ascent propulsion system burn to depletion
		18	SO-368	S-IVB/SLA/LM (inspection), docking, LM ejection, docking target during third SPS burn; LM landing-gear deployment, descent propulsion system plume (from LM), undocking, LM jettison
		5	SO-368	Extravehicular transfer from LM to CM and return
			SO-168	Interior crew activities
Multispectral camera (four ganged EL Hasselblads)	70	80	SO-368, SO-246 (black-and-white IR), SO-180 (color IR), Ektachrome 3400	Multispectral terrain photography
Television	NA	--	NA	Interior of CM and LM, EVA

[a]Not applicable.

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION - Continued

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Apollo 10				
Hasselblad EL	70	80	SO-368	Transposition, docking, and extraction (TD&E); S-IVB/SLA/LM (inspection); lunar surface targets; undocking; LM (inspection); rendezvous
Hasselblad EL	70	250	SO-368	Earth (long distance), lunar targets of opportunity, moon (long distance)
DAC	16	75	SO-368	Rendezvous
		18	SO-368	TD&E, S-IVB/SLA/LM (inspection), undocking, LM (inspection), rendezvous, lunar surface
		5	SO-168	Intravehicular transfer (commander), crew activities in spacecraft
Television	NA[a]	--	NA	Transposition and docking, spacecraft interior, undocking, lunar targets
Apollo 11				
Hasselblad EL	70	80	SO-368	Earth from high altitude after translunar injection, transposition and docking, earth and moon, undocking, LM (inspection), lunar targets
			SO-168 (LM)	Lunar surface through LM window
		250	SO-368	Earth and moon (long distance), lunar targets
			3400	Moon (long distance), lunar targets, landed-LM location
		80	3400	Lunar mapping (strip, CM), lunar surface through LM window
DAC	16	75	SO-368	Rendezvous, lunar targets
		18	SO-368	TD&E, undocking, LM (inspection), rendezvous, docking
		5	SO-168	Crew, spacecraft interior, entry
		10	SO-168	Descent as seen through LM window (60 000 feet to touchdown), EVA, ascent, CM at rendezvous

[a]Not applicable.

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION - Continued

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Apollo 11 - Concluded				
Closeup stereo-scopic camera	--	--	SO-368	Lunar surface details
Television (CM)	NA[a]	--	NA	Earth, moon, spacecraft interior, crew
Television (lunar surface)	NA	--	NA	EVA, lunar surface, LM on surface
Hasselblad data camera (DC)	70	60	SO-168	Lunar surface, LM, crewmen during EVA, deployed experiments
Apollo 12				
Hasselblad EL	70	80	SO-368	TD&E, earth, moon, undocking, lunar targets, Fra Mauro, rendezvous and docking
			3400	Vertical stereoscopic strip, moon (long distance), lunar targets
		250	SO-368	Earth and moon (long distance), lunar targets
		500	3400	High-resolution oblique photography of Lalande, Descartes, and Fra Mauro
DAC	16	18	SO-368	TD&E, undocking, rendezvous and docking, LM jettison, high-resolution oblique photography (concurrent with Hasselblad EL with 500-mm lens)
			SO-168	Entry
		5	SO-168	Interior crew activities
		10	SO-368	LM descent, EVA
Hasselblad DC	70	60	SO-168	Lunar surface during EVA, Apollo lunar surface experiments package, LM, crewmen
			SO-267	Lunar geological targets, sample documentation, Surveyor III
Closeup stereo-scopic camera	--	--	SO-368	Lunar surface details
Television (CM)	NA	--	NA	Transposition and docking, intravehicular transfer, spacecraft interior, lunar surface, undocking, formation flying, docking, earth

[a]Not applicable.

TABLE I. - PHOTOGRAPHIC EQUIPMENT AND APPLICATION - Concluded

Equipment	Film size, mm	Lens size, mm	Film	Task/target
Apollo 12 - Concluded				
Television (lunar surface)	NA[a]	--	NA	Crewmen during EVA, LM, lunar surface (Camera failed during first EVA.)
Multispectral camera (four ganged Hasselblads)	--	--	3400, 3401, SO-246 (IR)	Lunar surface targets (from CM)
Apollo 13				
Hasselblad EL	70	80	SO-368	Transposition and docking, moon (long distance), service module, spacecraft interior
		250	SO-368	Weather, service module
Hasselblad DC	70	60	SO-168	Lunar surface during flyby, service module
		80	SO-168	Service module
DAC	16	18	SO-368	Transposition and docking
Battery-operated DAC	16	10	SO-368	Crew and spacecraft interior
		75	SO-368	Service module after separation
Television	NA	--	NA	Spacecraft interior and intravehicular transfer
Lunar topographic camera	[b]5	[b]18	3400	Not used because of early mission termination

[a]Not applicable.
[b]Inches.

In the Gemini Program, equipment was required to continue the synoptic-terrain and synoptic-weather experiments begun in Project Mercury; however, there was also a requirement for a motion picture camera to document the dynamic near-space operations (such as EVA, rendezvous, and docking) and to provide a continuous photographic strip of the earth for use in correlating the still photographs. Consequently, a low-frame-rate motion picture camera, later to be replaced by a sequence camera, became part of the Gemini camera inventory. The motion picture cameras generally had a complement of three lenses: a 5-millimeter lens for close-range wide-angle photography required for EVA and crew station operations, an 18-millimeter lens required for moderate-range photography (such as during docking), and a 75-millimeter lens required for longer range photography (such as photographs taken during rendezvous and ground strips).

The first motion picture camera used in the Gemini Program (fig. 1) had a single-frame rate of 6 frames per second and a fixed shutter speed of 1/125 second, and was originally battery operated. Later, this camera was modified to operate with spacecraft power, which considerably improved the frame-rate and shutter-speed accuracy. However, the camera still lacked the flexibility required for the program photography. Consequently, early in the Gemini Program, procurement of a more flexible and accurate sequence camera was initiated. The sequence camera incorporating frame rates of 1, 6, and 16 frames per second and shutter speeds of 1/50, 1/100, 1/120, and 1/250 second (fig. 2) was introduced for the Gemini VI mission. The camera frame rate was independent of shutter speed, unlike normal cinematic camera operation. This camera was used on later Gemini flights and on the first Apollo flight.

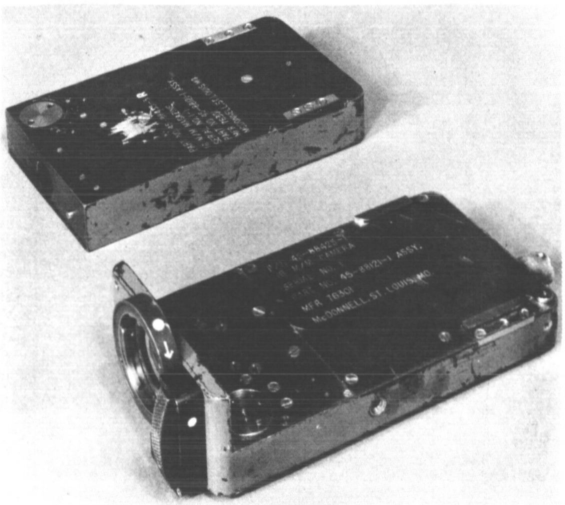


Figure 1. - The 16-millimeter camera used on early Gemini flights.

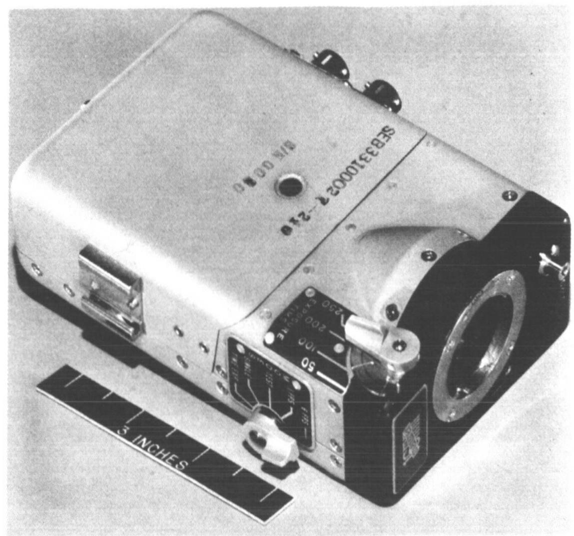


Figure 2. - The 16-millimeter sequence camera (used on later Gemini flights and on the first Apollo flight).

Three types of still cameras were used in the Gemini Program (table I). The 70-millimeter Hasselblad 500c camera, modified for space-flight use (fig. 3), was the primary camera used for the synoptic-weather and synoptic-terrain photography in the Gemini Program. Photography obtained with this camera contributed significantly to the program, as reported in references 7 to 13. A magazine for the 70-millimeter camera is shown in figure 4. On the Gemini IX to XII missions, a 70-millimeter scientific camera and a low-light, ultraviolet lens to meet specific experiment requirements were introduced. Valuable photographic results were obtained (ref. 5); however, the camera did not provide the required reliability and was later abandoned. A third still camera, the 70-millimeter Hasselblad super-wide-angle camera with 38-millimeter lens (fig. 5), was introduced for the Gemini IX mission to fulfill the wide-angle photographic requirements of EVA and also to provide wider angle ground-coverage data in support of synoptic-terrain and synoptic-weather requirements. Some of the most valuable and widely published photography of the Gemini Program was obtained with this

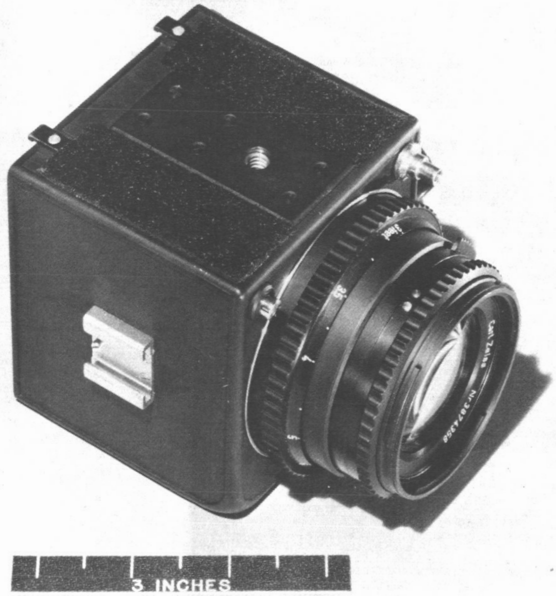


Figure 3. - Hasselblad 500c 70-millimeter still camera with 80-millimeter lens.

Figure 5. - Hasselblad 70-millimeter super-wide-angle camera with 38-millimeter lens.

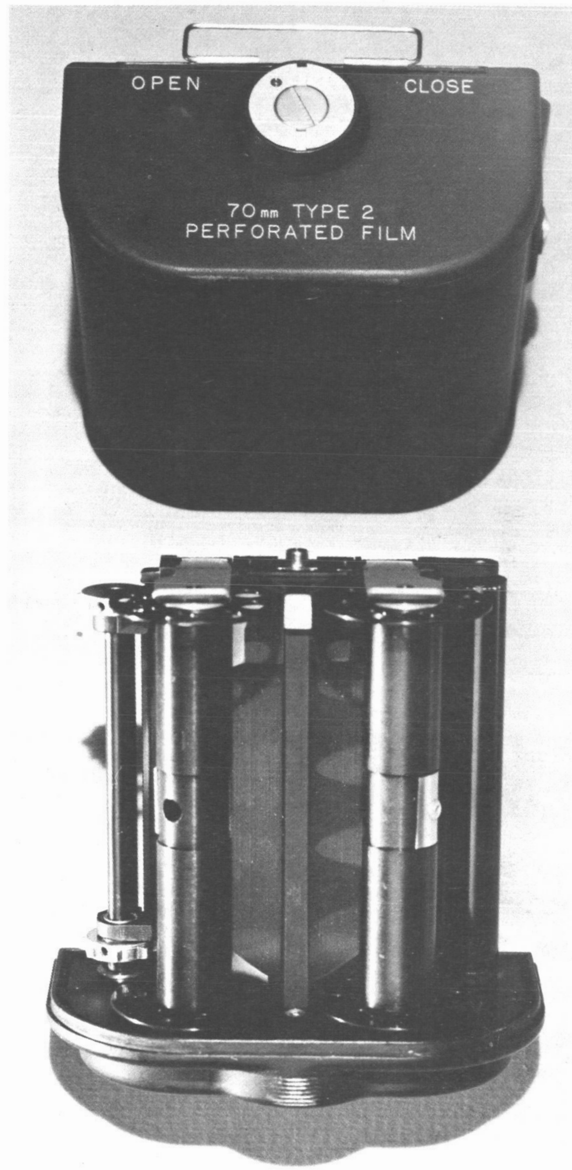


Figure 4. - Film magazine for 70-millimeter camera.

system. Reference 8 contains a summary of later Gemini photography. The required ground-support equipment is discussed later. Representative still photographs taken during the Gemini missions in support of the photographic requirements for engineering documentation, experiments, and vehicle inspection are shown in figures 6 to 17.

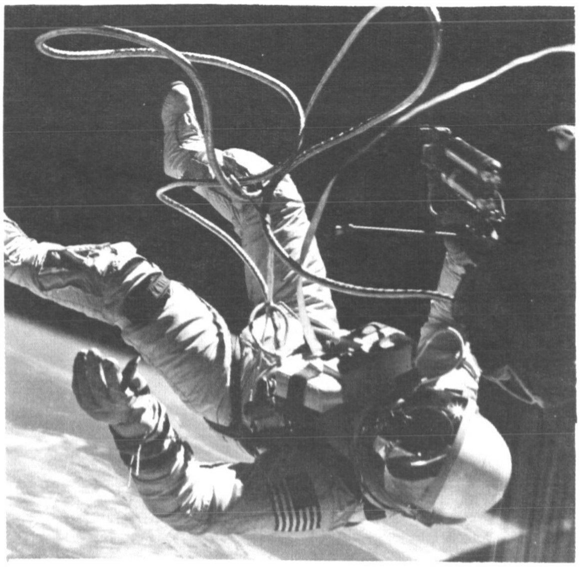
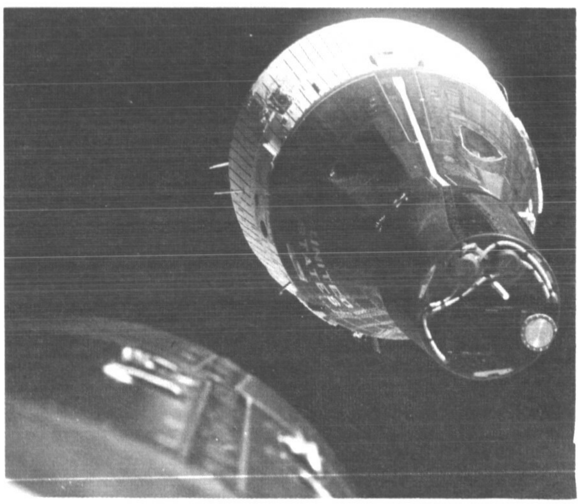
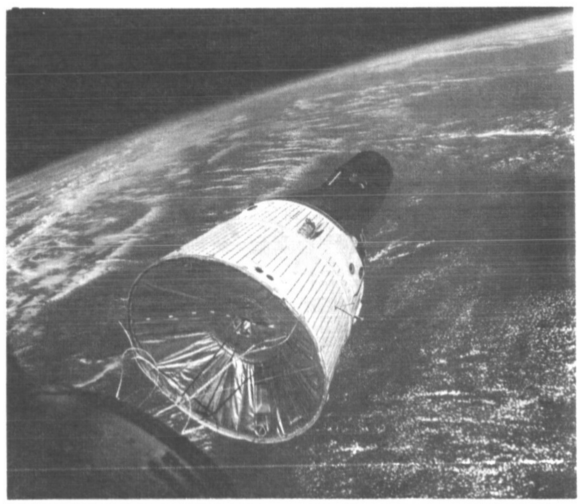


Figure 6. - Engineering documentation of EVA on Gemini missions.

Figure 7. - The EVA umbilical of Gemini IX.



(a) First view.



(b) Second view.

Figure 8. - Gemini VI and VII vehicle inspection after exposure to launch and orbital flight.

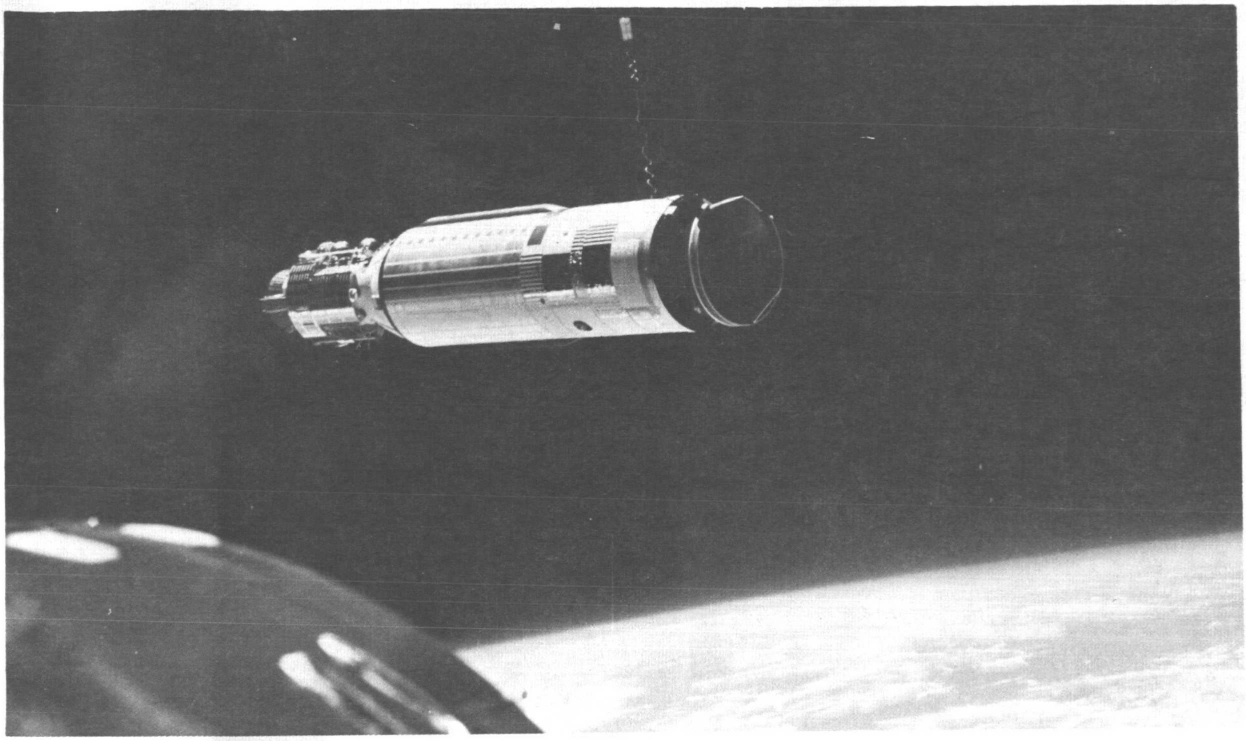


Figure 9. - Agena rendezvous sequence.

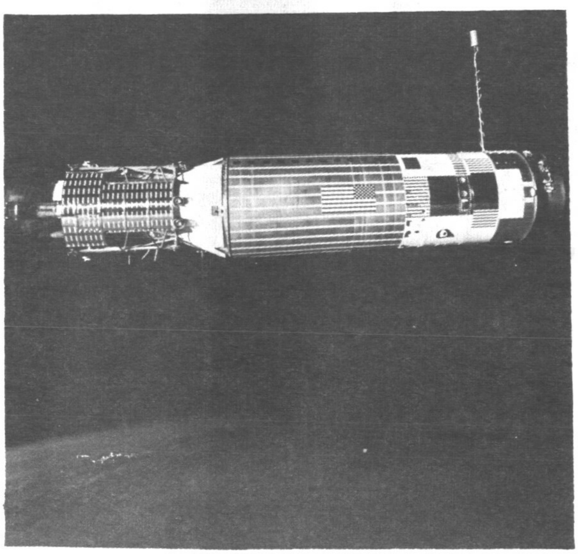


Figure 10. - Agena stationkeeping and vehicle inspection.

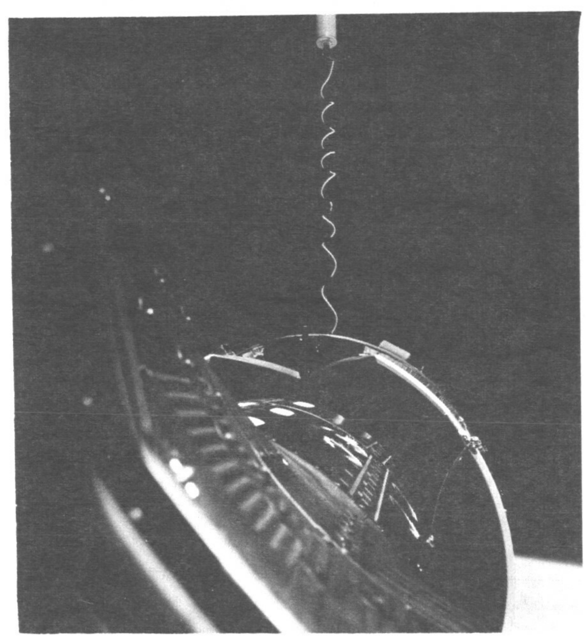


Figure 11. - Agena docking, showing Agena display panel (just below antenna), which is used as a docking-status indicator.

Figure 12. - Gemini IX crew station, showing Astronaut Thomas P. Stafford in the left-seat position and the 16-millimeter camera mounted in the window.

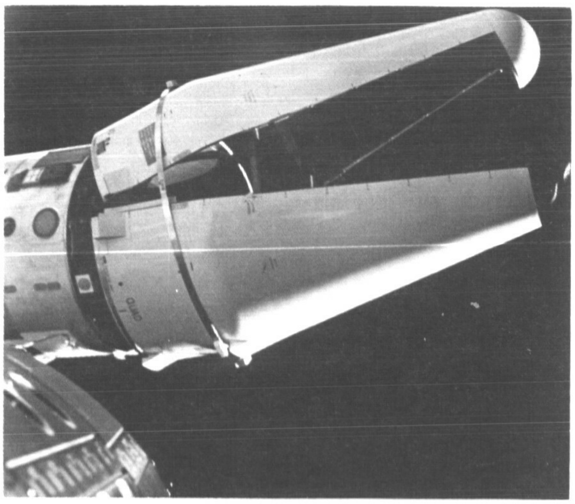
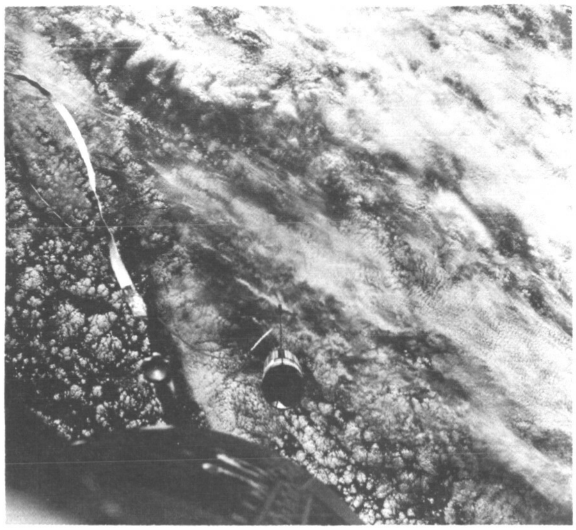
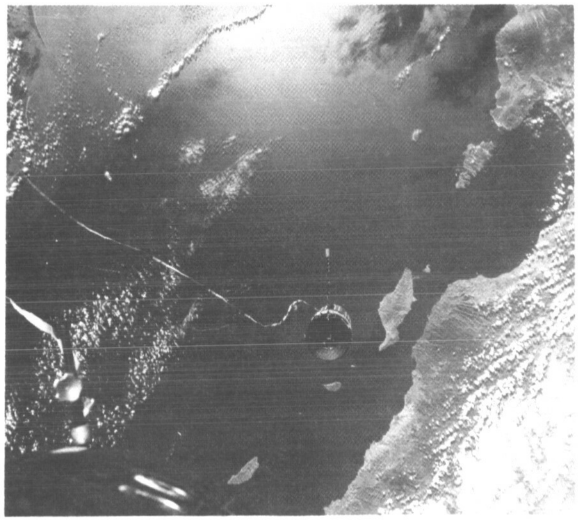


Figure 13. - Gemini IX target docking adapter.



(a) First view.



(b) Second view.

Figure 14. - Engineering documentation of vehicle-tether tests conducted during the Gemini Program.

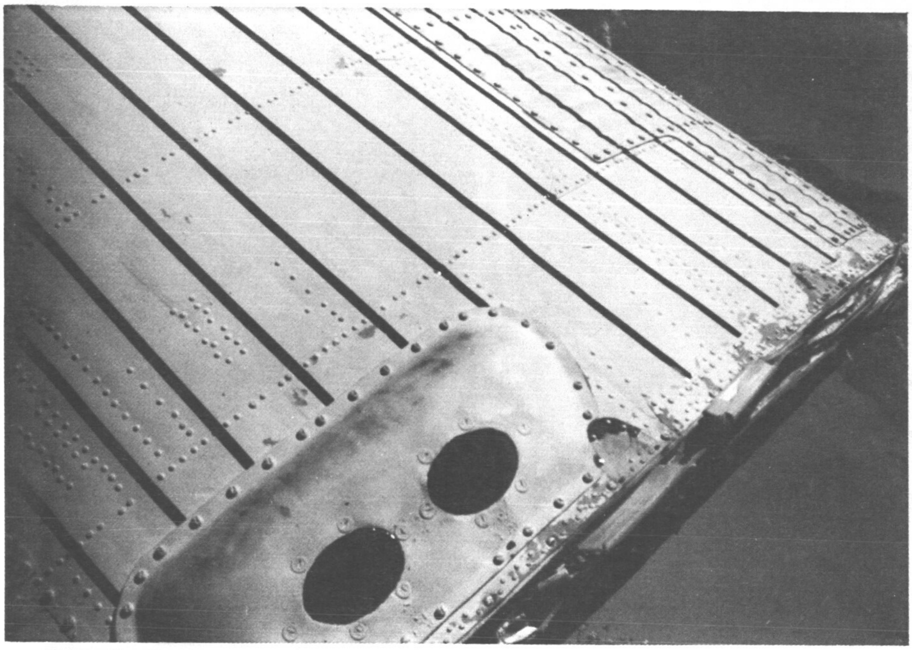
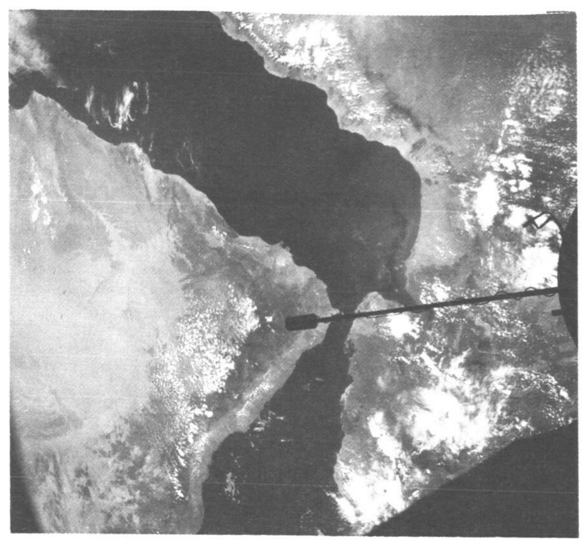


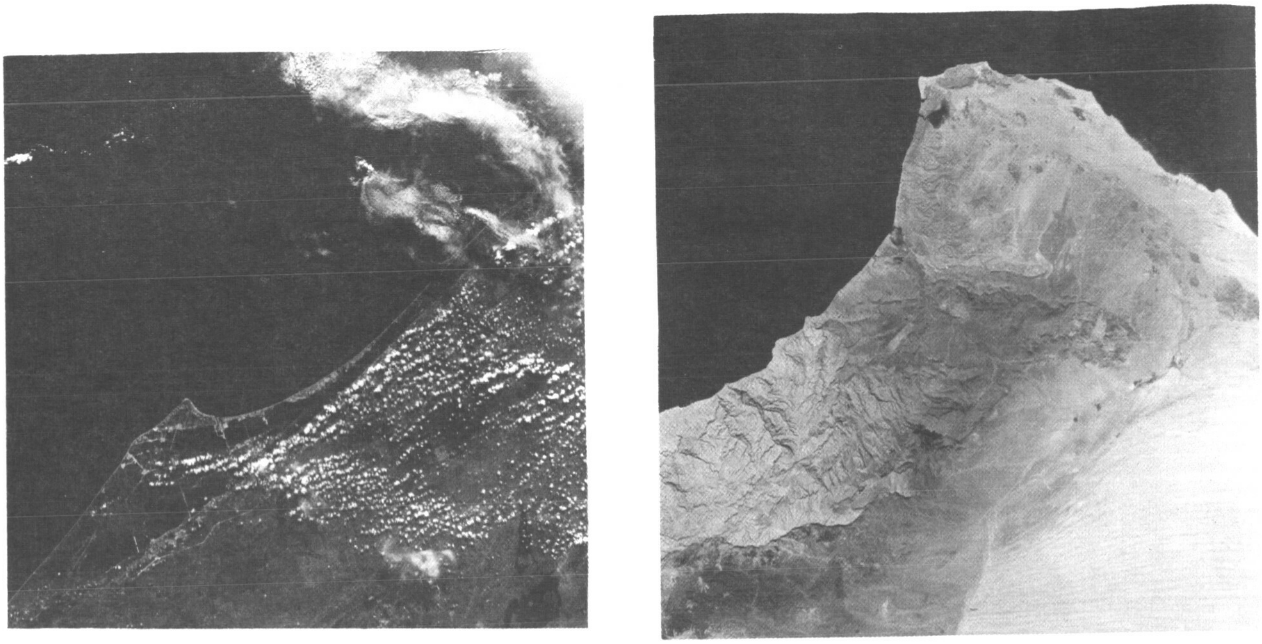
Figure 15. - Vehicle inspection during Gemini EVA.

Figure 16. - The Gemini window taken at a sun angle that accentuates the window deposits.



(a) First view.

Figure 17. - Synoptic-terrain and synoptic-weather photography.



(b) Second view. (c) Third view.

Figure 17. - Concluded.

A spotmeter (fig. 18) was first introduced to the manned space-flight inventory on the Gemini V mission for the purpose of measuring light values in situations in which light prediction was difficult, for example, inside the spacecraft and on areas of specific interest on a target vehicle. One example of the usefulness of the spotmeter was on the Gemini IX mission during photography of the failed docking adapter, when engineering photography was required of detailed parts of the vehicle. An example of this photography is shown in figure 13. The spotmeter was also extremely useful in confirming predicted nominal exposure values over different earth surfaces such as water, desert, and vegetation at various sun angles. The general problem of exposure determination will be discussed later.

Figure 18. - Spotmeter used in the Gemini Program, with external exposure scale.

The photographic requirements of the Apollo Program necessitated the upgrading and expansion of photographic equipment used for the Gemini Program. The Apollo Program required photographic equipment of sufficient quality to upgrade the available lunar maps and to map areas of the moon as an aid in landing-site selection. Also, landing-approach strip photography was required for crew training. Documentation and photogrammetric data of lunar surface features and of collected samples were required for lunar geology. Continuous photography of the lunar module (LM) descent and ascent was required to aid in LM landing-site location analysis. Vehicle-inspection photography was required during the LM engineering missions to determine that all vehicles suffered no damage during separation, docking, or rendezvous and that the landing gear on the LM deployed properly.

To meet the requirements of the Apollo Program, the 70-millimeter still cameras, the 16-millimeter sequence camera, and the spotmeter were upgraded; the 70-millimeter data camera (DC) and the 5-inch-format lunar topographic camera were introduced; and various lenses were added (table I). Also, a change was made to the modified Hasselblad electric (EL) camera (fig. 19), which is a motor-driven camera required for the lunar strip photography and for crew operation on the lunar surface. The modification work was contracted to the camera manufacturer which resulted in increased product control and quality. Camera subcontractors were also brought into direct involvement and handpicked the optics and assembled special shutters for the NASA cameras. A special version of the Hasselblad 500 EL camera with a newly designed 60-millimeter lens and reseau plate (fig. 20) was produced and was designated the Hasselblad DC. This camera was intended initially for photogrammetric work on the lunar surface and later for orbital mapping. The 70-millimeter DC is fitted with (1) a glass reseau grid at the film plane and a special 60-millimeter lens for lunar surface geological and engineering photography, (2) an 80-millimeter lens for orbital

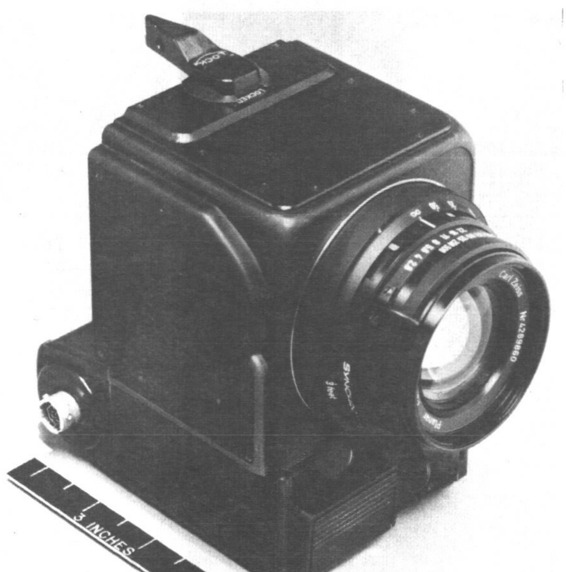


Figure 19. - Hasselblad 70-millimeter electric-drive camera with 80-millimeter lens.

Figure 20. - Reseau plate on 70-millimeter data camera.

photography, and (3) a 100-millimeter photogrammetric-quality fixed-focus lens for orbital mapping. Although the 100-millimeter lens has not been made part of the flight inventory, the lens is expected to be used on the later Apollo missions.

This equipment has yielded outstanding photographic results and has operated reliably in the lunar environment. The appendix contains additional descriptions of the Apollo 12 photographic equipment. The basic still camera equipment used in the Apollo Program is shown in figures 21 to 27. Representative photographs taken with the 70-millimeter still cameras in fulfillment of the photographic objectives are shown in figures 28 to 50.

Figure 21. - Hasselblad 70-millimeter electric data camera with 60-millimeter lens mounted to camera, 80-millimeter lens at left, and 100-millimeter lens at right.

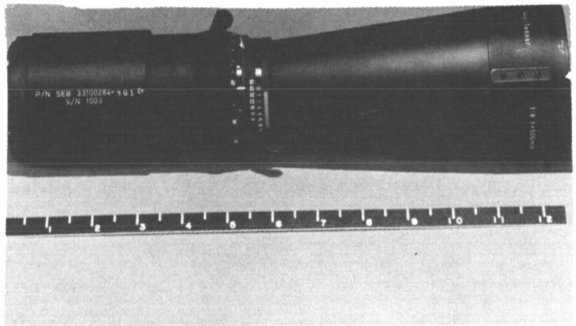


Figure 22. - The 500-millimeter lens used with the 70-millimeter electric Hasselblad.

Figure 23. - The 250-millimeter lens used with the 70-millimeter electric Hasselblad.

Upgrading of the 16-millimeter sequence cameras used in the Gemini Program resulted in the 16-millimeter data acquisition camera (DAC). The sequence modes were changed to 1, 6, and 12 frames per second, and a 24-frame-per-second cinematic mode was added. Shutter speeds were changed to 1/60, 1/125, 1/250, 1/500, and 1/1000 second. The DAC had increased film capacity, improved accuracy of frame rate and shutter speed, and improved reliability and ruggedness. Lenses for the 16-millimeter DAC were standardized for the Apollo Program, and a 10-millimeter lens and a 180-millimeter lens were added to the inventory. The new lenses, along with the upgraded camera body, significantly improved the 16-millimeter-camera photographic quality and flexibility.

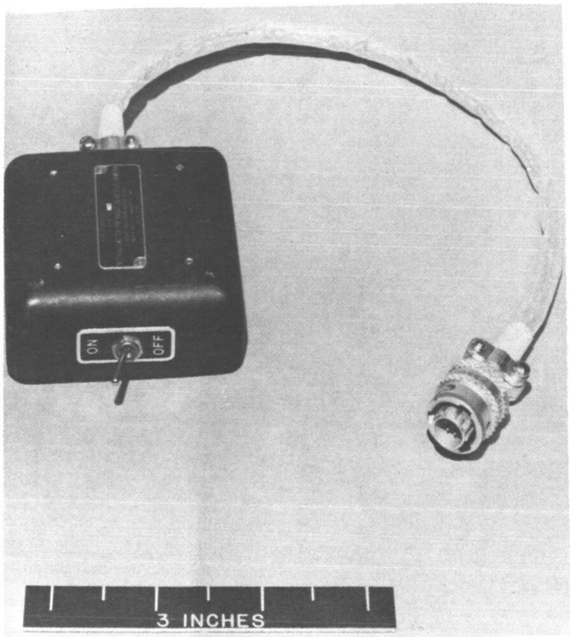


Figure 24. - Intervalometer used with 70-millimeter electric Hasselblad to obtain accurately timed stereo-strip photography from lunar orbit.

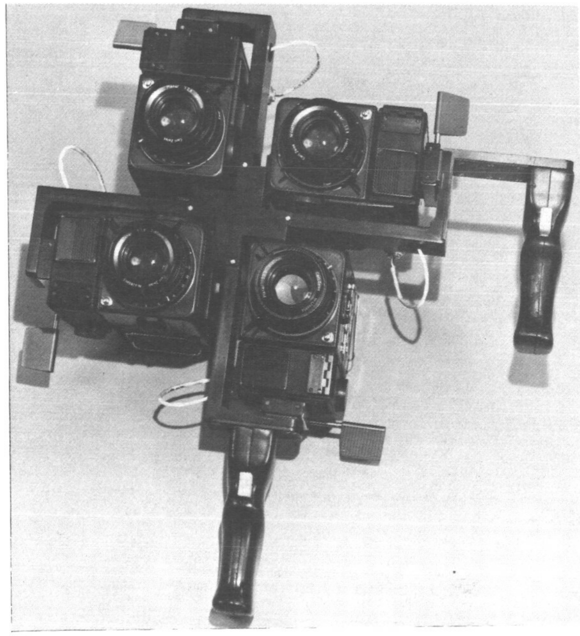


Figure 25. - Mounting of four 70-millimeter electric Hasselblads for simultaneous, multispectral photography.

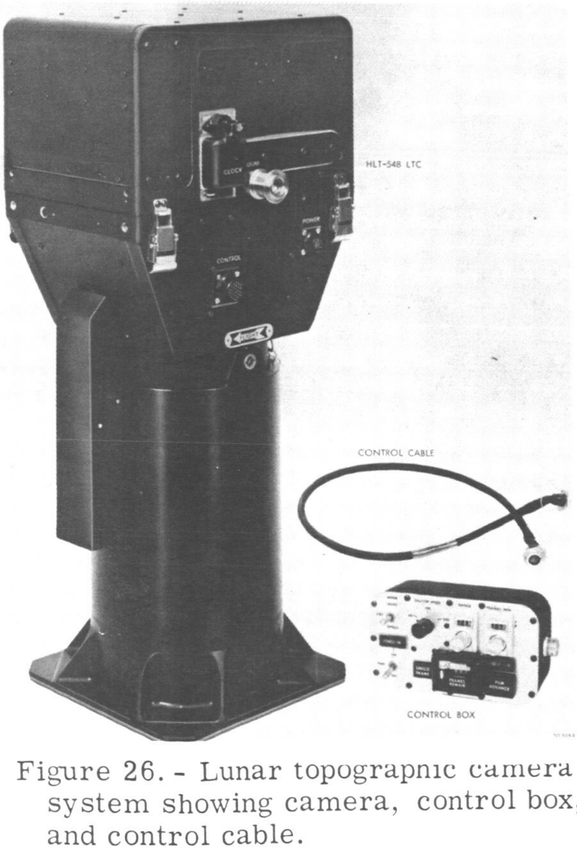


Figure 26. - Lunar topographic camera system showing camera, control box, and control cable.

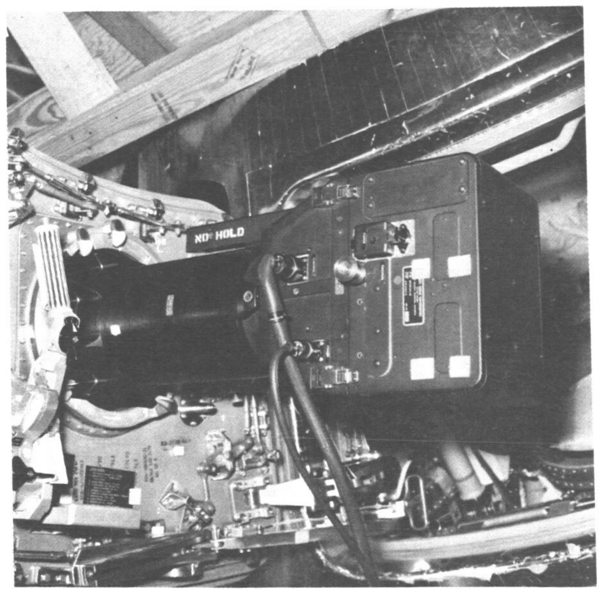


Figure 27. - Installation of lunar topographic camera on command module hatch window (photograph taken in command module mockup).

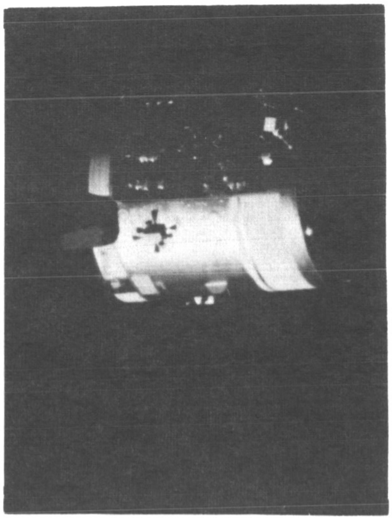


Figure 28. - Service module damage on the Apollo 13 mission.

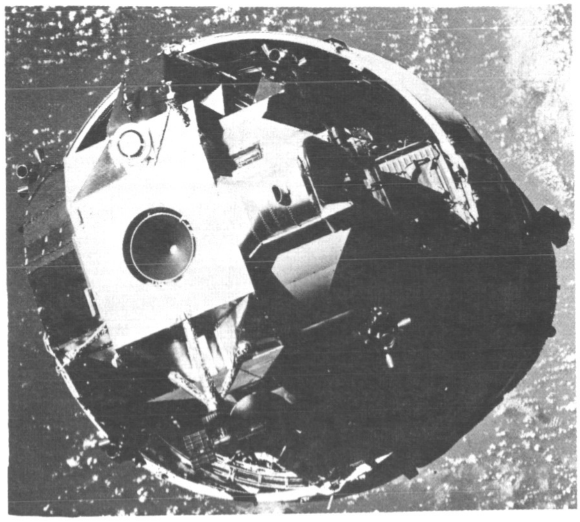


Figure 29. - Lunar module mated with S-IVB before LM extraction (photograph taken from the command module during docking maneuver).

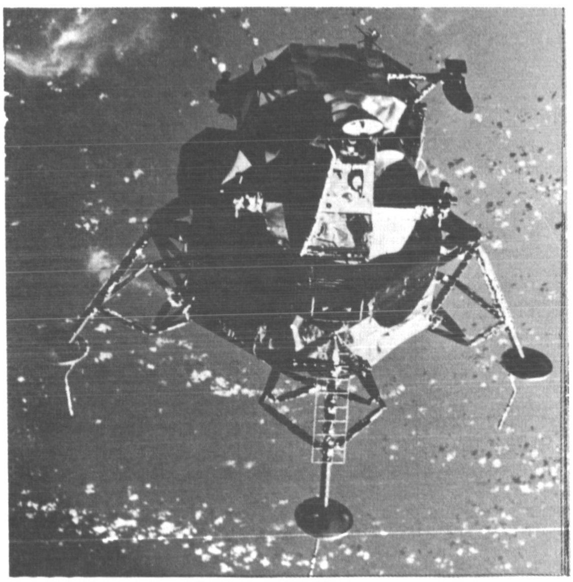


Figure 30. - Lunar module in descent configuration as viewed from the command module.

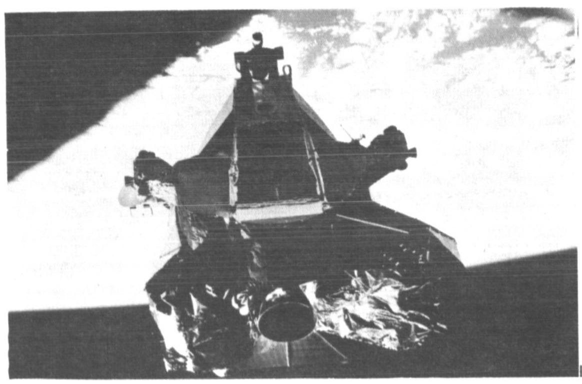


Figure 31. - Lunar module in ascent configuration before docking with command module.

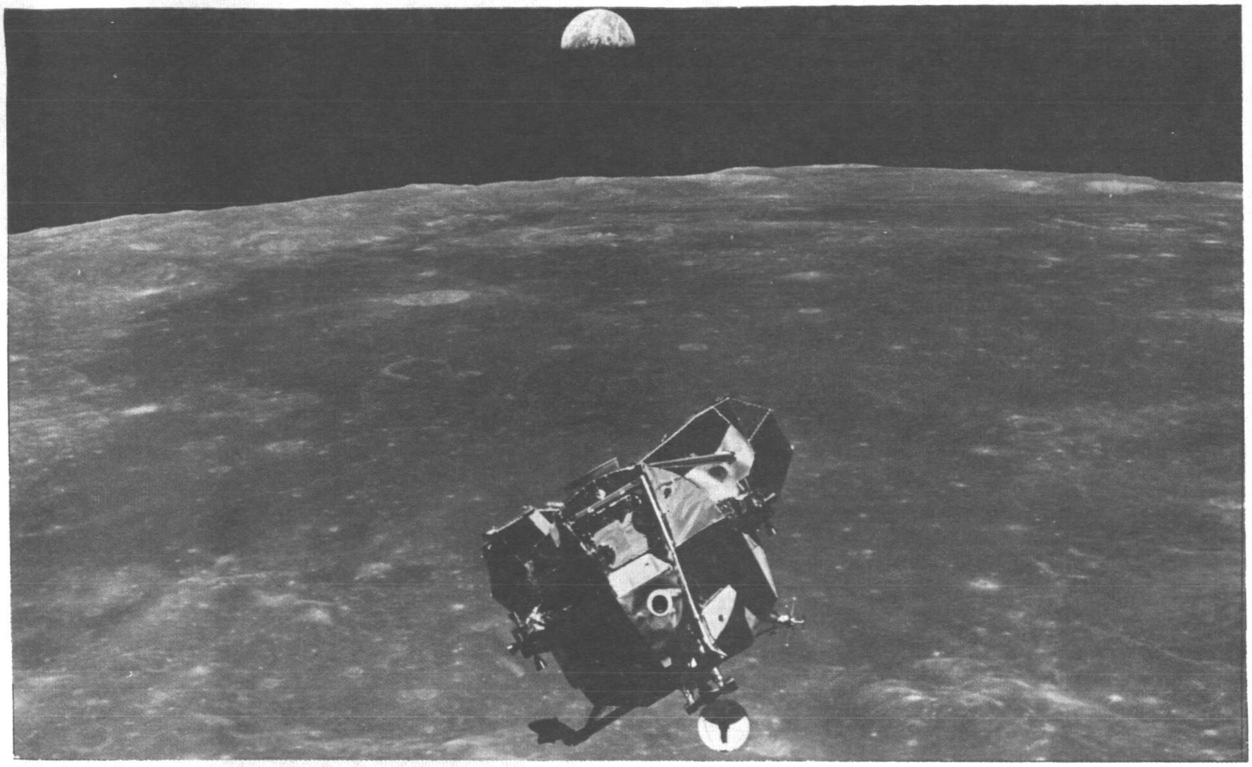


Figure 32. - Lunar module during docking maneuver with command module.

Figure 33. - Lunar module docked with command module, showing condition of LM thrusters and skin.

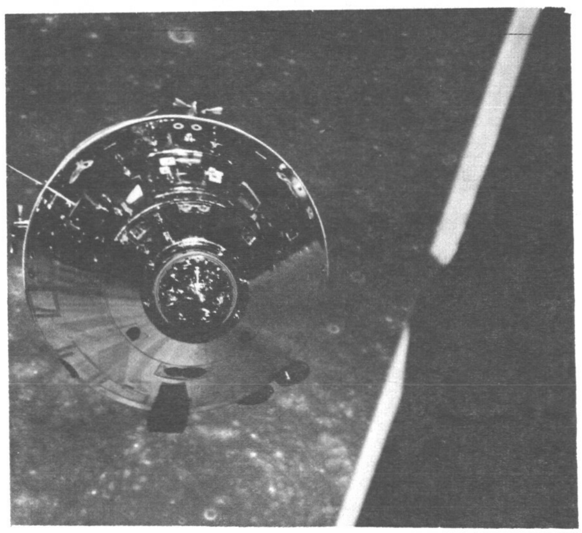


Figure 34. - Command module as viewed from the lunar module. Note the highly reflective skin of the vehicle.

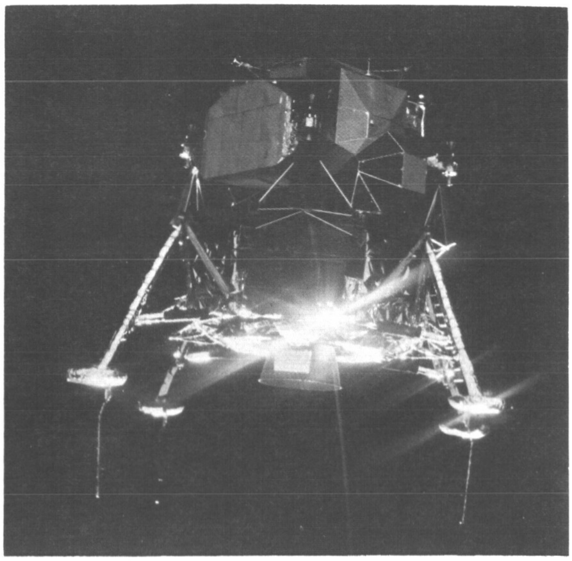


Figure 35. - Lunar module, showing sunglint from surfaces, which complicates space photography.

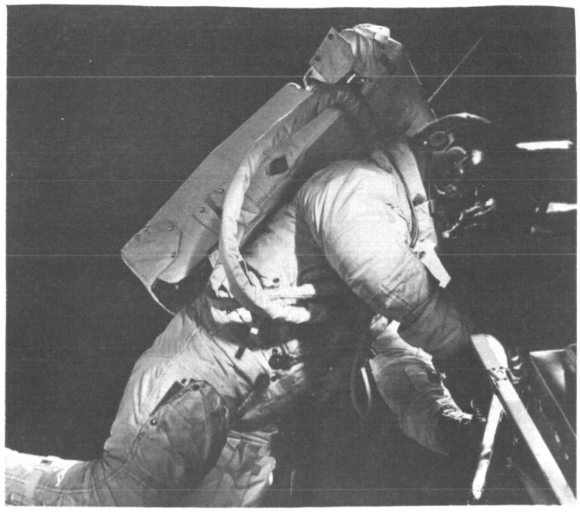


Figure 36. - Handrail evaluation during orbital EVA.

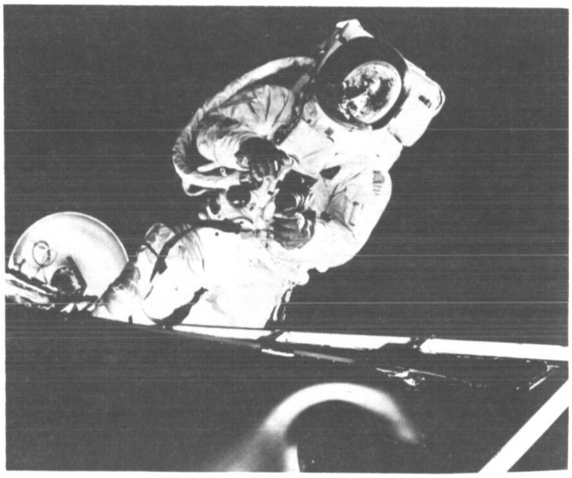


Figure 37. - Use of photographic equipment during EVA operations.

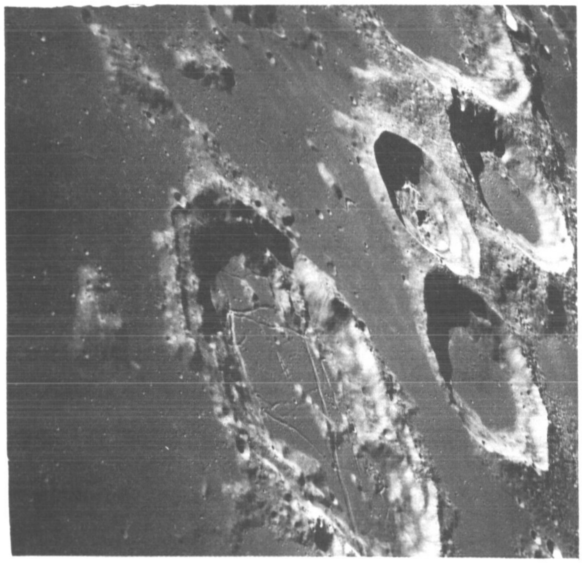
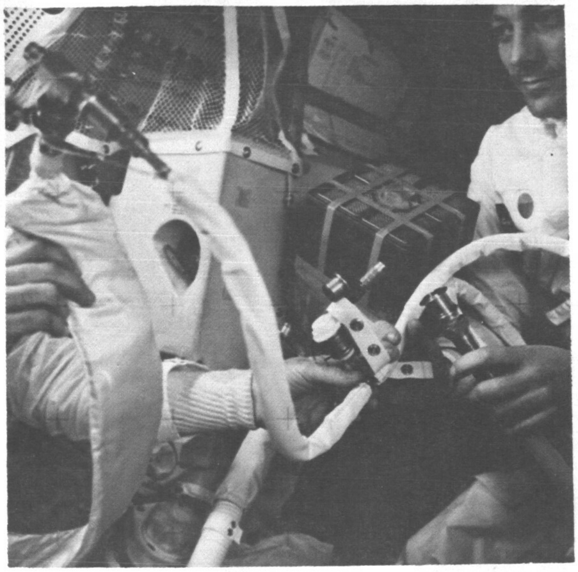
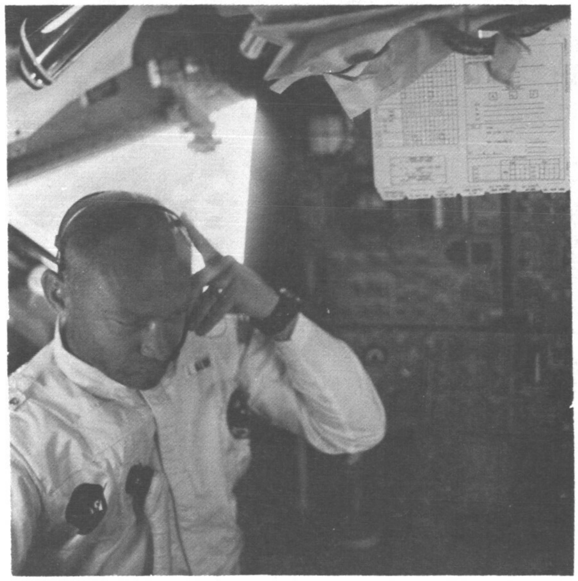


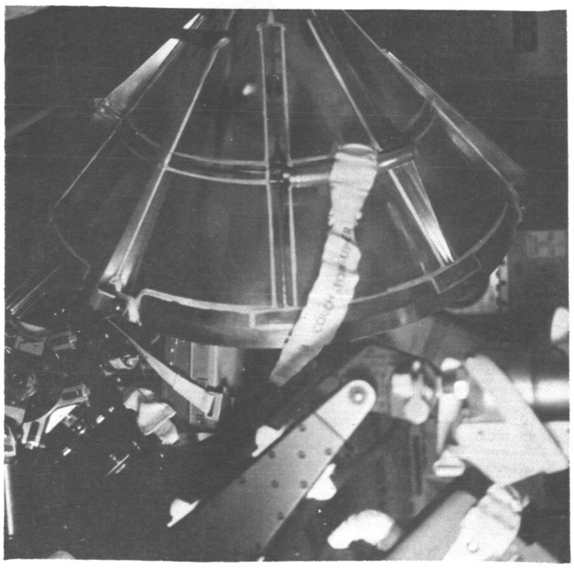
Figure 38. - Part of Mare Fecunditatis and the craters Goclenius, Magelhaens, Magelhaens A, and Colombo A.



(a) First view.



(b) Second view.



(c) Third view.

Figure 39. - Interior crew station photographs, showing handling and documentation of equipment inside the command module and general views of crewman inside lunar module.

Figure 40. - Egress of commander from LM.

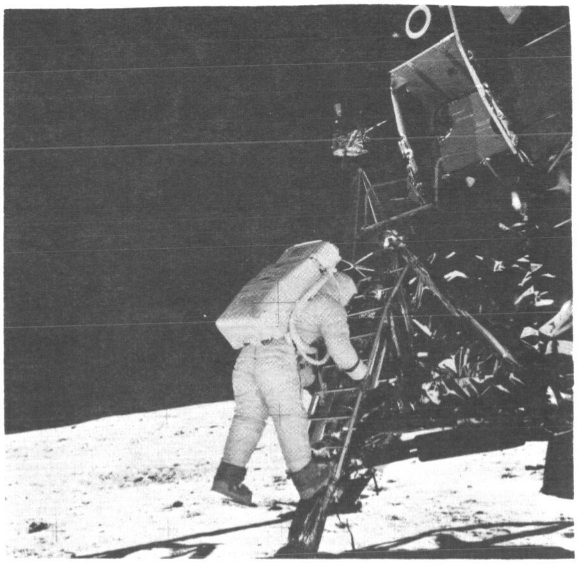


Figure 41. - Egress of LM pilot from LM.

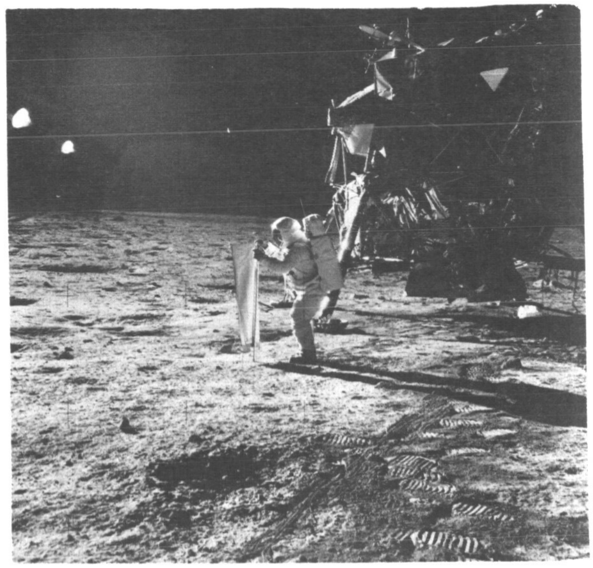


Figure 42. - Astronaut setting up solar-wind experiment. Photograph shows effect of low sun angle on photographic image.

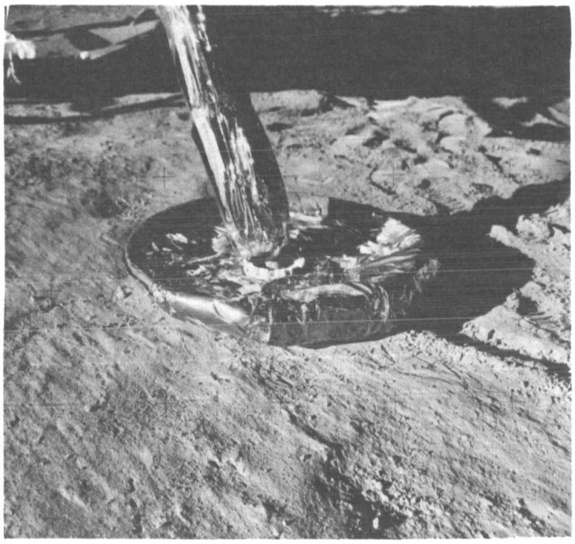


Figure 43. - Lunar module footpad.

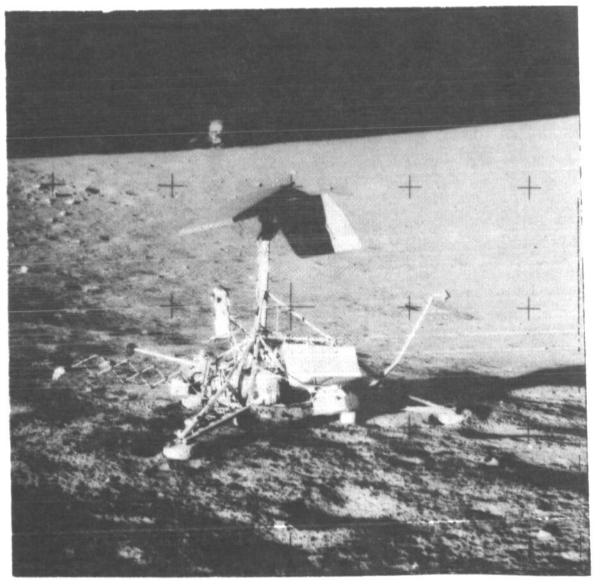


Figure 44. - Surveyor III on lunar surface.

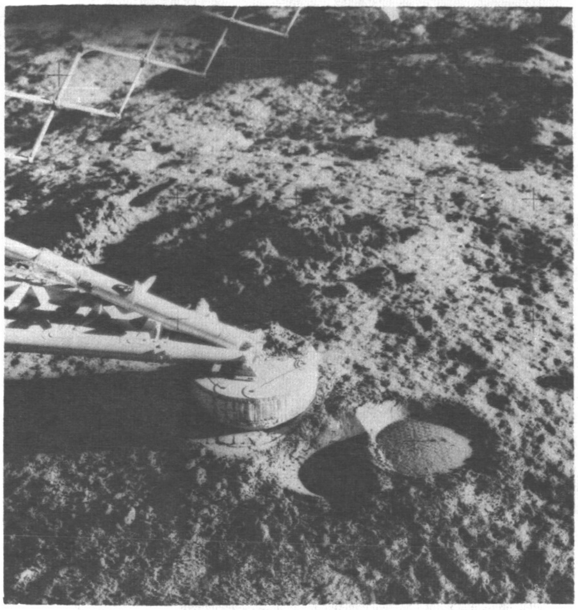


Figure 45. - Footpad of Surveyor III on lunar surface.

Figure 46. - Shadow of LM on lunar surface.

Figure 47. - Earth (photographed during transearth coast).

Figure 48. - Moon (photographed during translunar coast).

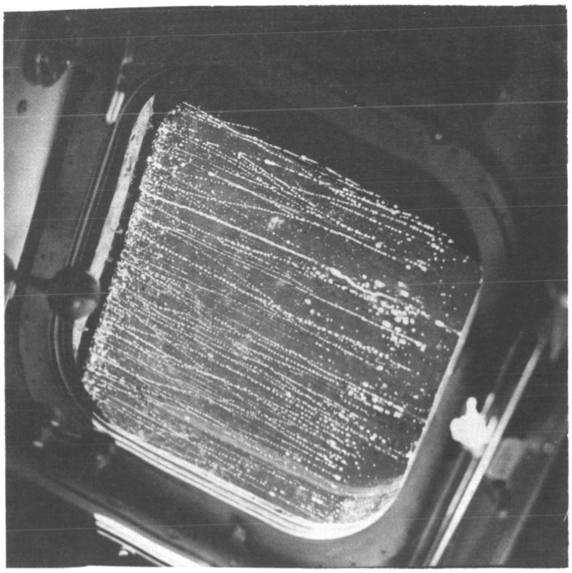


Figure 49. - Window contamination (photograph taken in support of special-events study).

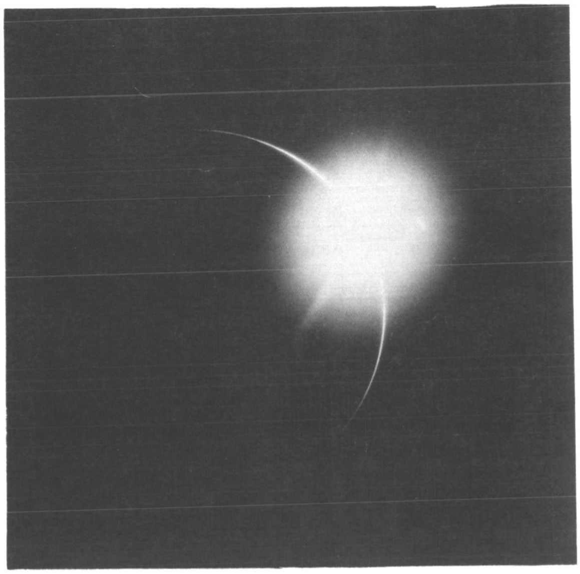


Figure 50. - Eclipse of the sun (photograph taken in support of special-events study).

The flexibility of this equipment has proved to be a substantial asset to the overall Apollo photographic program in that, when camera equipment was committed to contract, all the photographic requirements were not defined. However, such things as additional lenses, calibrated frame rate, and data output (for 70-millimeter-photography correlation) were designed into the system; thus, a wide variety of new photographic requirements was relatively easy to accomplish. The Apollo 16-millimeter camera system is shown in figures 51 to 53.

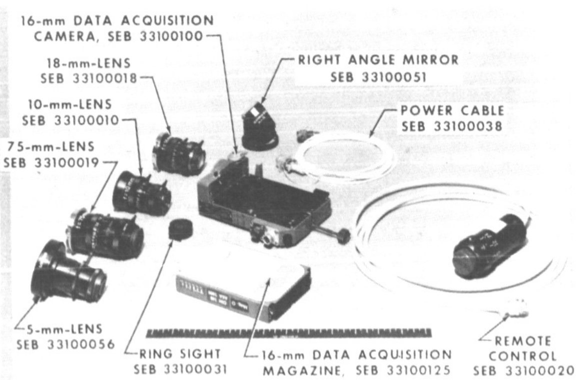


Figure 51. - Apollo 16-millimeter DAC system.

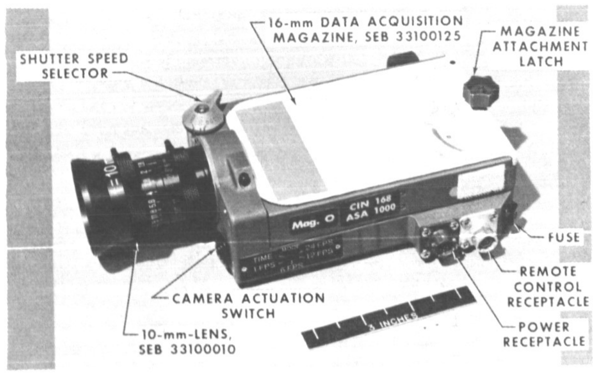


Figure 52. - The 16-millimeter DAC with lens and magazine attached, showing functional parts.

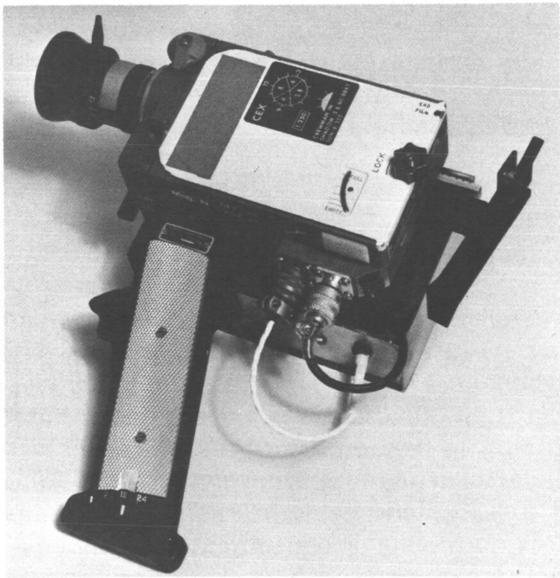


Figure 53. - The 16-millimeter lunar surface DAC system consisting of camera, 10-millimeter lens, camera handle, battery pack, and mounting bracket.

Requirements for high-resolution photography of proposed landing sites were defined early in the Apollo lunar-landing program. These requirements were fulfilled for the first three landing sites by photography from the onboard 70-millimeter camera systems and the unmanned lunar probes such as the Lunar Orbiter. However, more detailed photography was required to evaluate the rougher sites proposed for later lunar-landing missions; consequently, the lunar topographic camera (LTC) (fig. 26) was introduced on the Apollo 13 mission. The LTC is a 5-inch-format reoccurrence-type camera with an 18-inch-focal-length fixed-focus lens incorporating image-motion compensation and capable of continuous overlapping strip photography. The camera was designed for mounting in the command module hatch window and operation within the command module environment. This design approach considerably simplified the spacecraft interface and crew operational requirements, which were major factors in procuring this camera in the short time required and within the budgetary restrictions. Unfortunately, the LTC was not used for lunar photography on the Apollo 13 mission, because the spacecraft did not attain lunar orbit. Reference 14 contains a detailed description of this equipment, and a photograph of the LTC system and the command module hatch mounting is shown in figure 27.

The spotmeter was upgraded by semi-automating the exposure-value read-out and incorporating a photometer scale. The current spotmeter configuration is shown in figure 54. This instrument is required for interior crew station photography (possible in the Apollo Program to a much greater extent than previously because of the greater space). The crew activities in the zero-g environment can therefore be studied. Photometer readings of the earth and moon contributed to the accuracy of photographic exposure values. A photometer or photographic light meter can significantly contribute to defining the lighting environments encountered in orbit with nearby spacecraft and natural satellites, because the lighting conditions in space are very different (because of the absence of light diffusion and reflections) from those

Figure 54. - Spotmeter used in Apollo Program showing battery removed from handle and neutral-density filter used to extend the photometer scale.

on earth. Based on analysis of photographic results, predictions of photographic exposures for all normal and predictable situations have been very good; however, the crewman does need an aid to determine light levels during unplanned situations and during situations that come to his attention only. The Apollo automatic light meter has a 1° sensitive area within a larger viewing field, has proved extremely easy to operate, and has yielded reliable data.

Ground-Support Equipment

An important part of any space-flight operation is the ground-support equipment required to make the flight equipment flight ready. In this case, the term ground-support equipment may be somewhat misleading because, actually, a ground-support facility rather than only equipment is required. Flight-readiness preparation includes receiving, inspection and acceptance testing, storing in bonded storage at a central storage and control point, data analysis testing, calibrating, applying decals, cleaning, and final packaging in a clean room. Equipment testing and checkout are accomplished on semiautomated consoles for systems with a large amount of equipment to be processed, such as the 16-millimeter and 70-millimeter camera systems, and on laboratory setups when the test requirements are not as extensive. All tests and calibrations are conducted in accordance with established and controlled procedures.

Major testing and calibration of the 16-millimeter DAC are performed on two system test consoles (figs. 55 and 56). The system test console (fig. 55) is used to verify that a camera and magazine are performing according to specification requirements. The console is a self-contained unit that needs only a standard 115-V ac power input. The console measures all parameters (shutter speeds, shutter jitter, frame rates, telemetry pulse outputs, currents, voltages, run time, etc.) and provides a visual display to the operator. Thus, the console

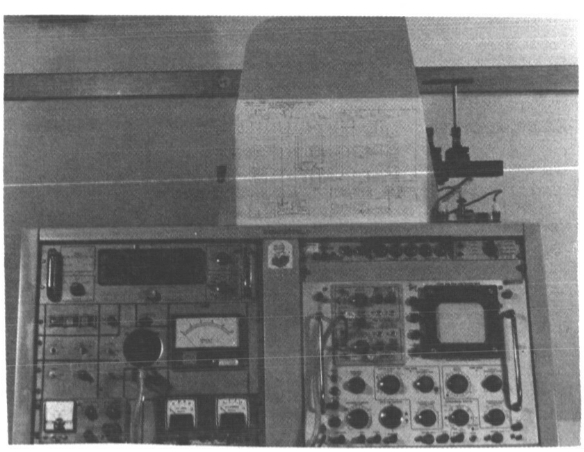


Figure 55. - Data acquisition camera system test console.

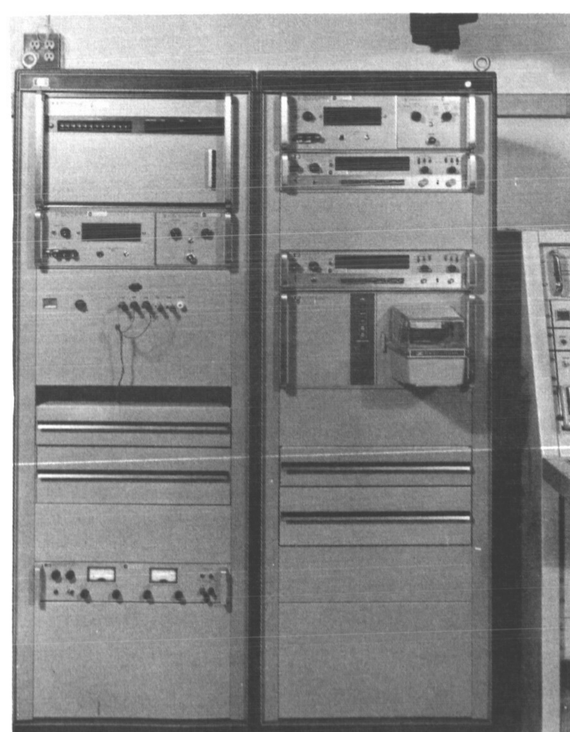
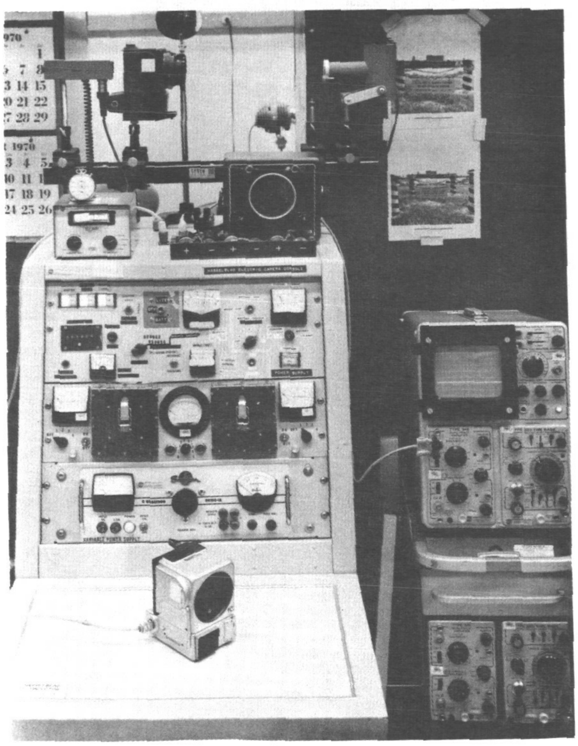


Figure 56. - Data acquisition camera calibration console.

provides an insight into the camera for all functions except actual photography. Photographic quality is verified by testing of the lens and complete photographic system, using standard resolution targets.

The calibration console (fig. 56) is designed to provide extremely accurate data about the operation of the 16-millimeter camera. The data needed for lunar surface photographic correlation required accuracies 100 times better than that for which the camera was designed. This calibration console provides this accuracy by special measuring and recording techniques, whereby the actual frame rates are measured one frame at a time and the data are printed by a high-speed recorder. A series of data is recorded before flight, and another series is recorded after flight. An extrapolation of the two sets of data yields the probable performance during flight to an accuracy of 0.03 percent. Since the development of this console, other uses have been applied, and the calibration feature is now performed on all cameras on a mission.

All 70-millimeter still cameras are tested on a test console (fig. 57) before acceptance by MSC. The test console consists of a power supply, light source, oscilloscope, ammeter, voltmeter, appropriate connecting cables, and switching circuitry.



After a mechanical test of the camera system, the camera is connected to the console for electrical continuity tests, diode checks, and motor operating-current measurements. All shutter speeds are measured, using the light source and oscilloscope. Resolution test photography at all apertures is performed with each camera system during the last phase of acceptance testing.

Testing and checkout of the LTC are performed, using the equipment and setup shown in figure 58. Such parameters as the shutter speeds, frame spacing, forward-motion-compensation (FMC) rates, data recording, and electronic-circuit pulses are checked to verify proper operation and performance within the specification requirements. For example, the camera test set, mounted in the central part of the console (fig. 59), is used to monitor the operating currents and to provide electrical outputs, such as the FMC-start signal, shutter-start signal, film-advance signal, and pulse-code-modulation signal, which can be checked and monitored, using the oscilloscope and remaining test-console equipment. The shutter-speed and frame-spacing tests are performed, using unexposed film and a light source — a stroboscope for the shutter-speed tests.

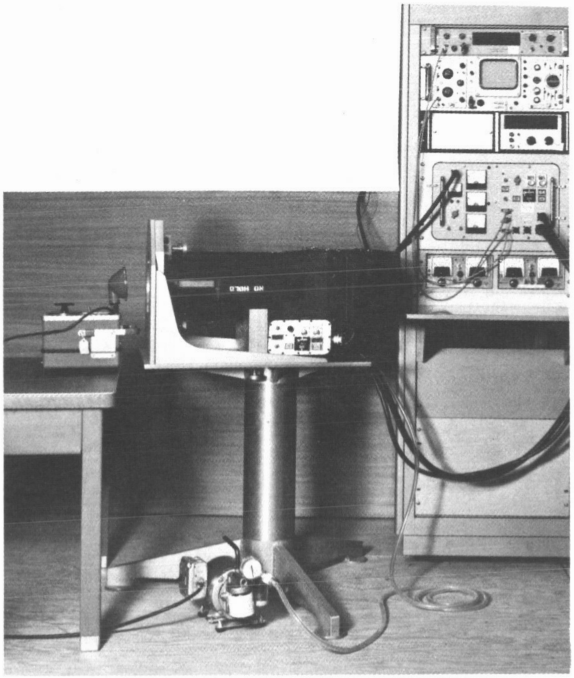


Figure 58. - Ground-support and calibration equipment for the LTC. Camera is shown on the test stand.

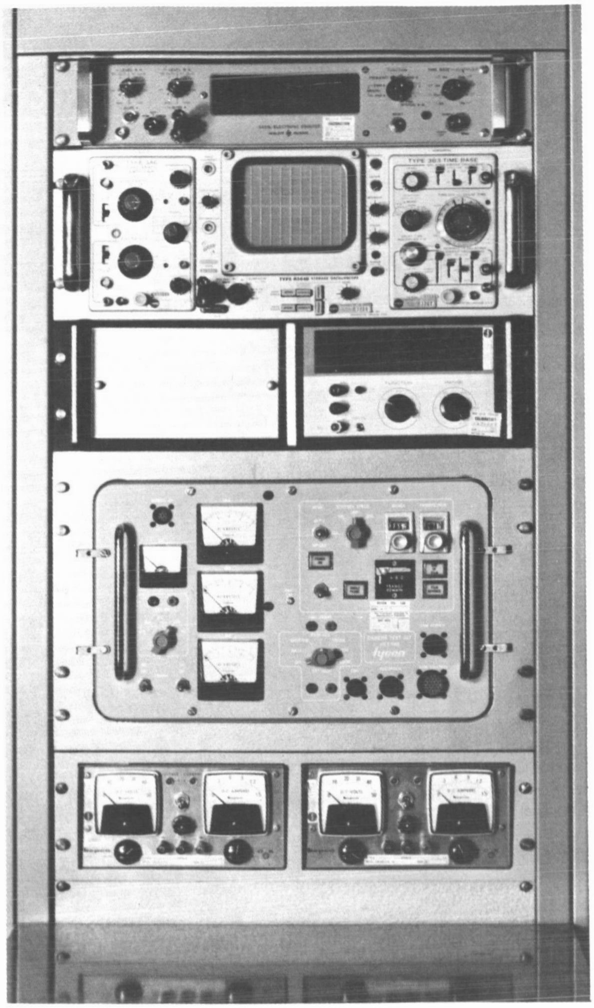


Figure 59. - Test set used to measure functional parameters of LTC.

The spotmeter checkout and calibration facility is shown in figure 60. This facility is used primarily for the calibration of the flight automatic spotmeter, but can be used to calibrate and check out any type of photometric device. Calibration of all flight automatic spotmeters must be accomplished every 6 months and is performed on the flight-assigned spotmeter. By comparison of a light source of known illumination with the spotmeter reading, an accurate calibration can be accomplished. This calibration is the only method of ensuring that the spotmeter reading is accurate. The flight automatic spotmeter is calibrated to an accuracy of one-fifth of an f-stop. To perform the calibration, a prescribed voltage is placed on the standard lamp, and the current is monitored to ensure that the lamp is drawing the prescribed current. The diffusing glass is then placed a distance corresponding to the desired foot-lambert reading from the standard lamp, and readings are recorded.

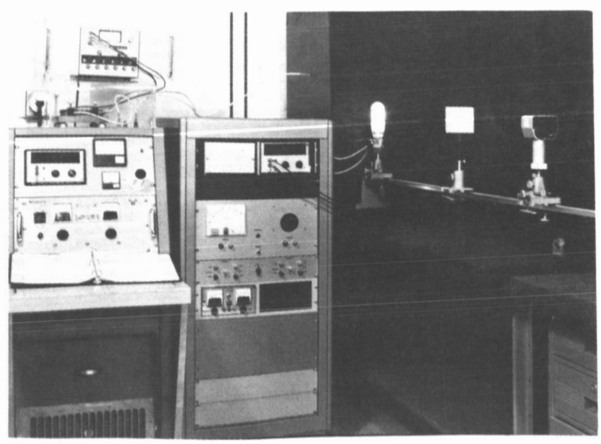


Figure 60. - Spotmeter ground-support and calibration equipment setup.

Resolution Testing

The ground-support equipment is intended primarily to check the mechanical and electronic performances of the photographic and related equipment. Optical performance is verified on a total system basis by photographing U. S. National Bureau of Standards high- and low-contrast resolution charts and analyzing the resulting film image. This test is part of the predelivery acceptance test. All testing is done in accordance with established standard practice. For the more critical photographic applications, the tests are supplemented by exacting calibrations of distention, spectral response, and whatever special characteristics are pertinent to the application. In the Apollo Program, much of this work is done in cooperation with U. S. Geological Survey and the NASA Manned Spacecraft Center Mapping Sciences Laboratory personnel, who have established photometric and photogrammetric calibration facilities.

OPERATIONS

Operations involving flight photographic equipment fall into two basic categories: (1) preflight testing of equipment and spacecraft interface support and (2) inflight operations. The preflight testing of equipment and spacecraft interface support is in accordance with established requirements. (Preflight or ground-support equipment has been discussed previously.)

Integration of Mission Requirements and Equipment Capability

Photographic-requirement inputs are first assembled in the mission requirements document (MRD), usually in the form of detailed test objectives. Each detailed test objective (DTO) defines test conditions, success criteria, and the background and justification for each photographic requirement. In parallel with the publication of the MRD is the publication of a mission equipment stowage list containing the types and amounts of photographic equipment allocated. It then becomes the task of the assigned photographic engineer to write the photographic and television procedures document to determine whether the equipment in the stowage list is sufficient to satisfy the requirements in the MRD. An important first step is to determine the total amounts and types of film needed to satisfy all the requirements and then to verify that the quantity is compatible with the number of magazines on the stowage list. This procedure also includes determination of the necessary mission-peculiar equipment, such as filters, brackets, and intervalometers. The photographic and television procedures document lists the objectives, equipment allocations, film allocation, and spacecraft stowage. Excerpts from the photographic and television procedures document for the Apollo 12 mission are included in the appendix.

Development of Photographic Procedures

The development of photographic procedures begins with the definition of photographic requirements. Most of the tasks are defined to some extent in a preliminary version of the MRD. These tasks are then reviewed and analyzed for any obvious incompatibility with the current edition of the flight plan and with the crew and spacecraft capabilities. After the initial review, procedures are reviewed with those persons who initiated the photographic requirements for discussions of any apparent problems and collection of any additional information required to develop crew procedures or integration of the task into the flight plan.

When the photographic equipment, camera setting, film usage, and spacecraft-attitude requirements are known, step-by-step crew procedures are written for each task. Past photographic and television procedures documents describing the same or similar tasks are used as guidelines. By determining the number of frames of each film type required, a preliminary analysis of the film budget is made. The appropriate personnel are then consulted to determine that adequate stowage is available for the film magazines. Photographic laboratory personnel are consulted to confirm the availability of the selected film type and any special film processing required. At this stage a crew briefing on all photographic procedures is held. The crew's comments are useful in refining the various photographic procedures. The photographic engineer is in contact with the crew and the flight planner to coordinate changes in photographic requirements and procedures.

The duration of the inflight task, landmark targets, sun angles, spacecraft attitudes, and effects on other crew activities must be considered before photographic-procedure integration into the flight plan. Lunar surface photographic procedures are inserted into the lunar surface time line. A final analysis of lunar surface photographic tasks follows numerous simulations of the lunar surface activities. Much of the photographic procedural development is accomplished during these exercises when the photographic engineers and the crewmen have an opportunity to observe the operation and determine the most efficient way of accomplishing the tasks. Camera settings and other procedural details must be complete by the time crew training progresses beyond the preliminary or developmental stage to ensure adequate crew-training time in all details of the photographic procedures and to assure that all procedures are updated in the onboard data for both training and flight.

Many of the camera settings are determined by the data users and other personnel supporting the photographic tasks. The required camera settings for the lunar surface, engineering, and Public Affairs Office photography are determined jointly by the geological investigators and the photographic engineers. Camera settings are required early in the procedures-development cycle, necessitating an early establishment of film types with the photographic user and processing laboratories so that, 3 months before flight, all aspects of the photographic operations are established. At this time, a preliminary photographic and television procedures document is published. The document categorizes the photographic tasks and lists the crew procedures required to accomplish the tasks. Diagrams outlining photographic activities on the lunar surface are included. Such diagrams may include a view of the LM area, planned deployment locations for experimental and operational equipment, and illustration of the standard procedure for documentation of geological samples.

Included in the appendix is an example of the results of the trade-offs made in obtaining the final photographic procedures, showing the manner in which all the data are integrated into the operational documentation. Camera decals indicating surface- and orbital-photography camera settings and the onboard cue card for lunar surface targets of opportunity and other miscellaneous photography are also presented. A time-line summary of all photographic tasks is included. This summary states the camera configuration code and designates the film magazine to be used for each task.

The preliminary photographic and television procedure document is published to aid in final training preparation, to provide a partial input to the onboard data, and to allow for a final review before publication of the final photographic procedures. The final copy of the photographic and television procedures document is published 1 month before flight and represents the photographic tasks and procedures as they are to be accomplished on the mission.

Integration Into Time Line and Flight Plan

The successful accomplishment of the mission photographic objectives is dependent on the proper integration of the objectives and associated procedures into the flight plan. On early Gemini and Apollo missions, the photography was mostly limited to operational photography. On later missions, the scientific objectives and associated photographic operations became more extensive. Because the operational photography generally consists of coverage of the nominal mission events, the major task of integration into the flight plan is making the photographic procedures compatible with the crew procedures and checklist for the particular mission phase. These events include rendezvous, docking, undocking, extravehicular activity, intravehicular activity, and transfer and reentry. Other events, such as lunar descent and ascent, lunar surface activity, and future-landing-site mapping, are considered operational photography and are accomplished on every lunar mission. On Gemini missions, the photographic procedures were placed in a section of the flight plan separate from the time-line section. On Apollo missions, the procedures are condensed into the camera configuration code as defined in the photographic and television procedures document and incorporated directly into the flight-plan time line. A photographic time-line summary is maintained in the photographic and television procedures document for the investigators primarily interested in photography; this document provides a ready reference to all the photographic tasks if real-time reprograming should be required.

Contingency photography for a mission anomaly or a suspected anomaly is planned in real time. A fairly high priority is usually assigned to this type of photography, and any of the onboard photographic equipment and film can be made available for mission-evaluation photography. The photographic and television procedures document is helpful because it is a ready reference for the selection of available film and equipment and also contains previously defined photographic procedures codes to simplify updating information for the crew.

Scientific photography is incorporated into the time line in much the same manner as is the operational photography. (Reference 14 contains a discussion on how the basic flight plan and trajectory are determined.) When the trajectory parameters and basic flight plan have been established, the photographic integration is refined to specify the exact time-line placement of the various photographic tasks. The appendix contains the photographic time line and onboard data notations as incorporated into the Apollo 12 mission. Television procedures and associated time lines are treated very similarly to the photographic procedures and time lines, and are included in the photographic and television procedures document.

Operational Considerations

Many operational considerations or constraints are of concern to the photographic engineer and the astronaut in obtaining space-flight photography. These constraints generally fall within the following categories.

1. Lighting

2. Time

3. Vantage point

4. Equipment

These constraints will be discussed briefly.

A review of space photography (particularly that taken inside the crew station, vehicle to vehicle, or on the lunar surface) reveals that, in many situations, the photographs were taken into the sun (with a resulting flare) or were taken with inadequate or excessive lighting. The photography also reveals harsh contrast and sunglint situations that, although they are "dramatic" photography, do not necessarily yield maximum data. With the absence of a light-diffusing atmosphere, these adverse conditions must be overcome. Photography taken inside the vehicle has areas of overexposure and underexposure, with sun shafting causing bright illumination and underexposure causing shadow areas. The crewman generally exposes the photographs at an average setting that usually does not yield good photography because of the extremes in lighting and because of the restricted latitude of the film. Another lighting problem is encountered on the lunar surface where the low sun angles result in sunlight impinging on the lens for all photographs not taken in the quadrant from directly cross sun to down sun. The retroreflective properties also contribute to the general exposure problems for lunar photography both on the surface and in orbit.

Time constraints are always present in manned space-flight missions and have a definite effect on photography. The crewman, on many occasions, does not have the time to analyze the photographic situation and set his equipment accordingly. In an effort to save time, photography is generally accomplished with precomputed nominal exposure values. Although a light meter is available on each mission, its use is usually reserved for off-nominal situations.

The optimal vantage point is perhaps one of the most critical considerations. Much photography is compromised because the camera is not oriented properly either in relation to the photographic object or in relation to the sun. Optimizing the vantage point generally requires the expenditure of spacecraft propellant, which is always a scarce commodity.

Equipment constraints also affect the photographic operations. The onboard equipment is limited in quantity and somewhat in flexibility. Onboard equipment is dictated by stowage volume and weight limitations. A greater variety of lenses and film types could overcome some of the lighting constraints at the expense of greater weight, volume, and crew time. A review of figures 6 to 17 and 28 to 50, showing Gemini and Apollo photography, will illustrate some of these points.

Support of Photography From the Mission Control Center

Support of photography from the Mission Control Center (MCC) is a task similar to other control-center functions. The MCC must, of course, have a clearly defined chain of command for all operations, and the appropriate photographic support capability for each specific mission must be integrated into these operations. The requirements of this task must be identified, the required control-center facilities (such as console configuration and communications capabilities) must be provided, the appropriate procedures must be developed, and the personnel staffing the positions must be adequately trained. The personnel in the Staff Support Room who are directly concerned with photographic operations support the Flight Activities Officer, who in turn supports the Flight Director. Primarily, this support involves photographic-procedures updates, computation of spacecraft trajectory and attitude data required for conduct of photography, and coordination and response to crew questions concerning photographic procedures and equipment.

The present capability of support operations to generate the data required to point a given spacecraft line of sight at a particular object at a particular time is highly developed. With nominal trajectory data, the photographic support personnel can provide the spacecraft roll, pitch, and yaw angles and mission time to point windows and bracket-mounted cameras at various photographic targets. This information can be transmitted to the crew before the event. These angles and the related ground-elapsed times are calculated by the use of real-time computer complex (RTCC) programs. Such programs were conceived and developed to fulfill photographic — as well as operational — spacecraft-pointing requirements, such as navigational sightings. In general, the programs can point a fixed line of sight at any celestial or terrestrial point and compute the required gimbal angles for the inertial platform in the spacecraft. Other programs exist to compute the shaft and trunnion angles of the navigational optics; to calculate earth-moon-sun look angles; to provide star acquisition of signal and loss of signal times; to provide closest-approach times of ground points; to supply such information as north or south of track, distance off track, and elevation angle at time of closest approach; and to compute sunrise-sunset and moonrise-moonset times for the spacecraft, along with terminator rise and set times. The procedures for the use of the programs are simulated during the premission training to ensure that they are correct and that the computers that are time shared with other users will be available when required.

Crew Debriefing

As a part of every postmission crew debriefing, each crewman comments on the adequacy of photographic equipment, flight plan and checklist procedures, and preflight training in photography and on the subject matter preselected to be photographed. Each crewman is also asked to make suggestions for changes to improve the photographic planning and to enhance the chances of obtaining better photography on future missions. At a formal photographic debriefing held approximately 10 days after recovery and attended by engineers and scientists with a special interest in the mission photography, each crewman is able to correlate his visual observations with the photographs and to answer questions from the photographic engineers.

Problem Discussion

Some general problems with the photographic systems were encountered with certain sealant compounds and lubricants and with extended shelf-life requirements and definitions. Early in the Apollo Program, considerable difficulty was encountered by migration of sealant compounds used to prevent screw fasteners from working loose. The compound caused the shutter release mechanism of one camera to freeze before the problem was detected. Extreme caution with the amount of this material used and careful application to ensure that the substance cannot work its way to delicate moving parts is necessary to prevent the migration.

Another area of concern is the migration of silicon base lubricants. Lubricant migrating from a motor gear box to the motor brushes caused a high resistance path. Also, when this lubricant migrated from its desired area, the area was left with insufficient lubrication. The lubricant migration was aggravated when the equipment remained on the shelf for long periods of time. The use of dry film lubrication resolved the problem. Dry film lubricant should be considered for future program applications where long duration and vacuum operation may be a requirement. However, careful analysis is required to ensure that the lubrication process is compatible with other materials used in the mechanism. In short, the requirement for a careful materials compatibility analysis in the operational environment cannot be overemphasized.

Testing requirements in support of space programs also have contributed to some of the problems encountered. Attention must be given to the number of equipment test hours to ensure that the limit life of a mechanism is not approached. Although this point may appear to be obvious and not worthy of mention, when all the various testing requirements are totaled, it is quite likely that the equipment can be subjected to an excessive number of hours unless one is continually aware of the potential problem and makes every attempt to limit testing to minimum requirements. This situation is compounded further by the requirement that photographic equipment be compatible with a vacuum and an oxygen atmosphere, a requirement which resulted in the use of special lubricants and motor brushes that are not necessarily compatible with extended ambient atmosphere operations. The slowdown in the Apollo Program also resulted in problems of exceeding equipment shelf life; in situations like this, a procedure for periodic operation of the equipment should be considered.

In photographic operations, the late definition of photographic requirements has been a problem throughout the space-flight programs because of the insufficient time to develop the required equipment. (Compromise equipment did not always accomplish the objective.) Early definition is not always possible because often the results of one photographic mission determine the requirements for the next. Also, because of other commitments, some of the photographic investigators are not available for early definition on a total program basis. The solution is to retain flexibility of equipment so that additions of items like lenses and film type can be readily accommodated in a basic photographic system. This design approach is strongly recommended.

During flight operations, difficulties were encountered with rapid and accurate selection of film magazines containing select film for specific operations and with selection of proper exposure parameters. These problems were solved by limiting to the maximum extent possible the number of different films required, by color coding magazines for film type and application, and by incorporating exposure information on each film pack. The result of this labeling is shown in figures A-7 to A-12.

One last problem encountered throughout the space-flight photography program and not yet totally solved is that of recording identifying information on the film. To achieve the most effective retrieval of data from the photography, certain basic data — such as time of exposure, aperture stop, and shutter speed — must be available with each photograph. Currently, only the LTC (fig. 26) has time recording on film available. Followon systems with onfilm data recording capability are proposed, and incorporation of this capability in all future photographic systems is highly recommended.

CONCLUDING REMARKS AND RECOMMENDATIONS

Photographic equipment and support have been important parts of the manned space-flight programs from the first Mercury orbital flight to the present time. Photographic requirements have steadily increased as space-flight programs progressed, and the quality and quantity of photographic equipment and associated crew procedures have increased correspondingly. Methods have been established for translating mission objectives into specific hardware requirements and flight procedures. These methods appear adequate for present programs but need to be reviewed for future programs.

A more advanced photographic system for future programs should incorporate certain features that could not be incorporated to date primarily because of the tight schedule of the manned space-flight program. Future programs should consider photography as a major system from the outset. Provisions for photography such as photographic stations with optical ports and all required power and vacuum facilities can, therefore, be incorporated into the initial design of the vehicles. Also, because photography supports many different data disciplines, it is not always possible to predict all photographic requirements; consequently, the photographic systems must remain flexible without, however, compromising photographic quality. Certain basic capabilities should be designed into future photographic systems. The basic capabilities could include mission time recording on film, automatic recording of aperture and shutter speed, and a tie-in with the vehicle navigational system so that vehicle attitude can be readily retrieved. These basic features will grossly simplify photographic data reduction and make the data usable for a larger number of investigators.

With the increased emphasis on Earth Resources support by space-flight photography, the future need exists for high resolution and photogrammetric camera systems with large film formats. Also, from an economic consideration, these systems must be designed with inherent flexibility of lens types and film types and must be designed to operate within the environmentally controlled cabin area to allow for inflight maintenance and to avoid design and fabrication complications caused by thermal and vacuum considerations.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, June 6, 1972
924-23-26-00-72

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APPENDIX

APOLLO 12 PHOTOGRAPHIC AND TELEVISION PROCEDURES DOCUMENT EXCERPTS

PHOTOGRAPHIC TASK CODING METHOD USED FOR QUICK INTERPRETATION AND INSTRUCTION TO THE CREW

The equipment to be used for each photographic task will be denoted in the following coded form:

AAA/BBB/CCC/DDD — XXXX, XXXX (M, N, O) P

The notations used in the coded form are defined in the following table.

Code	Interpretation
AAA	Location from which photographs are taken
CM	Command module
	1 — Left-hand (LH) side window
	2 — LH rendezvous window
	3 — Hatch window
	4 — Right-hand (RH) rendezvous window
	5 — RH side window
LM	Lunar module
EV	Extravehicular
BBB	Camera used
DAC	Data acquisition camera
EL	Electric Hasselblad
DC	Data camera (lunar surface Hasselblad)
TV	Television camera
CSC	Closeup stereocamera
LMC	Lunar multispectral camera (4 EL Hasselblads)
CCC	Lens used: 5, 10, 18, 60, 75, 80, 250, 500 mm
DDD	Film type
CEX	Color exterior, SO-368
HCEX	High-speed color exterior, SO-168 (ASA 160)
CIN	Color interior, SO-168 (ASA 1000)
BW	Black and white, 3400
BW164	Black and white (DAC film), SO-164
HBW	High-speed black and white, SO-267

Code	Interpretation
IRBW	Infrared black and white, SO-246
MBW	Medium-speed black and white, 3401
XXXX, XXXX	Data recording aids
SPOT	Spotmeter
IVL	Intervalometer
MIR	Right-angle mirror
BRKT	DAC mounting bracket, EL camera adapter, EL camera bracket assembly (500-mm lens) or LMC mounting
ULC	Utility light clamp
POLZ	Polarizing filter
47B FIL	Photar 47B filter (blue)
29+ FIL	Photar 29 filter (red) + 0.5 neutral density filter
87C FIL	Photar 87C filter (black)
58 FIL	Wrattan 58 filter (green)
HAND	Camera handle and trigger
SEXT	Sextant adapter
ALC	Automatic light control — interior (TV)
CONT	Remote control cable
M	Lens aperture setting — examples: f2.8 — focal length, 2.8 S — spotmeter reading CC — setting on cue card
N	Shutter speed — examples: 125 — 1/125 second 2 sec — 2 seconds
O	Focus distance (feet)
P	For EL and DC: number of frames For DAC: frame rate, magazine, percentage, and time (minutes)

A coded example is shown as follows, followed by the interpretation of the coded form:

CM4/DAC/18/CEX — BRKT, SPOT (S, 250, ∞) 12 fps, .5 mag (4 min)

Photographs will be taken from the CM right-hand rendezvous window, using the DAC with an 18-millimeter lens and SO-368 film. The camera will be bracket mounted with the following camera settings: f-stop from spotmeter reading, shutter speed 1/250 second, focus at infinity, 12 frames/sec, 0.5 magazine or 4 minutes to be used.

PHOTOGRAPHIC PROCEDURE WRITEUP USED TO FINALIZE OBJECTIVE AND FOR CREWMAN TRAINING (EXAMPLE: LANDING AND EXPLORATION SITES)

Description

During descent and ascent, the lunar surface will be photographed to record LM movement and surface disturbances and to aid in determining the landed LM location. Sextant photography of Lansberg will be accomplished on revolution 26.

Following an orbital plane change after LM jettison, stereostrip photographs will be taken of candidate exploration sites during two separate revolutions, using the EL and an 80-millimeter lens. During one stereostrip and two landmark revolutions, the DAC will simultaneously photograph the surface through the sextant.

High-resolution photographs, using the 500-millimeter lens, will be taken of Fra Mauro, Descartes, and Lalande. Oblique photographs of the sites will be taken from TCA - 3 minutes to TCA - 1 minute prior to optimum high-resolution photography (TCA - 1 minute to TCA + 1 minute). The DAC photography will be taken simultaneously.

The photography will accomplish the following:

1. Improve the accuracy of ground point locations on the surface

2. Define lunar topography to support scientific studies

3. Provide photography that can be used for topographic analysis of the approach paths to candidate exploration sites

4. Provide crew training film

Procedures

A contingency magazine of black and white 3400 film has been allotted for this photography. Typical procedures are shown as follows.

Descent/ascent:

1. Descent PDI + 6 min
   LM3/DAC/10/CEX — (f2.8, 500, 30) 12 fps, .75 mag (6 min)

2. Ascent APS burn — 1 min
   LM3/DAC/10/CEX — (f2.8, 500, 30) 12 fps, 1 mag (8 min)

Vertical stereostrip:

1. Rev 40
   CM4/EL/80/BW — BRKT, IVL (f4, 250, ∞) 180
   CM_/DAC/SEXT/CEX — (fixed, CC, fixed) 1 fps, 1 mag (93 min)
   +X-axis alined to local vertical

   a. TRN 45°, SFT 0°

   b. V83 (Aline FDAI 1)
      ORDEAL R __0, P 270, Y __0

   c. V79 R1 (pitch rate) -0.0507
      R2 (deadband) +000.50
      R3 (Y-axis) +111111

   d. V06 N65 (AGC time displayed on DSKY)

   e. ENTER, DAC — on and EL — on simultaneously
      GET 1 6 0 : 5 4: 3 2 and record time from AGC clock

   f. V16, N91 (SFT and TRN angles displayed on DSKY)

   g. DAC and EL — off at GET 1 6 1 : 5 8: 1 5 and record time from AGC clock

2. Rev 44
   CM4/EL/80/BW — BRKT, IVL (f4, 250, ∞) 180
   EL camera alined to local vertical

   a. V83 (Aline FDAI 1)
      ORDEAL R __0, P 258, Y __0

   b. V79 R1 (pitch rate) -0.0507
      R2 (deadband) +000.50
      R3 (Y-axis) +11111

   c. EL — on at GET 1 6 8 : 4 8: 3 6

   d. EL — off at GET 1 6 9 : 4 5: 4 3

   Record:

   (1) Magazine identification

   (2) Frame numbers and magazine percentage remaining

   (3) Nonnominal data

Landmark tracking sextant photography — Lansberg (rev 26), revs 42, 43:
CM_/DAC/SEXT/CEX — (fixed, CC, fixed) 1 fps, 1 mag (93 min)

a. ORDEAL R __0, P 338, Y __0 by GET ___:__:__

b. V79 R1 (pitch rate) -0.0507
R2 (deadband) +000.50
R3 (Y-axis) +11111

c. Exit V79, P22

d. At T2 (ELV 35°) — 1 min GET ___:__:__
DAC — on

e. DAC — off after completion of tracking

Record:

(1) Magazine identification

(2) Magazine percentage remaining

(3) Nonnominal data

High-resolution/oblique photography:
CM4/EL/500/BW — BRKT, CONT (f8, 125, ∞) 170
CM2/DAC/18/BW — BRKT, MIR (f8, 125, ∞) 6 fps, 2 mag (32 min)

1. Rev 39 — Lelande
T1 1 5 9 : 3 6 : 3 1 (3 min prior to TCA)
T2 1 5 9 : 4 0 : 1 5 (1 min past TCA)

a. Aline COAS along 500-mm BRKT, 10° pitched up from the +X-axis

b. V49 R __0, P 257, Y __0 by GET 1 5 9 : 2 6 : 0 6

c. At T1 start EL and DAC — initiate photographs approximately every 20 seconds

d. At T2 DAC and EL — off

2. Rev 41 — Descartes
T1 1 6 3 : 2 4 : 4 7 R __0, P 283, Y __0
T2 1 6 3 : 3 9 : 3 3

3. Rev 41 — Fra Mauro
T1 1 6 3 : 3 5 : 3 9 R __0, P 250, Y __0
T2 1 6 3 : 2 8 : 3 8

a. Aline COAS along 500-mm BRKT, 10° pitched up from +X-axis

b. V49 R ___, P ___, Y ___ by GET ___:__:__

c. Track target through COAS, using RHC

d. At T1 start EL — initiate photographs approximately every 20 seconds

e. At T2 DAC and EL — off

f. Repeat steps b to e

Record:

(1) Magazine identification

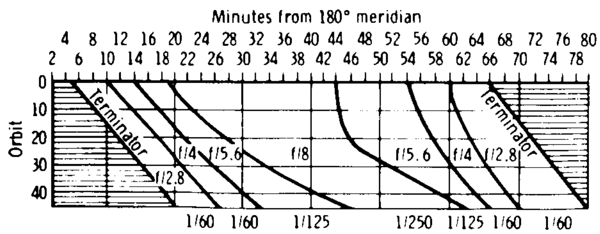
(2) Frame numbers

(3) Nonnominal data

PHOTOGRAPHIC INFORMATION FOR MISSION USE

Orbital photographic exposure information is presented to the crew for inflight use on cue cards (figs. A-1 to A-3). The checklist contains lunar surface photographic exposure information (fig. A-4). Photographic field-of-view information is also provided for the crew (fig. A-5). Figure A-6 is a ready reference of the allocation of equipment and film required to accomplish each objective. This table is used by the photographic engineer at the Mission Control Center.

Targets of opportunity (SO-368)
Shutter speed 1/250 (constant)
(Camera must be pointed due North or South)



Sextant photography shutter speeds
(To compensate for constant f/8 aperture)

Lunar orbit	Color TV	Cex 16	B&W 80
General	22	CC	4
Term	22	2.8	4/125
Zero phase	22	11	5.6
Site oblq	22	8	4
Veh/veh	22	8	5.6
Earth	22	11	5.6
Interior	5.6	S	S

Figure A-1. - Front side of command module pilot (CMP) and lunar module pilot (LMP) cue card.

Translunar/Transearth

	Color TV	CEX 80	CEX 250	CEX 500	BW 80	BW 250
Earth	22	11	11	11	11	11
Moon	22	5.6	5.6	8	5.6	5.6
Veh/veh	22	8	8	8	8	8
Interior	5.6	S			S	
Get when full frame		18mm	80mm	250mm	500mm	
Earth(translunar)		4:21	3:38	6:31	12:24	
Earth(translunar)		242:51	243:32	240:40	234:00	
Moon(translunar)		82:13	82:35	80:25	76:19	
Moon(translunar)		173:50	173:13	175:08	179:07	

Figure A-2. - Back side of CMP and LMP cue card.

Lunar orbit

Lunar orbit	Color TV	Cex 16	B&W 80
General	22	CC	4
Term	22	2.8	4/125
Zero phase	22	11	5.6
Site oblq	22	8	4
Veh/veh	22	8	5.6
Earth	22	11	5.6
Interior	5.6	S	S

Time from 180

Early rev's	Cex
5:20 11:00	2.8
11:00 14:30	4.0
14:30 20:00	5.6
20:00 43:30	8.0
43:30 54:30	5.6
54:30 60:00	4.0
60:00 66:00	2.8

Late rev's	Cex
18:30-25:00	2.8
25:00-31:00	4.0
31:00-41:00	5.6
41:00-59:00	8.0
59:00-64:00	5.6
64:00-68:00	4.0
68:00-79:00	2.8

Figure A-3. - Front side of LMP cue card.

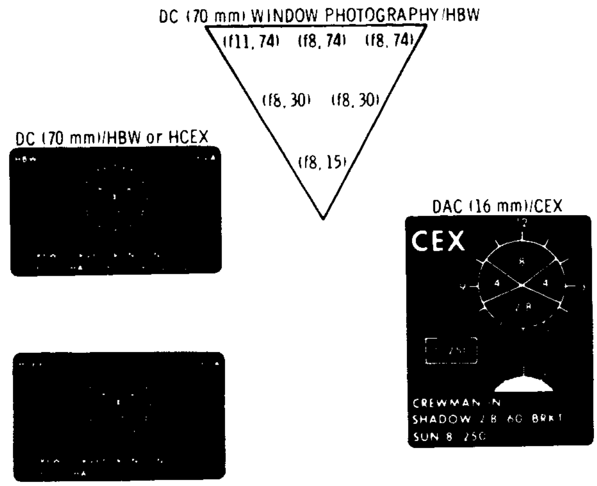


Figure A-4. - Camera settings for EVA photography.

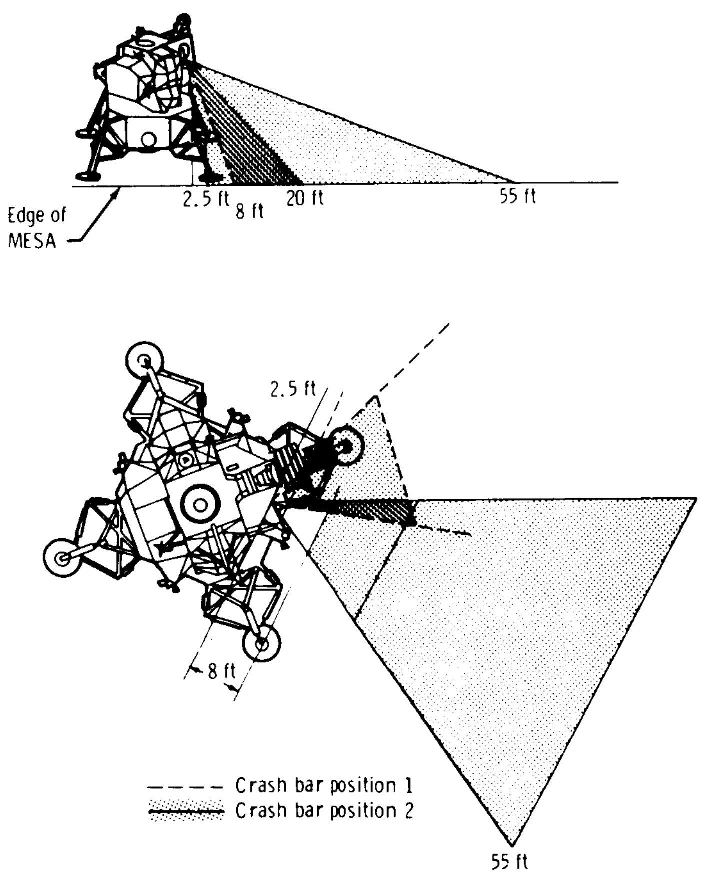


Figure A-5. - The DAC field of view from crash bar positions 1 and 2.

	EL camera (80mm lens)	250mm lens	500mm lens	DC(60mm lens) (2)	DC mount bracket	Intervalometer	Remote control cable (70mm)	Camera bracket assy(70mm)	Polarizing FIL (2)	Camera handle trigger (2)	Lunar multispectral camera (4 ELS)	Intervalometer (S158)	Camera mount (S158)	DAC system (2)	5mm lens	10mm lens	18mm lens	75mm lens	DAC power cable (2)	DAC BRKT (2) (CSM/LM)	Remote control cable (16mm)	Sextant adapter	Spotmeter	
CSM and LM engineering	X			X										X			X		X	X				
Distant earth/moon	X	X																						
Lunar surface structure (lunar orbit)	X	X									X	X	X											
Landing and exploration sites	X		X			X	X							X		X	X		X	X	X	X		
Lunar surface engineering				X	X					X														
Crew/surface compatibility				X	X					X				X		X			X	X				
Surface and sub-surface structure				X	X					X														
Surveyor III photography				X	X					X														
Crew/spacecraft compatibility														X	X				X				X	
Mission documentation	X			X	X																			

(a) Equipment.

Figure A-6. - Allocation of equipment and film.

	70mm film (frames)					16mm film (feet)			CSC film (frames)		LMC film (frames)			TV (time) hr: min	
	CEX	HCEX	BW	HBW		CEX	CIN	BW 124	CEX		MBW	IRBW		CM	EVA
CSM and LM engineering	35	15				595	140							1:55	
Distant earth/moon	40		10											:15	
Lunar surface structure (lunar orbit)	185										450	120		1:10	
Landing and exploration sites			710			525		280							
Lunar surface engineering		24													
Crew/surface compatibility		20		3		560									
Surface and sub-surface structure		397		336					100						8:15
Surveyor III photography				21											
Crew/spacecraft compatibility							140							1:55	
Mission documentation	40	4													
Total magazines	2	3	4	2		12	2	2	1		3	1		5:15	8:15

(b) Film.

Figure A-6. - Concluded.

DESCRIPTION OF PHOTOGRAPHIC EQUIPMENT ALLOCATED FOR A SPECIFIC MISSION

Hasselblad EL Camera and Associated Equipment

The following are the characteristics of the Hasselblad EL camera and the associated equipment:

1. A motor-driven mechanism, powered by two sealed nickel-cadmium batteries, advances the film to the next frame and cocks the shutter whenever the camera is actuated; recycle time is less than 1 second.

2. The normal 80-millimeter lens is easily replaced with the 250-millimeter lens.

3. The camera accepts any number of 70-millimeter Hasselblad film magazines.

a. 80-millimeter lens.

(1) Focal length: 80 millimeters, can be focused from 3 feet to infinity.

(2) Shutter speeds: B-bulb, 1 to 1/500 second with a click stop at each value.

(3) Aperture range: f/2.8 to f/22 with click stops at each half-stop value.

(4) Field of view: 37.9° side, 51.8° diagonal.

b. 250-millimeter lens.

(1) Focal length: 250 millimeters, can be focused from 8.5 feet to infinity.

(2) Aperture range: f/5.6 to f/45 with click stops at each half-stop value.

(3) Shutter speeds: B-bulb, 1 to 1/500 second with click stops at each value.

(4) Field of view: 12.5° side, 17.6° diagonal.

c. 500-millimeter lens (used with camera bracket).

(1) Focal length: 500 millimeters, can be focused from 28 feet to infinity.

(2) Aperture range: f/8 to f/64 with click stops at each half-stop value.

(3) Shutter speeds: B-bulb, 1 to 1/500 second with click stops at each value.

(4) Field of view: 6.2° side, 8.8° diagonal.

d. Camera bracket (500-millimeter lens) — The camera is oriented pitched up 10° from the +X-axis.

e. Hasselblad adapter — The bracket is used to mount the EL camera in the RH rendezvous window in two orientations. With the 80-millimeter lens, the camera is alined along a line pitched up 12° from the X-axis. For the 250-millimeter lens, the camera is alined along the X-axis.

4. Film magazines.

a. Capable of 190 frames of thin-base black and white film or 160 frames of thin-base color film.

b. The frame counter indicates every fifth frame with a line and every 10th frame with a line and number, to a maximum of 190 frames.

Hasselblad Data Camera and Associated Equipment

The following are the characteristics of the Hasselblad data camera and the associated equipment:

1. The Hasselblad data camera is electronically powered with semiautomatic operation and uses the 60-millimeter lens exclusively.

2. The operate sequence is initiated by squeezing a trigger mounted on the camera handle.

3. A reseau grid has been installed in front of the image plane to provide photogrammetric information.

4. Folding ringsight.

5. 60-millimeter lens.

a. Focal length: 60 millimeters; focus detents at 5, 15, and 74 feet where cameras are accurately calibrated.

b. Aperture range: f/5.6 to f/22 with click stops at each half-stop value.

c. Shutter speeds: B-bulb, 1 to 1/500 second with click stops at each value.

d. Field of view: 49.2° side, 66° diagonal.

6. Film magazine.

a. Capable of 190 frames of thin-base black and white film or 160 frames of thin-base color film.

b. Frame counter indicates every fifth frame with a line and every 10th frame with a line and number to a maximum of 190 frames.

7. Polarizing filter.

a. Retaining mechanism allows 60° rotation with click stops at each end of travel and one click stop halfway between the ends.

b. Filter installation, rotation, and removal can be performed by suited crewman on the lunar surface.

8. Camera mount bracket (two) mounts camera on front of EVA crewman.

Lunar Multispectral Camera S-158 Experiment Assembly

In the lunar multispectral camera S-158 experiment assembly, four EL Hasselblad cameras with 80-millimeter lenses are mounted together such that they can be aimed and operated simultaneously. The following are additional features of this assembly:

1. 70-millimeter EL Hasselblads (four).

2. 70-millimeter film magazines.

3. Photar 47B filter (blue).

4. Photar 29 (red) + 0.5 neutral density filter.

5. Photar 87C filter (black).

6. Wratten 58 filter (green).

7. EL Hasselblad intervalometer.

8. The camera mount mounts the LMC perpendicular to the hatch window, using shade tabs; alinement is 57.5° pitched up from the X-axis.

16-Millimeter Data Acquisition Camera and Associated Equipment

The following are the characteristics of the 16-millimeter DAC and the associated equipment:

1. Frame rates: 1, 6, and 12 frames/sec automatic; 24 frames/sec semiautomatic, with corresponding running times of 93.3, 15.5, 7.8, and 3.7 minutes. A green light pulses the frame rate.

2. Shutter speeds: 1/60, 1/125, 1/250, 1/500, and 1/1000 second.

3. Fiducial marks are recorded on film.

4. Camera may be hand held or used in boresight-mounted operation in the LH or RH CM rendezvous window.

5. Lenses.

a. 75-millimeter lens.

(1) Focal length: 75 millimeters; can be focused from 42 inches to infinity; focus detents at 10 feet and infinity.

(2) Aperture range: T2.5 to T22.

(3) Field of view: 7.9° by 5.7°.

(4) Mirror mounting adapter attached.

b. 18-millimeter lens.

(1) Focal length: 18 millimeters; can be focused from 1 foot to infinity; focus detents at 10 feet and infinity.

(2) Aperture range: T2.0 to T22.

(3) Field of view: 32.3° by 23.5°.

(4) Mirror mounting adapter attached.

c. 10-millimeter lens.

(1) Focal length: 10 millimeters; can be focused 6 inches to infinity; focus detents at 3 feet and infinity.

(2) Aperture range: T1.8 to T22.

(3) Field of view: 54.9° to 41.1°.

d. 5-millimeter lens.

(1) Focal length: 5 millimeters with fixed focus lens front to infinity.

(2) Aperture range: f/2.0 to f/16.

(3) Field of view: 118° by 80°.

(4) Hand held.

6. The right-angle mirror assembly bayonet quick-mounts onto the front of the 18-millimeter and 75-millimeter lenses for bracket-mounted photography.

7. The power cable supplies CSM power to the camera. The cable length is 108 inches.

8. Remote control cable.

9. The boresight bracket mounts and positions the DAC for boresight operations through the rendezvous windows along the X-axis.

10. The utility light clamp is used for mounted operation of the DAC through LM window 1 or 3.

11. Sextant adapter.

a. Adapts the DAC to the sextant for viewing the sextant's two lines of sight.

b. Focal length: 9 inches, with the film plane at the focal plane of the sextant optics, eliminating the need for the lens.

c. Shutter speed is the only exposure variable; effective f-stop is f/8.

12. Right-angle bracket adapter.

13. 16-millimeter magazine.

a. Capacity: 140 feet of thin-base film.

b. Red light illuminates when approximately 6 feet of film remain.

Film

The characteristics of the types of film used are given as follows:

1. SO-368 film (CEX).

a. Ektachrome MS, color reversal, ASA 64.

b. Good resolution.

2. SO-168 film (HCEX and CIN).

a. Ektachrome EF, high-speed color reversal; normal ASA 160 can be pushed to 500 or 1000.

b. HCEX film is exposed and developed at ASA 160, and CIN at ASA 1000.

c. Resolution: 80 lines/mm for 1000:1 test object contrast.

d. Use: low-light-level photography.

3. 3400 film (BW).

a. Panatomic-X, black and white, ASA 80.

b. Resolution: 170 lines/mm for 1000:1 test object contrast.

c. Use: high-resolution terrain photography.

4. 3401 film (MBW).

a. Plus-X, medium-speed black and white, ASA 64 (with filter).

b. Resolution: 105 lines/mm for 1000:1 test object contrast.

c. Use: terrain photography.

5. SO-267 film (HBW).

a. Plus-XX, high-speed, black and white, ASA 278.

b. Use: terrain photography.

6. SO-246 (IRBW) — infrared black and white.

Intervalometer

The intervalometer has the following characteristics:

1. Activates Hasselblad camera every 20 seconds, using camera battery power.

2. Automatic spotmeter.

3. Automatic reflectance light meter with an angle of acceptance of 1°.

4. Meter scales are automatically rotated to give correct aperture/shutter speed values.

PHOTOGRAPHIC EQUIPMENT LABELING

The inflight photographic equipment is labeled to aid the crew in selection and use. Figures A-7 to A-13 are examples of equipment labeling.

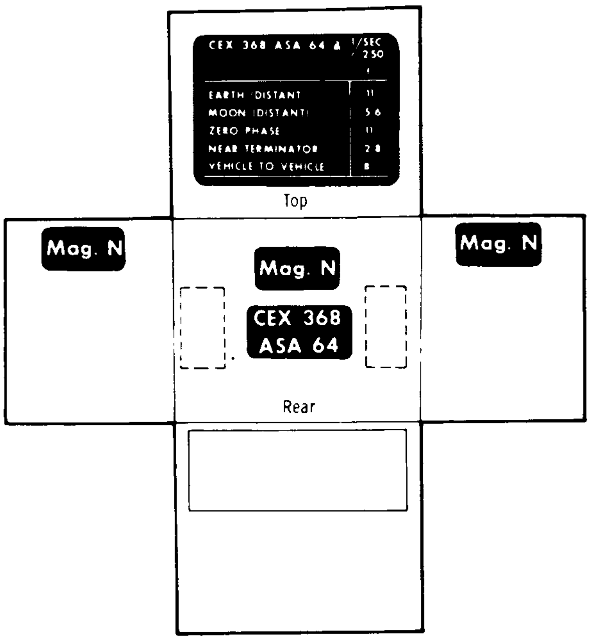


Figure A-7. - Electric Hasselblad/CEX.

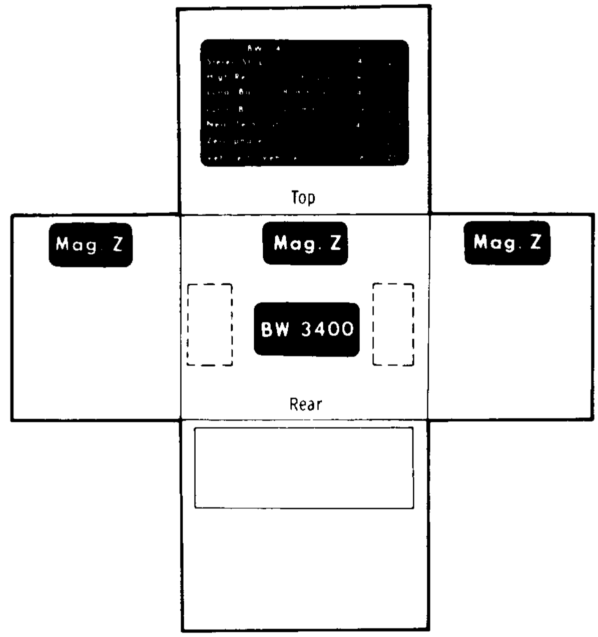


Figure A-8. - Electric Hasselblad/BW.

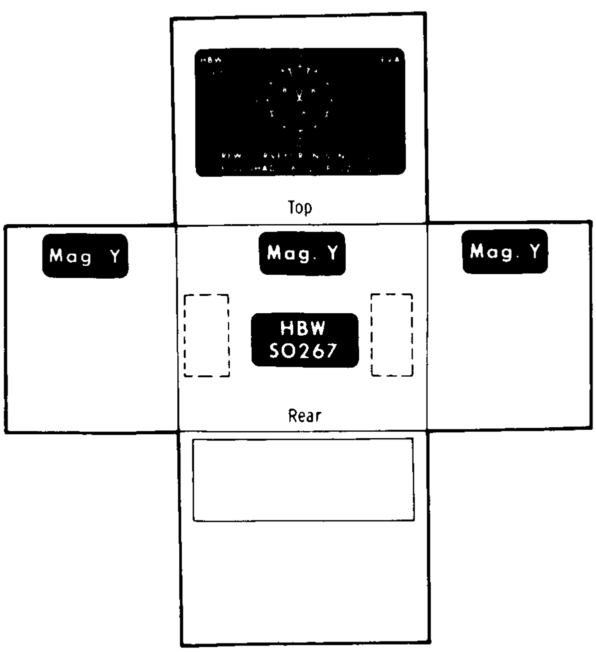


Figure A-9. - Hasselblad data camera/HBW.

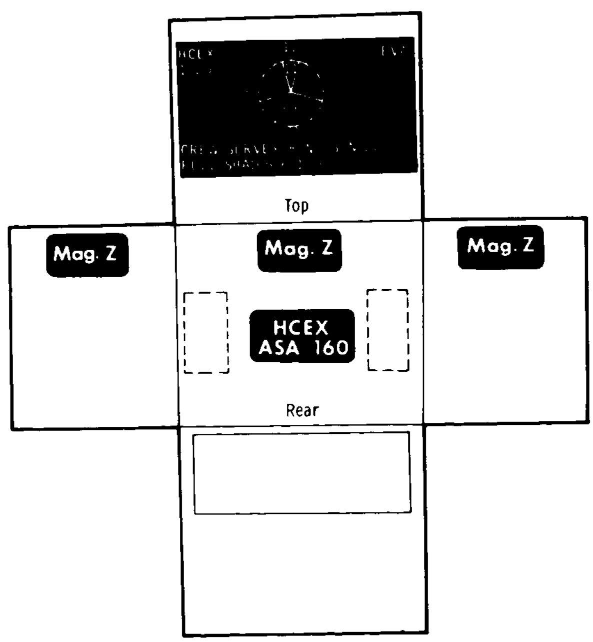


Figure A-10. - Hasselblad data camera/HCEX.

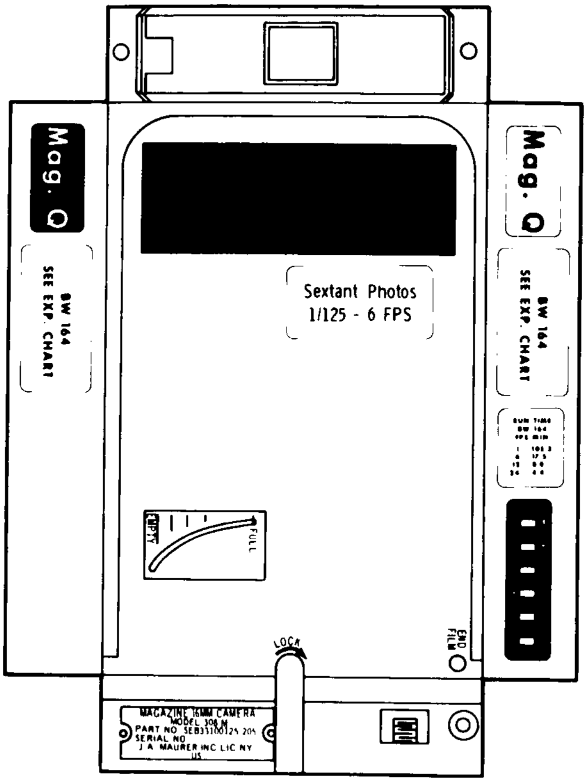


Figure A-11. - The CSM data acquisition camera.

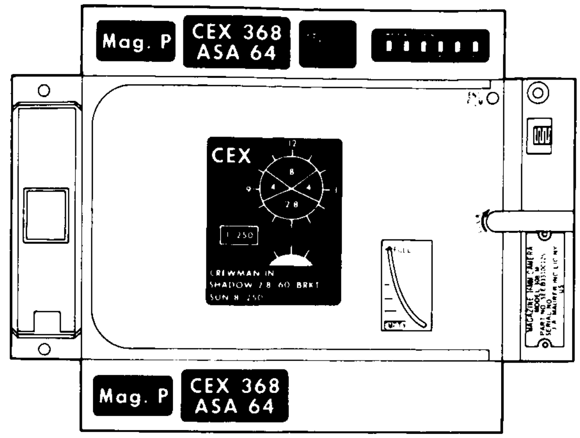


Figure A-12. - The LM data acquisition camera.

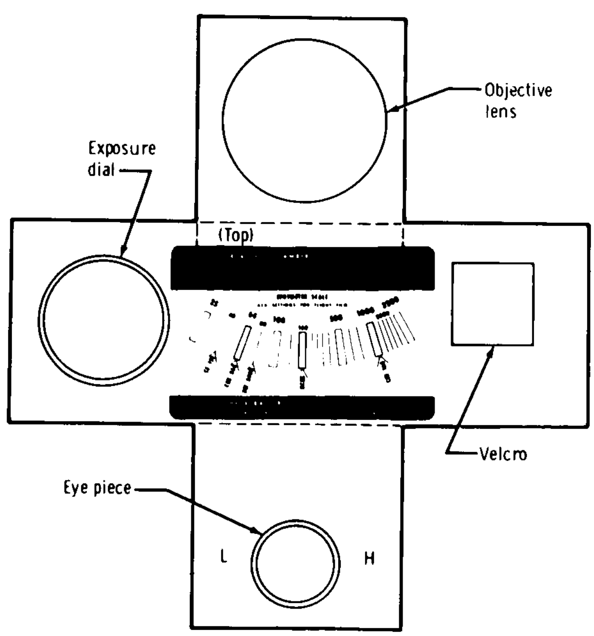


Figure A-13. - Spotmeter.

PHOTOGRAPHIC TIME-LINE SUMMARY

Time	Activity or target	Camera configuration code	Magazine
3:20	Transposition and docking	CM2/DAC/18/CEX - BRKT, MIR (f8, 250, 7) 6 fps, .3 mag (5 min)	A
		CM2/EL/80/CEX - (f8, 250, 30) 10	Q
		CM4/TV - IN, BRKT (f22) 1 hr 05 min	
4:15	LM ejection	CM2/DAC/18/CEX - BRKT, MIR (f8, 250, 7) 12 fps, .7 mag (6 min)	A
		CM4/EL/80/CEX - (f8, 250, 30) 5	Q
TLC	Earth photography	CM_/EL/80 or 250/CEX - RING (f11, 250, ∞) 20	Q
	Distant moon	CM_/EL/250 or 80/CEX or BW - RING (f5.6, 250, ∞) 5/5	Q S
30:25	Hybrid burn (MCC-2) crew activities	CM/TV - IN (f5.6) 35 min	
63:30	IVT transfer	CM/TV - IN (f5.6) 50 min	
81:30	Pre-LOI 1 lunar surface	CM/TV - IN (f22) 20 min	
84:00	Lunar surface	CM/TV - IN (f22) 30 min	
107:55	Undocking	CM2/DAC/18/CEX - BRKT, MIR (f8, 250, 7) 6 fps, 1 mag (16 min)	B
		CM2/EL/80/CEX - (f8, 250, 50) 10	Q
		LM1/DC/60/HCEX - (f11, 250, 50) 10	Y
		LM_/DAC/10/CEX - (f11, 250, 7) 6 fps, .25 mag (4 min)	K
		CM4/TV - IN, BRKT (f22) 20 min	
Lunar orbit	Targets of opportunity	CM/EL/80 or 250/CEX - (CC, 250, ∞) 175	Q R
	Fra Mauro	CM/EL/80/BW - (f2.8, 250, ∞) 10	S
110:26	PDI + 6 min/descent	LM3/DAC/10/CEX - (f2.8, 500, 30) 12 fps, .75 mag (6 min)	K
114:40	EVA 1	See surface photography and television time lines	L M N V W X
133:17	EVA 2		X Y Z O
134:10	Sextant photography - Lansberg revolution 26	CM/DAC/SEXT/CEX - (fixed, 60, fixed) 1 fps (5 min)	F
135:19 137:25	Lunar multispectral	Blu - CM3/LMC/80/MBW - IVL, 47B FIL (*, fixed) 150	BB
137:47	North wall of Theophilus	Red - CM3/LMC/80/MBW - IVL, 29+ FIL (*, fixed) 150	CC
137:51	Descartes	Grn - CM3/LMC/80/BW - IVL, 58 FIL (*, fixed) 150	DD
138:01	Fra Mauro	Blk - CM3/LMC/80/IRBW - IVL, 87C FIL (*, fixed) 120	AA
142:00	LM ascent	LM3/DAC/10/CEX - (f2.8, 500, 30) 12 fps, 1 mag (8 min)	P

Time	Activity or target	Camera configuration code	Magazine
145:30	Rendezvous and docking	CM2/DAC/18/CEX - BRKT, MIR (f8, 250, 7) 6 fps, 1 mag (16 min) CM2/EL/80/CEX - (f8, 250, 30) 10 LM/DC/60/HCEX - (f11, 250, 40) 5 CM4/TV - IN, BRKT (f22) 30 min	C R Y
148:00	LM jettison	CM4/DAC/18/CEX - BRKT, MIR (f8, 250, 7) 12 fps, .5 mag (4 min)	D
	Crew option	CM/DAC/SEXT/CEX - (fixed, 250, fixed) 1 fps, .5 mag (46 min)	
159:40	High-resolution/oblique photography - Lalande	CM4/EL/500/BW - BRKT, CONT (f8, 125, ∞) 40 CM2/DAC/18/BW - BRKT (f8, 125, ∞) 6 fps, .5 mag (8 min)	S I
160:54	Vertical stereostrip	CM4/EL/80/BW - BRKT, IVL (f4, 250, ∞) 180 CM_/DAC/SEXT/CEX - (fixed, CC, fixed) 1 fps, 1 mag (93 min)	T E
163:20	High-resolution/oblique photography		
	Descartes	CM4/EL/500/BW - BRKT, CONT (f8, 125, ∞) 120	S
	Fra Mauro	CM2/DAC/18/BW - BRKT, MIR (f8, 125, ∞) 6 fps, 1.5 mag (24 min)	I J
164:50	Landmark tracking sextant photography	CM/DAC/SEXT/CEX - (fixed, CC, fixed) 1 fps, ~1 mag (88 min)	F
168:51	Vertical stereostrip	CM4/EL/80/BW - BRKT, IVL (f4, 250, ∞) 180	U
172:55	Lunar surface	CM/TV - IN (f22) 20 min	
TLC	Distant moon	CM_/EL/80 or 250/BW or CEX - RING (f5.6, 250, ∞) 5/5	S R
	Earth photography	CM_/EL/80 or 250/CEX -RING (f11, 250, ∞) 10	R
223:15	Earth, interior	CM/TV - IN (f22) 30 min	
	Reentry	CM/DAC/18/CIN - (f11, 250, 7) 12 fps, .5 mag (4 min) Fireball OM/DAC/18/CIN - (f8, 250, 7) 12 fps, .5 mag (4 min) Parachutes	 G
Crew option	Crew/spacecraft compatibility	CM/DAC/5/CIN - (f2.8, 60, ∞) 6 fps, 1 mag (16 min)	H
	Stowing/unstowing equipment (aft bulkhead)	CM/TV - IN (f5.6)	
	LM to CSM crew transfer donning/doffing spacesuit		
	Crew observations	CM_/EL/80 or 250/CEX - (Decal) 40	R
	Contingency magazine		EE

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