

NASA GRANT NGR33-011-031

FINAL TECHNICAL REPORT

ASTRONOMICAL ACTIVITIES OF THE
APOLLO ORBITAL SCIENCE PHOTOGRAPHIC TEAM

January 31, 1974

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ASTRONOMICAL ACTIVITIES OF THE
APOLLO ORBITAL SCIENCE PHOTOGRAPHIC TEAM

Prepared for

Headquarters

National Aeronautics and Space Administration
Washington, D. C. 20546



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January 31, 1974

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Abstract

This is the Final Technical Report on National Aeronautics and Space Administration Grant NGR33-011-031 entitled, "Astronomical Activities of the Apollo Orbital Science Photographic Team". It presents a partial accounting of Apollo Photo Science Team (APST) work as reported by one of its members, Mr. Robert D. Mercer, who provided scientific recommendations for, guidance in, and reviews of photography in astronomy. This report, together with its conclusions and recommendations, represents solely the views of the author. It is meant to satisfy his final contractual commitment to document those APST matters in which he was involved for the Apollo Program Office through Headquarters and the Manned Spacecraft Center.

This report presents background on the formation of the team and discusses its functions and management. The report necessarily draws on experiences and documentation associated with astronomical tasks to provide an insight into the manner of the team's day-to-day operations. Only a few small additions have been made to these documents, included as attachments, since they were first written. This allows the reader to better understand the typical problems in a much less hectic environment than existed when these documents were created.

The conclusion of this report is that the Apollo Orbital Science Photographic Team clearly performed the overall objective for which it was established--to improve the scientific value of the Apollo lunar missions. Specific reasons for this success are given. Ultimately, team success depended on the individual contributions by its members, and by all NASA and contractor personnel associated with the team's activities. But even more importantly, it depended on the simple desire by all of these people to work together for a common purpose.

This may be the only final report on team activities that NASA requires of a team member. In that sense the author hopes it will perform a final service for everyone on the team, and he apologizes for its limitations. He also wishes to express his own gratitude and profound admiration to NASA for undertaking this new approach to the management of scientific effort. Participation on the team has been one of the most satisfying and professionally rewarding experiences for the author, personally, over his twelve and one-half years of association with manned space flight programs.

Background

The idea for an Apollo Orbital Photographic Science Team (APST) originated in 1969 as NASA reviewed experimental proposals for the final lunar missions. Up to that time scientific experiments on early Apollo flights had been kept to a minimum for two reasons. First the spacecraft fire on the pad had already delayed the program's tight timetable. Second, and more significantly, the ensuing investigations into the cause of that fire turned up engineering and manufacturing deficiencies indicating more urgent attention should be given to primary equipment than to the build-up and integration of experimental equipment. Management wisely chose to do just that in order to achieve its primary goal--to land men on the moon and to return them safely to earth within the decade of the sixties.

By early 1969 flight schedules and accomplishments gave such good indications that the primary objectives would be met, that Apollo Program management could again turn its attention to experiments and to maximizing scientific opportunities. One logical use of these missions was high-resolution photoreconnaissance of the lunar surface, particularly of those areas overflowed by the Command and Service Modules (CSM) that are seen off-normal or not at all from the earth. The vehicle contractor was requested to perform studies for integrating available camera systems in an unused bay of the Service Module (SM); this became the Scientific Instrument Module (SIM) bay. Then, when the Announcement for Flight Opportunities was issued containing these suggested uses of the vehicle, many proposals were received for mapping, geodesy, cartography, geological photography, and the like. Such proposals indicated interrelationships in many experimental requirements. This, quite naturally, led to the concept of a photo science team made up of experiment investigators and others qualified to synthesize common requirements.

A charter for this team was created and members appointed; a copy of that charter and a list of members are included as Attachment 1 and 2. All of the thirteen members except two, Messers Dunkelmann and Mercer, were concerned with lunar surface photography. These two were added to the team specifically to ascertain opportunities and to coordinate requirements for photography in astronomy and aeronomy. It is this photography that will be the main concern of the remainder of this report.

Within each of the disciplines represented, the team reviewed, recommended and followed up on scientific objectives, and on technical and operational aspects required to integrate appropriate tasks into the flight. Preflight and postflight photocalibrations and photoprocessing were also within the team's purview, as were the design, operation and supporting data collection aspects of all on-board photographic equipments. The team

provided real-time support on Apollo missions 13 to 17, inclusive, and interfaced with the Science and Applications Directorates (S&AD) representatives at the Manned Spacecraft Center (MSC). Team members received, in turn, excellent support for their needs from many government and contractor groups at MSC. They include the Apollo Program Office, the Lunar Mapping Sciences Division, the Photographic Technology Division, the Flight Crew Integration and Flight Crew Procedures Division, and Mission Control Center (MCC) teams. On occasion the APST members assumed other responsibilities or assisted with special requests beyond those specifically called out in their charter. For instance, some team members provided direct or indirect support to NASA's Public Affairs Office by participations at press briefings, and by providing technical or scientific information to the news media concerning photographic equipments or tasks under the team's cognizance. Attachment 3 to this report is some of the handout material for the press distributed prior to the launch of Apollo 15 at the Cocoa Beach, Florida, Press Site of the NASA Kennedy Space Center and during the mission from the Press Site at MSC.

The team chairman was Mr. Frederick J. Doyle of the U. S. Geological Survey. Officially, all inputs were submitted by him to the Apollo Program Director, Dr. Rocco A. Petrone, through the Director's Lunar Exploration Office (Code: MAL) at NASA Headquarters. However, since the Apollo Program Office at MSC, supported by S&AD, had the main responsibility for integrating equipment and operational requirements, authority and responsibility for accepting APST inputs were delegated directly to MSC under the cognizance and review of MAL. NASA established a very smooth management technique by this arrangement. This played a very large part in the success of the APST's efforts, because it not only required contributions from the APST, it also expected the members to work directly with NASA/contractor personnel to solve the detailed, day-to-day problems. This brought the team right into the midst of things, instead of requiring them to serve at arms length as an experienced, but uninformed advisory body with no real responsibility for the outcome of their advice.

One crucial element which was necessary to maintain this close association was the early establishment by the MAL office of a travel fund account for team members' use. The Team Chairman controlled trip-by-trip disbursements of this fund while MAL kept the overall level ample for team member participation in required activities. This provided everyone on the team the freedom to work and contribute when and where needed, which was greatly appreciated by team members.

The APST was able to enhance scientific return from the last four lunar missions for a great number of reasons, some of which have just been cited. Such reasons are best grouped into the following three main areas.

First, the team was established under a sound charter, and throughout its tenure the team enjoyed the strongest backing and continuing personal interest of the Program Director, his Lunar Exploration Office representatives and their counterparts at MSC. This was translated into mutual feelings of respect and high professional regard, which built a good working environment right from the start.

Second, the NASA monitors and the Team Chairman kept the overall effort goal-oriented, and they were rapidly able to reach agreement on what those goals should be. Both NASA and the team adhered to the method of assigning coordinated action items on team members or on supporting NASA/contractor groups with close follow-up. Working groups within the team were established to handle matters cutting across several areas of interest. The Chairman directed team activities in an outstanding manner, considering the diversity of scientific and technical backgrounds possessed by team members and the difference in views each exhibited in his desire or availability for participation. Nevertheless, the Chairman could report with dispatch the team's decisions, actions and activities to individual members and to NASA, so that few communication gaps or misunderstandings occurred.

Third, each team member's desire for the highest quality and quantity of data return in his own special area of scientific expertise was soberly balanced against long experience working within the framework of large, government R&D projects. Everyone realized the need for tight program control as the only acceptable technique for achieving success where technical and operational requirements were very broadly based. Team members did not expect miracles, and if matters did not go correctly, they quickly joined with NASA to rectify the situation. All were motivated to solve the problem at hand or arrive at an acceptable plan of action, not just to find fault. Team members tried not to forget that they were serving NASA's Apollo Program as invited guests, while given wide latitude in their functions. Also, they were careful to make their recommendations through those NASA representatives who held the appropriate authority and responsibility.

Team Activities in Astronomy

NASA's Announcement for Flight Opportunities also brought in proposals for photographic studies of celestial phenomena. One of these, Experiment S178, involving photography of the Geggenschein/Moulton Region, indicated the need for representation on the APST from the astronomical community. Mr. Lawrence Dunkelman, the Principal Investigator on Experiment S178, and Dr. Franklin E. Roach were appointed. However, the latter was not able to serve and was subsequently replaced with Mr. Robert D. Mercer of the Dudley Observatory. The Lunar Exploration Office acquired his services from July 1, 1970 through June 30, 1973 under the Grant for which this report was prepared.

Mr. Dunkelman also organized a Low Light Level Working Group to assist in reviews and recommendations to the team. Besides Messers Dunkelman and Mercer, it included Mr. Douglas D. Lloyd of Bellcomm, an APST member interested in lunar surface photography requiring fast optics and films used by astronomers, and Mr. Charles L. Ross of the High Altitude Observatory who advised on all solar corona photography. In many instances Mr. Ross, who was not an official member of the APST, contributed directly to APST business at a level equal to or exceeding the workload of some of its official members. The Low Light Level Working Group recommended photographic tasks to acquire data on low brightness, diffuse sources that would capitalize on the unique vantage points available in lunar orbit; namely, the double umbra and the sharp occulting edge provided by the lunar limb. This avoided the inherent problems in collecting such data from the earth's surface, where one must contend with airglow and atmospheric extinction.

A general description of the astronomical subject matter with illustrations is given in Attachment 3. A condensed version of the background, specific scientific objectives of the photography and its flight history is given in Attachment 4. Attachment 5 is a preprint of a paper presented at the May 1972 meeting in Madrid of the Committee on Space Research (COSPAR) giving early results from astronomical photography performed on Apollo 15. In addition to this, members of the Low Light Level Working Group have contributed to mission Preliminary Science Reports and together, presented a short review paper of Apollo 15 early results at the October 1971 Optical Society of America meeting in Ottawa. In this regard, some interesting pictorial results from Apollo 17, reported quite recently, are shown in Attachment 6. Early in 1972 many of the active APST members received data analysis contracts to obtain technical and scientific results from data obtained under APST tasks, and their findings have appeared and continue to appear in NASA documents, scientific journals and the like.

Team Activities for Operational Support:

The operational support activities for astronomical tasks required at least 80% of team members' time and energies. Moreover, the timing of their work was dictated by mixed events and schedules, such as Configuration Control Board meetings, crew training schedules, equipment preparation and calibration schedules, postflight photo-processing plans and postflight debriefing schedules. It was not unusual for team members to plan trips so as to attend to premission requirements from one mission while on the same trip covering post-mission activities of the previous flight. Every team member's personal working schedule was dictated almost exclusively by NASA's schedules. If travel funding arrangements had not been established as described above, the value of team inputs would have been slight, indeed. Team operational support activities can be placed into nine general groupings:

1. Mission Planning Inputs
2. Equipment and Procedures Development Review
3. Crew Briefings and Training/Simulation Inputs
4. Flight Planning Inputs and Review
5. Preflight and Postflight Photocalibration Activities
6. Real-Time Flight Support Activities
7. Ground Supporting Data Collection Activities
8. Postflight Mission Analysis and Reporting
9. Data Analyses Review

Mission planning inputs consisted of written breakouts of scientific tasks in terms of Detailed Test Objectives (DTO's) with supporting statements on scientific justification and background for inclusion in the Mission Requirements Document (MRD). A sample of this for the Apollo 14 mission is given in Attachment 7. These MRD inputs also outlined equipment utilization. If new or revised equipment development became necessary, the team members provided engineering information and technical assistance directly to the NASA systems engineers and their contractors through S&AD representatives and, when warranted, included team member's presence at Configuration Control Board (CCB) briefings. A quick review of equipment changes or additions for

low light level astronomical tasks is given in the table on flight history in Attachment 4. The full development of crew operating procedures required additional detail beyond the MRD description, and this is shown in revised procedures for Apollo 15 in Attachment 8.

These procedures were eventually reduced to line item entries in the crew's checklists. Here, too, revisions had to be defended at Crew Procedures Control Board (CPCB) meetings. It was this checklist form that was used in preflight briefings with the crew, and it was their constant reference during training and simulation sessions. An outline of a typical preflight crew briefing is shown in Attachment 9. Generally, if changes were necessary to the initial procedures and checklists, all other documents were modified to agree with the current status of those sources. Thus, flight planning inputs were derived from them. However, because of flight plan complexities, it was always necessary to review each new version to assure that constraints on task accomplishments had not, inadvertently, been violated. Such problems could occur through revised placement of optically contaminating dumps or fuel cell purges too close to photographic periods, changed start times in photo sequences versus trajectory dependent times of earthset or sunrise, choice of thruster configurations to control vehicle attitude during individual exposures, and the like.

Attachment 10 is the preflight film budget for Apollo 15 based on the final flight plan. That budget was drawn up to determine exactly how many frames of film would be used or left unused on each film cassette. This insured that the Command Module pilot would not run out of film in the middle of a photo sequence with no time planned for change out of cassettes. Such important considerations could not be left to chance, and yet their details could not be finalized until the scheduling of each event in the flight plan was completed.

A unique example of the opportunity for an APST member to assist and the degree of his involvement can be shown in the following--The mounting bracket design and window clearance assessment for the 35mm Nikon camera's first use on the Apollo 15 mission had been carefully engineered by MSC with inputs from the astronomical members on the APST. Nevertheless, when crew equipment engineers attempted fit tests behind the right-hand rendezvous window, the camera could not be locked into its bracket in the prescribed position. In fact, the fit was so bad that only a portion of the camera's field-of-view would have been useable, and the data collected virtually worthless.

At the request of S&AD representatives, the author traveled to KSC on the 4th of July, just three weeks prior to launch. Working together with NASA and contractor engineers in the spacecraft atop the booster on the launch pad, he was able to quickly ascertain the adequacy of the fix with regard to field-of-view. The major part of the problem had been discovered

just as the author arrived at the pad; however, the subsequent fit tests still showed a slight blockage of the camera's field-of-view. But, since the author was familiar with the scene expected through the viewfinder, he was able to provide the necessary continuity from design to ultimate use. He could verify immediately that the partial obscuration at the lower edge of the scene was fully expected, and that design requirements had, indeed, been met, whereas the spacecraft engineers would have considered the discrepancy as an open item. This would have caused great concern to NASA and the prime contractor, so close to the launch date, and would most certainly have jeopardized or eliminated the opportunity to collect scientific data. As it turned out, astronomical data collected with this first use of the Nikon system was some of the finest ever obtained during the program and it gave great credence to the arguments used to justify its inclusion on that, and subsequent missions.

Throughout the succession of flights supported by the APST, the astronomy team members were able to improve their technique in applying absolute photometric calibrations to the flight and backup films. The backup film was utilized for ground based photography to match flight photography when meteorological conditions permitted. MSC's Photographic Technology Laboratory and the Crew Equipment Branch of the Flight Crew Integration Division were especially helpful and understanding towards the scientific calibration requirements that were necessary to enhance the quality of returned data. Attachment 11 is an early write-up of the calibration details that were incorporated into NASA's own preflight and postflight testing preparations. As the results of each mission became known, these procedures were revised and extended to provide the desired improvements.

Another example of photo team follow-up on problems affecting the quality of science occurred after Apollo 14. The astronomy members were somewhat puzzled at the weak registration of stellar images on the 2485 high-speed film. One possibility that had serious consequences for future flights was poor transmission characteristics of the right-hand rendezvous window. NASA arranged, through North American Rockwell, to let these team members make transmission measurements to support or refute this possibility. These tests were performed in a few hours with little disruption in the contractor's post-flight analysis of spacecraft and systems performance. The outcome indicated that window transmission was not a serious problem, and subsequent planning could continue with confidence.

The ground support photography was collected to satisfy three additional needs. First, by photographing the same celestial scenes from both the ground and the spacecraft at nearly the same time it is possible to measure parallax for nearby phenomena. Second, by using the same emulsion for ground

and spacecraft photography which had been calibrated and later, processed together, the effects of night airglow and atmospheric extinction could be measured. Third, the amount of Van Allen belt radiation to which the flight film had responded while leaving and returning to earth could be determined by comparing the differences in background base fog levels. These subtle, scientific points were the sort of considerations that definitely came under APST responsibilities, but are often overlooked or considered unimportant in terms of gross scientific requirements.

To recount or explain the real-time flight support activities of the APST would be ludicrous, let alone impossible. Essentially it involves the undoing and on-the-spot redoing of all prior planning, while remembering very carefully why flight activities had been so planned in the first place. It is a constant tussle between opportunities, constraints, and time, with discontinuities always coming from the most unexpected quarter. In this battleground, usually the Mission Control Center, allies are made, lost, and made anew until one doesn't know where to keep his loyalties, if there are any to be kept. Perhaps it can all be summed up in the Latin phrase, "Flexibilis sine flexibilissimus," which translates rather loosely into, "Be flexible without going limp".

Finally, the team had responsibilities for submitting reports on scientific accomplishments required by program management. The value of this reporting must be judged by others, and the reader is referred to post-flight scientific documentation to determine the usefulness of such contributions. Besides the well delineated tasks, the team could report on the non-nominal and spontaneous scientific photography that crewmen invariably perform when targets of opportunity occur. This service by the team borders more nearly on the exploratory portion of mission accomplishments than does the reporting requirements levied on formal investigators. The team could and did touch upon interdisciplinary sciences using photography. In so doing they necessarily delved into considerations of what primary and supporting data ought to be required to permit or enhance the later task of data analysis. So, when the MAL office asked for suggestions on this topic, the author outlined a technique given in Attachment 12 which seemed reasonable and thorough in dealing with this future consideration.

Conclusions

The author has drawn several of his own general conclusions from this participation on the Apollo Orbital Science Photographic Team. They are:

1. Team participation and accomplishments did improve quality and quantity of data returned from the final lunar missions.

2. Ad Hoc teams formed to assist NASA must be conceived under a strong charter and have the full backing of management, particularly at the highest levels, if their work is to be effective.
3. The team must accept responsibility commensurate with its chartered authority, and in fulfillment of that responsibility, it must be allowed to participate in those activities shown to be vital to its interests.
4. Individuals serving on such teams must already be aware of or must gain an early understanding of NASA's organizational structure. They must quickly recognize how to fit into its internal workings. The ability of a team member to do this is very often as important to the accomplishment of final objectives as the level of scientific or technical expertise he brings to the team. In short, a few ideas, well integrated, are worth far more than many ideas falling on deaf ears.

Recommendations

From the above conclusions and from many other experiences over twelve and one-half years of involvement in manned space flight programs, the author offers the following recommendations:

1. The concept of a chartered Photographic Science Team should be continued on all, future manned programs. It has proven to be the only effective way in which to acquire scientific and exploratory data from the many opportunities not provided for under formal arrangements with Principal Investigators.
2. Such teams should be composed of a small number of members who have some experience in government R&D program operations. If situations occur requiring greater effort than the members, themselves, can provide, support to the team should be obtained through working groups formed from team members, outside experts and NASA technical personnel.

Acknowledgements

The author wishes to express his sincere appreciation to the many people in NASA, its supporting contractors, and the APST who made his participation possible and more effective in many ways. In addition to those persons already mentioned in the body of this report or its attachments,

the author wishes especially to thank Mr. George Eesenwein, Dr. Floyd Roberson and Mr. Nat Hardee from NASA, Mr. Wesley Simpson of Lockheed Aircraft Corporation, and Mr. Marty Barone and Dr. Jerry Fuller from TRW, Inc. for their direct contributions to the scientific, technical and administrative management and support of this work. And, indeed, the constant traveling required would not have been possible without the efficiency of Mrs. Rosalie Breckenridge at the U. S. Geological Survey.

The author is greatly indebted for the unfailing technical support he has grown accustomed to receiving from his research assistants, Miss Karen Jacobs and Mrs. Linda Schwabe. And finally, preparation of this report and its supporting documentation required the ready skills of Mr. David Wachtel, photography, Mrs. Gail Chien, drafting and Mrs. Gen Pruscop, typing.

AUG 18 1970

APOLLO PROGRAM DIRECTIVE NO. 54A

TO : DISTRIBUTION

FROM:

Rocco A. Petrone
APOLLO PROGRAM DIRECTOR

AUG 18 1970

SUBJECT: Apollo Orbital Science Photographic Team Charter

OFFICE OF PRIME RESPONSIBILITY: MAL

I. PURPOSE

This directive is the charter for the Apollo Orbital Science Photographic Team. The Team is established to provide scientific guidance in the design, operation, and data utilization of photographic systems for Apollo Program lunar orbital science.

II. ORGANIZATION

The Orbital Science Photographic Team shall consist of a Chairman and Team Members. The Chairman shall be empowered to delegate responsibility, appoint committees, direct the Team activities, and will be the spokesman for the Team.

The Team shall include authorities in the field of geology, geodesy/cartography, photogrammetry, astronomy and space photographic instrumentation.

Appointment of Team Members is the responsibility of the Apollo Program Director. Team appointments will require the concurrence of the Chairman. Duration of Team Membership and selection of Apollo missions for which team functions will apply shall be specified by the Apollo Program Director.

Membership on the Team does not preclude an individual from participating in the analysis of photographic data for scientific investigations.

III. NASA/TEAM INTERFACE AND REPORTING REQUIREMENTS

The Team Chairman shall submit all Team recommendations and reports to NASA. The Team's working interface with NASA is the Manned Spacecraft Center (MSC). As designated by MSC, the Team Chairman's specific point of functional contact will be:

Chief, Lunar Missions Office
Science and Applications Directorate
Manned Spacecraft Center

Copies of all Team recommendations will also be forwarded to:

Manager, Experiments and GFE
Apollo Spacecraft Program Office
Manned Spacecraft Center
and
Director, Apollo Lunar Exploration
Apollo Program Office
NASA Headquarters

The Chief, Lunar Missions Office (MSC) will submit a report to the Chairman, Apollo Orbital Science Photographic Team regarding the implementation of Team recommendations within thirty (30) days following the recommendations. Copies of this report will be sent to the Manager, Experiments and GFE, ASPO and the Director, Apollo Lunar Exploration Office.

The Photographic Team will submit a report to the Manned Spacecraft Center on photographic operations for each Apollo 45-day mission report.

If the Team Chairman feels that NASA implementation of photographic systems is such that scientific objectives will be compromised, the Chairman will notify the Apollo Program Director.

IV. TEAM RESPONSIBILITIES

The Apollo Orbital Science Photographic Team will participate and will be responsible for providing written recommendations in the following areas:

1. Equipment Functional Specifications

- a. The Team shall recommend functional requirements for orbital photographic systems.
- b. The Team shall provide technical advice during the procurement phase for photographic systems.
- c. The Team shall be represented at photographic equipment reviews.

2. Equipment Utilization

- a. The Team shall participate in preparation of plans for scientific utilization of the photographic systems and support mission operations planning.
- b. The Team shall participate in planning for coordinated use of photographic systems to support other experiments.
- c. The Team shall participate in planning for other experiments which will support photography.
- d. The Team shall participate in operations planning for photographic requirements to support Apollo Lunar Landing Site Selection.
- e. The Team shall review, by missions, all planned orbital photographic tasks whether scientific or operational, and recommend relative priorities of scientific tasks.

3. Crew Training

The Team shall provide technical advice for and will support, as requested by the Manned Spacecraft Center, astronaut training related to photographic tasks.

4. Real-time Operations

The Team shall support operations, as requested, by providing real-time scientific and technical advice to astronauts for photographic and related tasks.

5. Data Analysis

- a. The Team shall provide technical advice in selection of film and film processing requirements to optimize post mission scientific analysis by photographic users.
- b. The Team shall recommend major data reduction equipment and analysis procedures to assure that optimum scientific use is made of the photographic data obtained.

V. CSM PHOTOGRAPHIC TASKS

Utilization of the facility camera systems shall be accomplished through CSM Orbital Photographic Tasks. These tasks will be based on the recommendations of the Photo Team for each mission. They shall be submitted by the Team in sufficiently descriptive detail such that if approved, the task can be adequately described in the Detailed Objectives of the Mission Requirements Document.

VI. LIMITS OF TEAM RESPONSIBILITY

The responsibility of the Apollo Orbital Science Photographic Team shall be subject to the following limitations:

1. Final selection of camera systems and vendors is the sole responsibility of NASA.
2. The Team does not have exclusive rights nor release authority for photographic data.
3. The Team is not responsible for scientific analysis and publication of results beyond the operational report required for each mission.

CHARTER AMENDMENT

Recommended changes to this charter will be submitted to the Apollo Program Director for consideration. The Program Director will submit proposed changes to the Team Chairman for review and concurrence. Approved changes will be released in the form of a revision to this directive.

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LOW LIGHT LEVEL ASTRONOMY ON APOLLO 15

BACKGROUND INFORMATION

USEFULNESS OF APOLLO

Photographs of solar corona and special regions of the interplanetary dust will be taken during Apollo 15 while a Command Module is once again in the darkest part of space ever reached by man. This is the double umbra portion of lunar orbit where neither direct sunlight nor sunlight reflected from the earth can reach the spacecraft or its surrounding cloud of effluents. Also, the very dark nightside lunar horizon provides a sharply defined occulting edge where no atmosphere can scatter or refract sunlight or earthshine to create an unwanted twilight effect which could swamp the solar corona or close-in zodiacal light images. And finally, the vantage point of lunar orbit allows parallax photography of astronomical subjects nearby the earth and moon--the Moulton region (See write-up on Experiment S-178, Gegendhein/Moulton Region Photography from Lunar Orbit) and lunar libration point, L_4 -- which will yield important, new information when compared to similar earth based observations. Thus, the Apollo lunar flights offer a unique opportunity for man to use simple camera systems and easily return to earth the images on high-speed, black and white film.

IMPORTANCE

These data are important to scientists as they explore the universe, driven by their insatiable curiosity. But, it will also have practical benefits to all of mankind in many ways. Studies of solar corona will eventually help to clarify the processes by which energy flows from the life-giving sun and how the various forms of this energy react with the magnetosphere and atmosphere of ours or other planets and satellites that man will eventually inhabit (See NCAR Fact Sheet, "Apollo XV Solar Corona Photography," dated July 1, 1971).

As man moves out from his own planet--as he certainly will, in time--he must contend with interplanetary dust and the concentrations or voids in its distribution created by the interlocked gravitational fields of the sun and planet-sized bodies of the solar system. Indeed, these very simple, experimental tasks on Apollo are already beginning to build the necessary background of knowledge for designers of future space ships coursing between man's solar system colonies. This may sound very much like "way out" science fiction, but who is so clairvoyant today as to dismiss the importance these matters may have for man's future.

The Ranger, Surveyor and Lunar Orbitor series of spacecraft were sent up with an ever increasing sense of urgency to obtain crucial design and operational data necessary for man's first landing and walking on the moon. Final decisions on the initial landing site, the number of LM landing struts and the size of the foot pads were delayed because appropriate scientific data were not available when first needed.

One wonders if the current crisis about atmospheric and waterway pollution here on earth would seem so staggering to us today if we had been more curious and more diligent about measuring and understanding our environment starting

one-hundred years ago. Anyone proposing even a modest program of environmental study of the post Civil War Congress would probably have been laughed right out of chambers.

The American people and, indeed, all of mankind must be made aware that such projects which take one or more decades to complete should be expected to produce results not only for current technologies, but also for overcoming problems that will not exist until after our lifetime. If this were not the case, then such projects would most assuredly be wasteful of our material resources and time compared to their full promise for mankind. We must learn to expand our interests to include concern for the problems of generations who are to follow and forget the parochial chronology, "What's in it for me--RIGHT NOW?"

USEFULNESS OF MAN IN THESE TASKS

These astronomical studies have been greatly simplified in cost and effort because manned vehicles are available now, even in comparison to doing the same tasks with unmanned spacecraft. These studies represent the quickly conceived, low priority tasks, whose importance are not yet fully known, that could not possibly justify the cost to build automated payloads and launch systems necessary to reach the lunar region so vital for their successful accomplishment. They can proceed today instead of waiting several decades until we establish observatories and communications facilities on the far side of the lunar surface to collect greater quantities and better quality of such data.

On Apollo, an astronaut using familiar camera equipment with special procedures, training and ground team support can negotiate the complicated tasks of low light level astronomical investigations. Only a few people are required to carry out all of the support work over the period of about one year. This clearly demonstrates how the flexibility of man and machine, integrated together, can obtain useful information without long delays and great, additional expense.

A trivial, but illustrative example on the utility of man's presence versus total automation might be the design of an automatic bed-making machine for the home. The size, weight and complexity of such a mechanical device would be enormous to cope with the many patterns of disarray in unmade beds that could be encountered. The cost and maintenance would be very high, to say nothing of the problems in moving it from room to room, supporting it on the average floor, and storing it when not in use. And yet, a person can swiftly and easily perform this intricate mixture of simple and non-linear tasks properly. This example does not imply that certain functions cannot and should not be automated. It simply illustrates that options using the man or machines or the man-machine combination can be very useful to science when properly applied.

SCIENTIFIC DESCRIPTION

The gegenschein, Moulton region, lunar libration point and zodiacal light are all a part of the interplanetary dust; so, it is important to understand how they are related. Interplanetary dust is comprised of countless, grain-like particles with almost all of them a few microns or less in size. The very few larger ones that we can observe separately are called asteroids. They are all in various solar orbits along with the planets. We can study them indirectly by

observing the vast array of impact craters they cause on the moon or on specially prepared surfaces flown and recovered from space or through telemetered data from other impact/penetration detectors. An insignificant number of them--somewhere in the billions--burn up as meteors during their entry trajectories in our earth's atmosphere every twenty-four hours. Some of the bigger of these, grain-of-sand size or larger, create spectacular displays for the nighttime watcher of the heavens who, by chance, is looking in the proper direction at just the right moment.

But, another way is required to study the vast majority of the interplanetary dust grains not in the vicinity of earth, moon or our spacecraft. That method uses sunlight reflected from each of the particles just as the other planets and moons in our solar system can be seen by the sunlight they reflect. Because of this, the interplanetary dust grains collectively act like a very low brightness source located over an extended region near the ecliptic plane. This is referred to as "zodiacal light" because it appears as a faint background of light lying in the constellations of the zodiac. Its brightness diminishes as an observer looks at ecliptic regions further and further from the sun. Even though zodiacal light is brightest close to the sun, this portion can only be seen by ground observers after evening twilight has almost disappeared or before morning twilight has reappeared. An artistic rendition has been included to show how it might appear to an astronaut in lunar orbit, if we could control the dark adaptation of his eyes and also selectively alter the light levels of objects in his field-of-view.

The concentrations of matter represented by the planets, their moons and the largest asteroids can influence and distort the smooth distribution of dust in the solar system. This effect was studied mathematically by Lagrange during the 18th century. The equations he used could be solved for a two-body system, but were too complicated for solution of three or more bodies. However, he realized that in the special case of a three-body system where one of the bodies contained at least 96% of all the mass, the equations could be restricted to solvable form--the "restricted 3-body problem." The results indicated five places called libration points in the orbital plane of the two larger bodies where a third, granule-sized mass would experience a directional change in the gravitational attraction. A set of figures is included to show this geometry.

The point marked L_2 is the unstable point between the two larger bodies where a small mass at relative rest would just balance, not knowing which way to fall. The L_1 point is also a precarious balance fully described in the S-178 experiment, Gengschein/Moulton Region, write-up; that description also applies to the L_3 point.

The L_4 and L_5 points are isolated minima of the gravitational force field so that relatively stationary particles near those positions would tend to stay there or move in tightly curved paths about those points as if trapped. In the sun-Jupiter system where the sun contains 99% of the mass we do, indeed, see over a dozen large bodies, the Trojan Asteroids, at these points and in orbit about the sun ahead and behind Jupiter. In the earth-moon system the mass ratio of the two bodies does not strictly obey the necessary conditions of Lagrange's restricted 3-body problem; however, this does not mean that L_4 and L_5 do not exist. It simply means these minima are very slight within the overall gravitational force field so that their power to trap particles is very weak. The probability for particles to collect is reduced to a possibility that particles may, at best, linger briefly.

The slightest perturbations could fling them away into orbits of either the earth or the moon. Such perturbations are frequently present due to the other planets and to the change in the sun's pull as both the earth and moon constantly vary their heliocentric distances.

Reports by earthbound observers cover a wide range--from being able to see the lunar libration points with the naked eye--to absolutely no indication of their presence through the most sensitive photometric instruments. However, all of these reports had to look through the earth's sheath of nighttime air-glow. Apollo 15 photography from the double umbra of the moon will not have to contend with this foreground veil of light.

CONTACTS FOR FURTHER INFORMATION

Preflight to Launch

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27 July to Splashdown

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or	Nassau Bay Motel, MSC Area	(713) 591-3000
L. Dunkelman		

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Illustration by artist Jinx Mercer for the Dudley Observatory shows zodiacal light as seen from the orbiting Command Module several minutes after the sun has set behind the moon while the seperated Lunar Module begins its descent to the lunar surface. Brightness of both the zodiacal light and earthshine on the lunar surface have purposely been enhanced by the artist compared with sunlight reflected from the Earth and Venus. Zodiacal light is sunlight reflected from the countless, small, dust-like particles orbiting the sun in the extended region of the ecliptic plane.

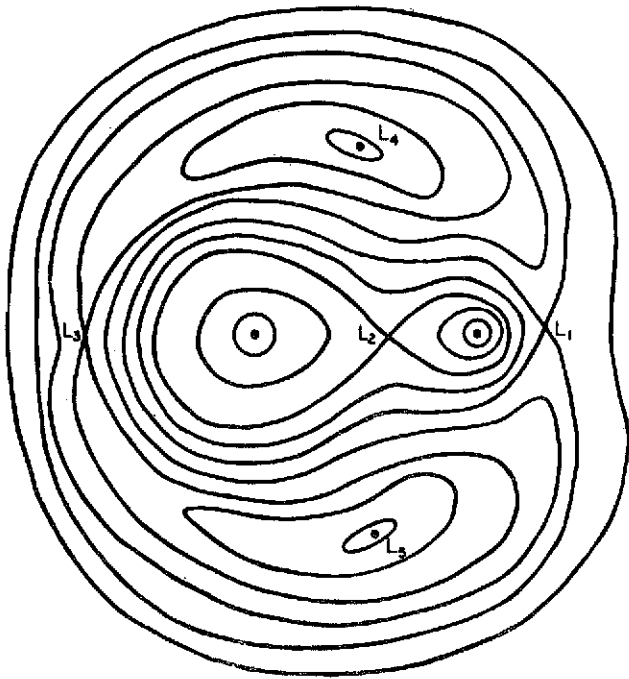


FIGURE 1

CONTOURS SHOWING COMBINED GRAVITATIONAL-ORBITAL FORCE FIELD ON A SMALL MASS NEAR TWO CELESTIAL BODIES, ONE OF WHICH IS VERY LARGE; "RESTRICTED 3-BODY PROBLEM" RESULT.

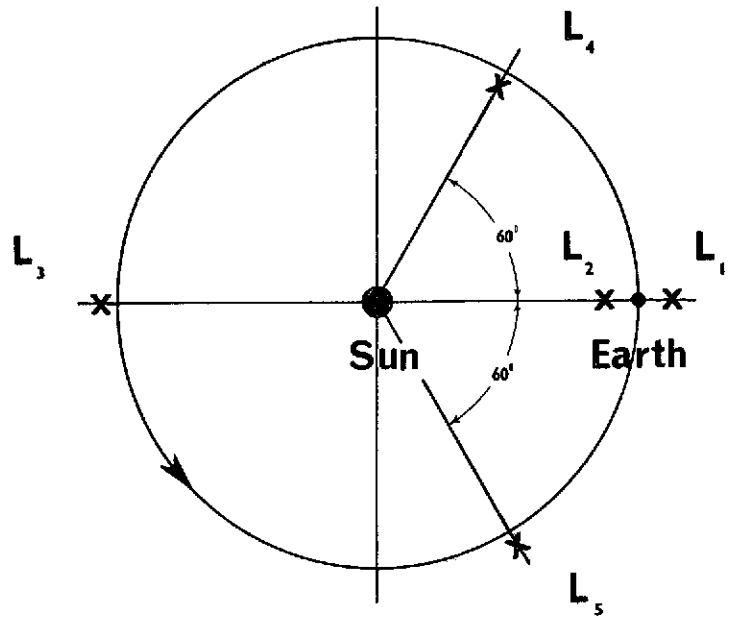


FIGURE 2

SUN-EARTH CELESTIAL REPRESENTATION WITH FIVE LAGRANGIAN POINTS INDICATED. THE L_4 AND L_5 POINTS MARK LIBRATION REGIONS WHERE INTERPLANETARY DUST MAY ACCUMULATE.

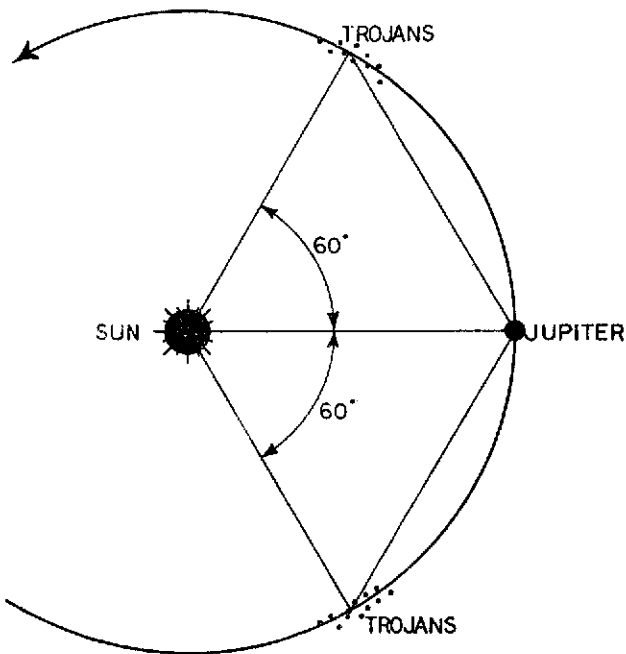


FIGURE 3

SUN-JUPITER SYSTEM'S REPRESENTATION WITH TROJAN ASTEROIDS NEAR LAGRANGIAN POINTS L_4 AND L_5 ORBITING BOTH SUN AND JUPITER.

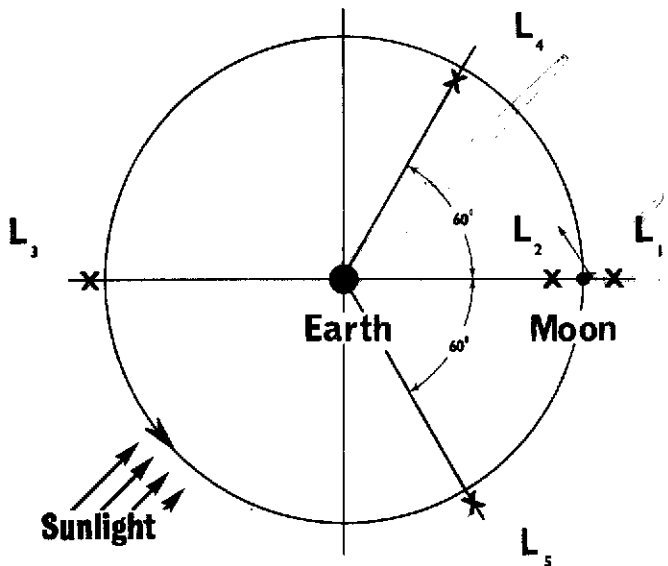
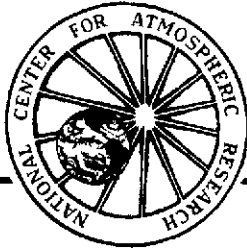


FIGURE 4

EARTH-MOON GEOMETRY ON APOLLO 15 SHOWING HOW L_4 REGION CAN BE PHOTOGRAPHED WHILE LUNAR ORBITING CSM IS IN DOUBLE UMBRA.

NCAR



Fact Sheet

July 1, 1971

APOLLO XV SOLAR CORONA PHOTOGRAPHY

According to solar astronomers, the greatest barrier to observing the sun's atmosphere clearly is the earth's atmosphere. To bypass this barrier, scientists of the National Aeronautics and Space Administration (NASA) and the High Altitude Observatory (HAO) of the National Center for Atmospheric Research (NCAR) have designed an observing program in which an Apollo XV astronaut will photograph the sun's "atmosphere," the solar corona, from lunar orbit, far beyond the ocean of air that surrounds our planet.

The solar corona, which is not really an atmosphere in the terrestrial sense, is the envelope of incandescent gas that surrounds the sun, extending far out into space and growing more tenuous as its distance from the sun increases. It is visible as an irregular halo around the sun during a total eclipse, when the moon comes between the sun and the earth. At other times, the flood of light from the face of the sun, about a million times as intense as the corona, makes the sky so bright that the corona cannot be observed with a regular telescope.

Observing the Solar Corona

Why would anyone want to observe the solar corona? According to scientists at the High Altitude Observatory of NCAR, better observations of the corona are needed to try to answer such fundamental questions about the sun as:

What is the connection between structures visible in the corona, the solar wind--the charged particles and electromagnetic radiation that stream out into space from the sun--and variations in the earth's magnetic field?

What is the three-dimensional structure of streamers--the structures that are visible, spreading out from the sun, during total solar eclipses?

-more-

How do magnetic fields at the sun's surface interact with the solar wind to mold the structure of the streamers?

Answers to these questions will be of immeasurable value in increasing man's understanding of the atmospheres of both the sun and earth, and of the subtle and complex interactions that occur between sun and earth.

Coronagraph Observations

For many years, solar astronomers could observe the corona only during total eclipses. But in 1930, a French astronomer named Bernard Lyot devised an "eclipse-making" telescope which he called the coronagraph. This instrument uses a round metal disc to block the bright image of the sun. A system of lenses and apertures reduces the scattered light that gets past the occulting disc. The coronagraph does not provide as clear a view of the corona as a natural eclipse, but it gives astronomers a way to observe day-to-day changes in the structure and behavior of the sun's atmosphere.

To operate effectively, a ground-based coronagraph must be used where the air above is thin, dry, and clear. Water vapor, dust, and even the molecules of air scatter the sunlight and reduce the ability of the coronagraph to provide a clear image of the corona.

The western hemisphere's first coronagraph station was established in 1940, ten years after Lyot proved that his invention would work. The site was near the little mining town of Climax, Colorado, in the southern Rocky Mountains at an elevation of more than 11,000 feet above sea level.

The Climax observing station, established by the Harvard College Observatory, grew into the High Altitude Observatory, which joined NCAR in 1961. The original Climax coronagraph has been replaced with a larger and more sophisticated instrument, but Climax is still the primary observing station for HAO scientists. Solar observations of the K-corona, the part of the corona that comes from light scattered by electrons, are made from a temporary station located near the summit of Mauna Loa, an intermittently active volcano on the island of Hawaii. These observations are made with

an electronic coronagraph known as the K-coronameter, or Koronameter.

But even the clear air over the Rockies and the Pacific Ocean is like a dirty windowpane between the astronomers and the solar corona. The Climax coronagraph can observe the corona out to a distance above the solar limb (the edge of the solar disc) of about 0.2 of the radius of the sun, and the Koronameter can trace the structure of the corona only to about one solar radius above the limb.

Satellite Observations of the Solar Corona

Under a program supported by NASA, HAO scientists and engineers are developing a satellite coronagraph which will be one of several solar observing instruments flown on the Apollo Telescope Mount (ATM) as part of the Skylab orbital laboratory program in 1973.

The observations from the Apollo XV missions, while not nearly so comprehensive or precise as those planned for the Skylab missions, should answer some important questions. For one thing, the timing of the Apollo observations will provide an opportunity to photograph the outer corona during a 50-degree rotation of the sun, providing new information on the three-dimensional structure of the corona. The Apollo observations also should provide some useful inputs for planning the observing program for the ATM Coronagraph.

The Apollo XV solar corona photographs will be made by the command module pilot from lunar orbit, while the other two Apollo XV astronauts are on the surface of the moon. He will use a 70-millimeter Hasselblad camera mounted on a bracket in the window of the module, which will be maneuvered to aim the camera properly. A 16-millimeter camera, operating automatically, will provide a backup system.

The moon will serve as an occulting disc to block off the light from the face of the sun. A series of photographs will be made as the sun begins to emerge from behind the moon, and another sequence will be made as the sun "sets" behind the moon. The first pair of sunrise/sunset sequences will be photographed on July 31, and a second pair on August 4. Each sequence will

consist of 14 photographs taken at intervals of about one frame per second.

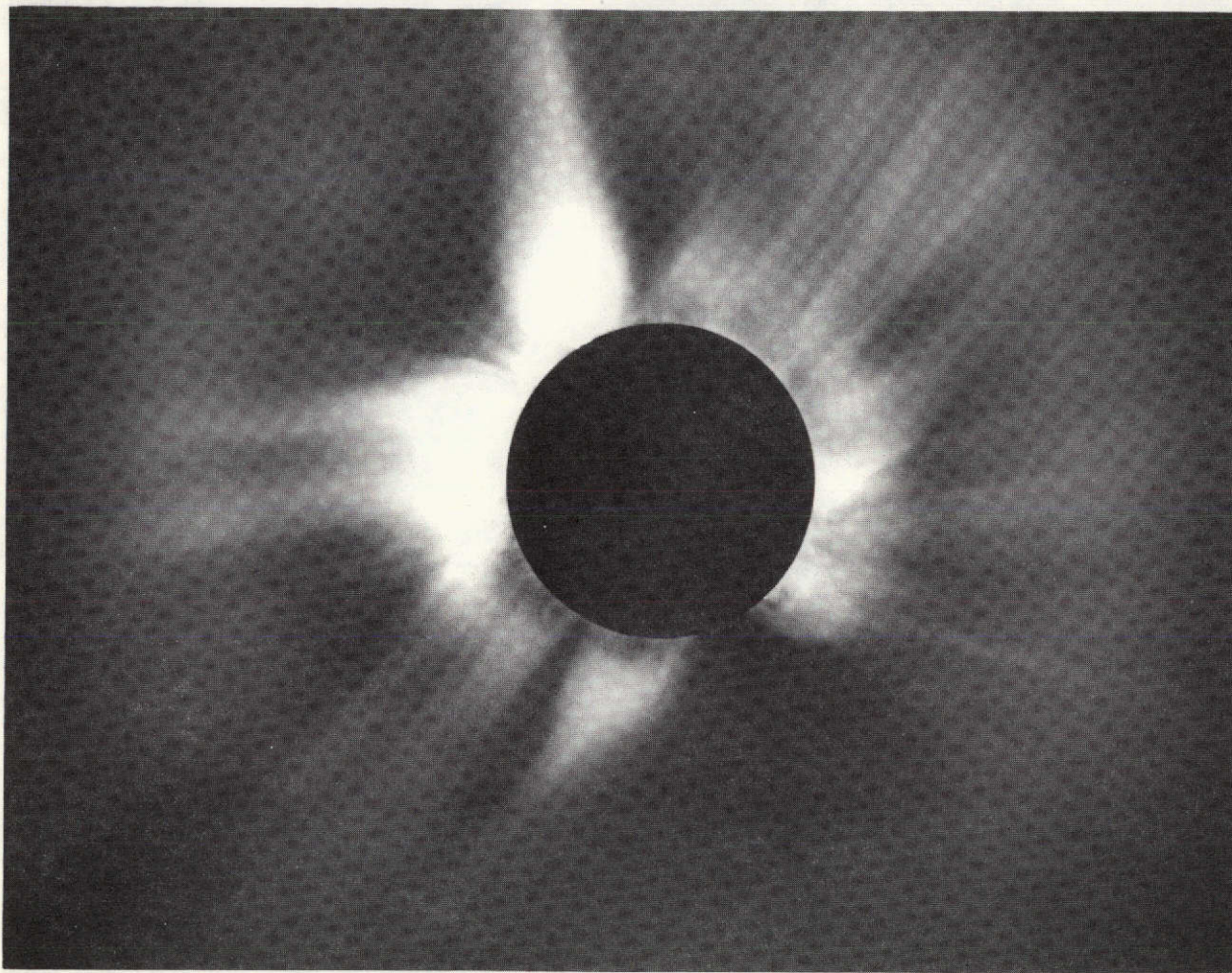
The Apollo XV solar corona observations are being made by an observer, instead of with automatic equipment, for two reasons. First, because the inner region of the corona is much brighter than the outer region, the exposure time must be changed between exposures to avoid underexposure or overexposure of the film. Also, the experience of the astronaut in making these observations should be useful to the Skylab astronauts who will make the ATM Coronagraph observations.

The Apollo XV solar corona observations are one of a number of "dim light" photographic tasks that are being performed during Apollo missions. They are being used to identify the extent, locations, configurations, and light levels of astronomical sources such as zodiacal light, galactic light, and lighting patterns on the earth's dark side. The solar corona observations and other dim light studies are very complex in the number and timing of camera settings intermixed with the appropriate vehicle attitudes and stabilization. The cost and weight of an automatic payload designed to accomplish these tasks without human manipulation would be prohibitive. An Apollo astronaut, using familiar photographic equipment with carefully planned procedures and appropriate ground support, can carry out the complicated tasks of dim light investigations in a comparatively simple and direct fashion, obtaining the necessary observations over a short period of time and at a fraction of the cost that would be required to make the observations with unmanned space vehicles.

The National Center for Atmospheric Research is operated under the sponsorship of the National Science Foundation by the University Corporation for Atmospheric Research, a nonprofit consortium of 31 universities.

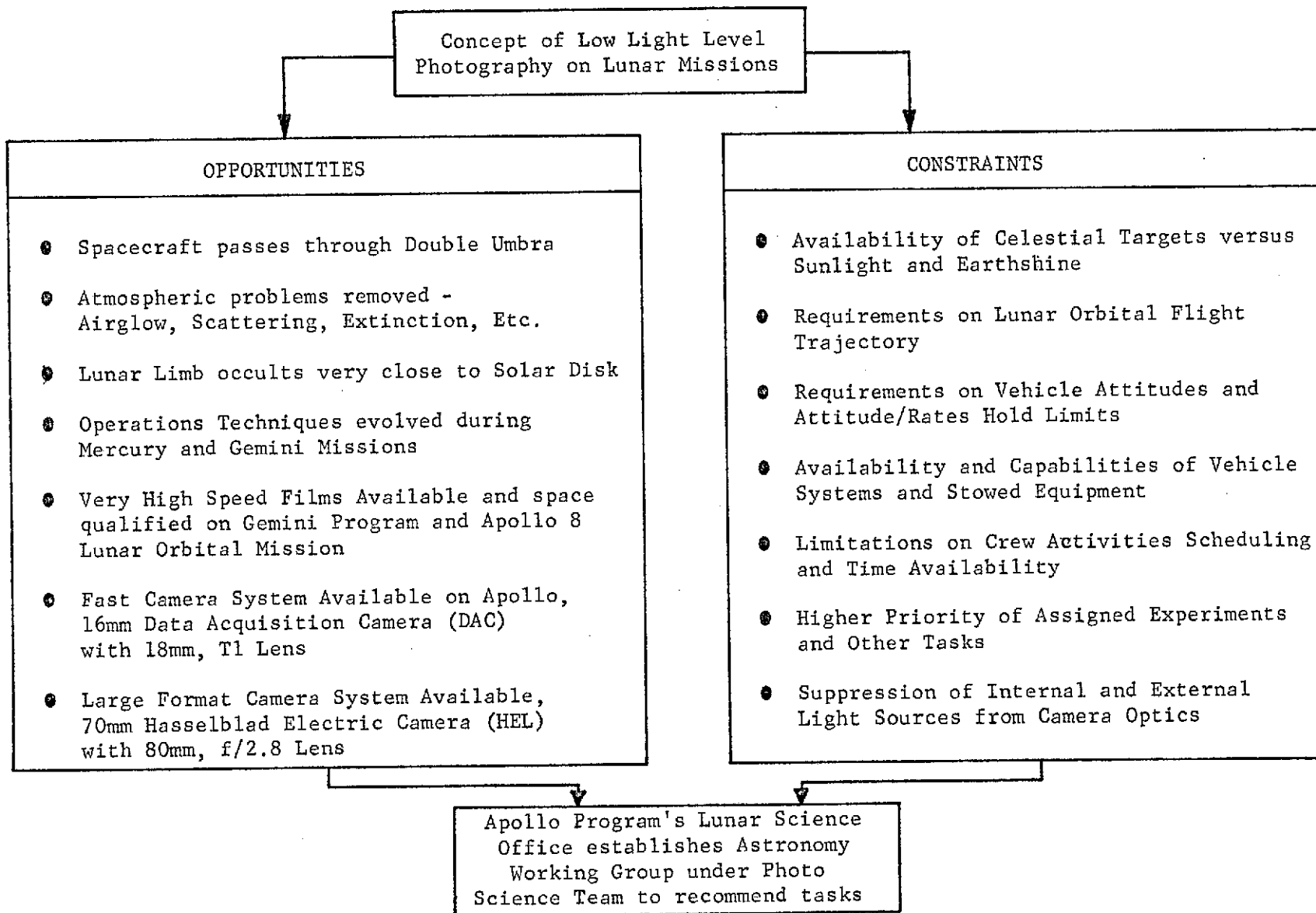
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The solar corona, photographed during the total solar eclipse on March 7, 1970. This photograph was made by Dr. Gordon A. Newkirk, Jr., director of the High Altitude Observatory of the National Center for Atmospheric Research. He used a radially graded, neutral density filter to compensate for the steep decline in brightness between the inner and outer portions of the corona. The result is a picture that shows structural features of the corona with great clarity out to a distance of about 4.5 solar radii from the solar limb.

APOLLO LOW LIGHT LEVEL PHOTOGRAPHY: BACKGROUND



APOLLO LOW LIGHT LEVEL PHOTOGRAPHY: SPECIFIC OBJECTIVES

- Solar Corona - Inner Coronal Structure, Morphology and Change in Appearance with Solar Rotation
- Zodiacal Light - White Light scattering by Interplanetary Dust to obtain information on Particle Sizes and their Large Scale Distribution in space
 - Polarized Component of White Light to obtain information on the Optical Properties and Types of Constituent Materials for the Particles
 - Red versus Blue Color Brightnesses to determine Local Distributions in Particle Sizes within the Large Spacial Distribution
- Galactic Light - Detection of Halo Extensions outward from Galaxies to observe Structure and to Measure Brightnesses
 - Studies of Interstellar Light from several regions in our Milky Way Galaxy
- Lunar Libration Region - Diffuse light scattered by the L_4 Earth-Moon Gravitational Holding Region which might contain a Cloud of Trapped Particles.
- Gum Nebula - Red Light emission of $H\alpha$ by Pulsar-Excited Hydrogen Gas Clouds versus Spacial Distribution of Blue Light Emission from Singly and Doubly Ionized Oxygen Clouds.
- Earth's Darkside - Lightning Pattern Distribution
 - Airglow Detectability
 - Aurorae Detectability
- Special Opportunities - Studies of Diffuse Cometary Brightness around Nucleus and of Gas and Dust Components in Comet's Tail
 - Eclipsed Moon's Disk Brightness and Color in Umbra due to Sunlight scattered by Earth's Atmosphere
 - Sun eclipsed by Earth to obtain Baseline Data on Planetary Atmospheres and eclipsed by Moon to obtain further information on Solar Corona

APOLLO LOW LIGHT LEVEL PHOTOGRAPHY: FLIGHT HISTORY

<u>Apollo No.</u>	<u>Additions/Changes for Tasks</u>	<u>Phenomena to be Observed</u>	<u>Results</u>
8	Several emulsion types carried for radiation effects studies.	(Film strips carried with calibration exposures only)	Successful results showed very high speed emulsions useable on lunar flights.
13	16 mm DAC magazines with 2485 film. Window shield to block cabin lighting from camera.	Comet Bennett Solar Corona east of Sun Zodiacal Light	Not Successful Not Attempted Not Attempted
14	Exposure times no longer than 20 sec. used to minimize image smear from undamped vehicle rates.	Zodiacal Light east of Sun along ecliptic Lunar Libration region, L ₄ Interstellar Light Survey of the Milky Way Earth's Darkside using Sextant S-IVB Photos using Sextant	Successful, but weak signal Not Successful Partially Successful Not Successful Not Successful
15	35 mm Nikon Camera (NK) with 55 mm, f/1.2 lens added to improve resolution versus 2485 grain size for S178. Exposure times increased up to several minutes. Film calibration improved.	Solar Corona east and west Zodiacal Light eastward Lunar Libration Region, L ₄ Lunar eclipse both in color and in 2485 Test for usefulness of sextant photography	Both Successful Successful Successful, results under study Both Successful Not Successful
16	Polaroid, Red and Blue filters for Nikon Camera	Solar Corona east and west Gum Nebula Zodiacal Light, Polarized Galactic Clusters in Virgo and Centaurus North Celestial Pole	Successful eastward only Partially Successful Not Successful Successful, but image smear limitations reached. Not Attempted
17	None	Solar Corona east and west Lunar Libration Region, L ₄ Zodiacal Light, Polarized and in Red and Blue passbands Galaxies M31 and M81	Not Attempted Not Attempted Successful in all three filters Not Attempted

LUNAR ORBITAL PHOTOGRAPHY OF ASTRONOMICAL PHENOMENA

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This paper reports further progress on photography of faint astronomical and geophysical phenomena accomplished during the recent Apollo missions. Through procedures developed by the Low Light Level Working Group of the Lunar Orbital Photographic Science Team, command module pilots have been able to photograph such astronomical objects as the solar corona, zodiacal light-corona transition region, lunar libration region (L_4), and portions of the Milky Way. The methods utilized for calibration of the film by adaptation of the High Altitude Observatory sensitometer are discussed. Kodak 2485 high-speed recording film was used in both 35mm and 70mm formats. The cameras used were Nikon f/1.2 55mm focal length and Hasselblad f/2.8 80mm focal length. Preflight and postflight calibration exposures covering a range of 10^{-9} to 10^{-14} solar surface luminance were included on both the flight and control films, corresponding to luminances extending from the inner solar corona to as faint as 1/10 of the luminance of the light of the night sky (~ 20 10th magnitude stars/square degree or 1.5×10^{-9} cd cm $^{-2}$). The photographs obtained from unique vantage points available during lunar orbit are discussed.

COSPAR 1.e
May 1972, Madrid

This paper reports on astronomical photography from the Apollo 15 Command Module as it orbited the moon in late July - early August, 1971. This work is a continuation of visual and photographic observations made from U.S. spacecraft over the last decade^{1,2,3}.

Apollo 15 tasks dealt with the low surface brightness sources difficult to study from the earth or even from low earth orbit. In general, these phenomena are associated with concentrations of interplanetary dust that derive their luminance from scattered sunlight. This includes solar F-corona, zodiacal light, lunar libration regions, Moulton region and Gegenschein. They lie in the ecliptic and, in some instances, are under the influence of the Lagrangian points associated with the restricted three-body problem involving earth-moon-particle or sun-earth-particle, as shown on the left in Figure 1. We can only report here on preliminary results from the F-corona and zodiacal light studies.

The lunar flight program provides a very unique and necessary vantage point free from sunlight and earthshine which we refer to as the double umbra. During the Apollo 15 mission the Command Module in low, lunar orbit was within this region from thirteen to twenty-eight minutes every two hours. This spacecraft-to-shadow geometry, as shown on the right in Figure 1, resulted from trajectory considerations to establish the optimum lighting at the Hadley-Apennine site during Lunar Module descent and landing. The great value of the double umbra is its access to a large part of the celestial scene from a totally dark region undisturbed even by light from the earth's airglow. In addition, the lunar limb, with no intervening atmosphere, provides a sharp-edged occulter

for radially dissecting the different light levels within the inner zodiacal light and outer solar corona.

On the other hand, the operation of spacecraft systems supporting these observing programs can also restrict the usefulness of the double umbra unless special care is taken in the preflight planning. It is important for us to note these considerations, because they illustrate important details on how our experimental procedures are coordinated with vehicle operations.

The preflight development of experimental task checklists, the refinement of these procedures, and careful training thereto were absolutely required. Particularly so when very close timing was required on a series of manipulations, or when vehicle pointing had to be quite precise with the lowest possible residual drift in rates. For instance, the individual timing and shutter speeds for every photograph in both the solar corona and the zodiacal light series were carefully designed to achieve the most useful exposure density on the film as the occulted sun moved towards the sunrise limb or away from the sunset limb at the spacecraft's orbital rate of three degrees per minute. An improper starting time, either too early or too late, would have resulted in underexposed or overexposed values for the entire series; an extension or compression of the times between sequential frames would have been detrimental to a portion of the series.

In the case of fixed celestial pointing at the lowest brightness objects, a moderate exposure of one minute and along exposure of three or four minutes were used. The shorter exposure obtained photometric

data on brightness regions that were burned out on the longer exposures, and they also suffered less from residual rates of attitude changes. The longer exposures recorded the faintest portions, and they were necessarily preceded by five minutes of rate damping to minimize drifts in attitude prior to deactivating all thrusters while the camera shutter was open. Even when in orbital rate attitude control for the corona and zodiacal light photography, in order to hold the occulting lunar limb at a relatively fixed position on the photographic image, the forward firing thrusters were shut down to avoid stray light directly from their plumes or indirectly scattered from any local cloud of particles surrounding the vehicle.

Finally, strict precautions were taken to keep internally reflected, cabin lighting from the window and camera lens systems. For pressure integrity the spacecraft windows are composed of three separate panes of glass. The smallest amount of light in this vicinity undergoes a multitude of reflections and scattering that are impossible to keep from an unshielded camera line-of-sight. The alternative of totally darkening the cabin is not operationally possible, because the crewman cannot monitor warning and alarm indicators vital to the safety of his flight; nor can he read the computer driven, lighted, digital clock display to time the start and duration of each photographic exposure. Lack of some small amount of cabin lighting further interferes with his ability to check camera settings and to log supporting data on operational anomalies important in the final data analyses.

To cope with this, a light-tight window shield with lens port and

drawstring fabric sleeve was installed in the window before attaching the camera and its bracket. The sleeve was closed snugly around the lens body so that window glass and camera objective were isolated from internal lighting, but allowing the crewman to make the necessary shutter speed selections. This added extra complexity to the experiment preparations, however.

All of these difficulties with low light level photography caused astronaut Stuart Roosa, the Apollo 14 Command Module pilot, to remark that these tasks were the most difficult of all of the photography he had to perform⁴. For these same reasons we cannot overemphasize the necessity for close coordination between the investigating scientists, equipment engineers, flight and procedures planners, and the astronauts in order to achieve even modest success on manned space flights.

A modified 70mm Hasselblad Electric camera with 80mm, f/2.8 lens was the primary system used on the relatively bright outer corona where large format was important. A modified 35mm Nikon camera with 55 mm, f/1.2 lens was used on the remaining tasks. Both camera utilized Kodak 2485, high speed recording film.

Photometric calibration was accomplished on the flight film using a sensitometer developed by the High Altitude Observatory⁵. It uses a voltage regulated lamp monitored by a photo-resistive cell. The light is diffused by an opal to illuminate a step wedge uniformly. A filter color-corrects the image to match the solar output. The box is calibrated against a set of modified opals by photographing the sensitometer box step wedge on the same strip of film as a series of exposures taken of

the sun through the modified opals. The fourteen steps of the sensitometer box wedge on 2485 film using the f/2.8 Hasselblad range in solar luminance from 2.82×10^{-9} to 1.78×10^{-11} .

By introducing a 3.0 neutral density filter between the diffusing opal and the step wedge, this calibration range is extended downward from 10^{-11} to 10^{-14} of the sun's surface brightness in the case of the Nikon operated at f/1.2. Thus, the total range covers levels corresponding to the inner corona down to about one-tenth that of a moonless, night sky as seen by an earthbound observer.

A preliminary measurement from a four minute exposure of a faint region in the Milky Way, two hundredths of a density unit above emulsion background, gives a reading of 7×10^{-15} of the sun's surface brightness. This is equivalent to the light from twenty, tenth magnitude stars per square degree or 1.5×10^{-9} candella per square centimeter. A comparative list of typical phenomena luminances is given in Table 1.

Exposures were spaced ten seconds apart in the solar corona sequence and proceeded from seventy to ten seconds prior (subsequent) to apparent sunrise (sunset). Image scale is 0.72 degrees per millimeter. One exposure in a series of seven sunrise photographs taken on 31 July 1971 shows four or five streamers extending beyond twenty solar radii from the central portion of the eastern solar limb. From the original negatives and optimum printing, streamers have been traced to well beyond thirty solar radii, and they appear to have curvature towards the north solar pole. These outer coronal streamers can be correlated with inner coronal activity observed from Hawaii at almost the same time

by the High Altitude Observatory's K-coronameter as shown in Figure 2. This instrument recorded a broad, bright feature at a polar angle of 100 degrees east. Using the assumption that the magnetic field lines define the path of the solar wind material, we can apply these data as boundary conditions on the model of a co-rotating solar magnetic field.

Sunset coronal photographs of the western solar limb again show streamers to twenty solar radii, and one of these is visible on the original negative to the apparent position of Venus, eight degrees from the sun's center. K-coronameter features at forty degrees west polar angle and at mid-latitudes on the west limb are measureable to one-and-a-half solar radii. They, too, underlie the streamers recorded on the Apollo 15 photography. This work, previously reported in greater depth⁶, provides the furthest distances that man has recorded photometric data on solar activity.

Two other photographs, one from a sunrise series and one from the sunset series, having about a ten-second shutter speed are shown in Figure 3. They provide exceptionally good observations of the transition region where one ceases to refer to F-corona and normally calls the phenomenon zodiacal light. It has never been possible to observe this region from earth or earth orbit because of atmospheric twilight. Both photographs were taken about one minute from the moment of solar occultation; therefore, the sun is about three degrees below the horizon in each case. The merged region of corona and zodiacal light is seen to an ecliptic elongation of at least twenty degrees. The sunset corona shows a lunar mare in earthshine with a large crater and highland peaks well defined.

The zodiacal light is clearly seen in the four views of Figure 4. They were taken from the series of twenty-three photographs made as the spacecraft approached the sun from the east. The lunar limb at lower right occults the sun approximately twenty-five degrees away in the upper two photographs and fifteen degrees away in the lower two photographs. Frame centers are an additional twenty degrees eastward along the ecliptic. The exposure times from upper left to lower right were twenty, sixty, ten and thirty seconds. These photographs will be further processed to remove lens vignetting, image smear and starlight in order to obtain final photometric information on the phenomenon.

Acknowledgements

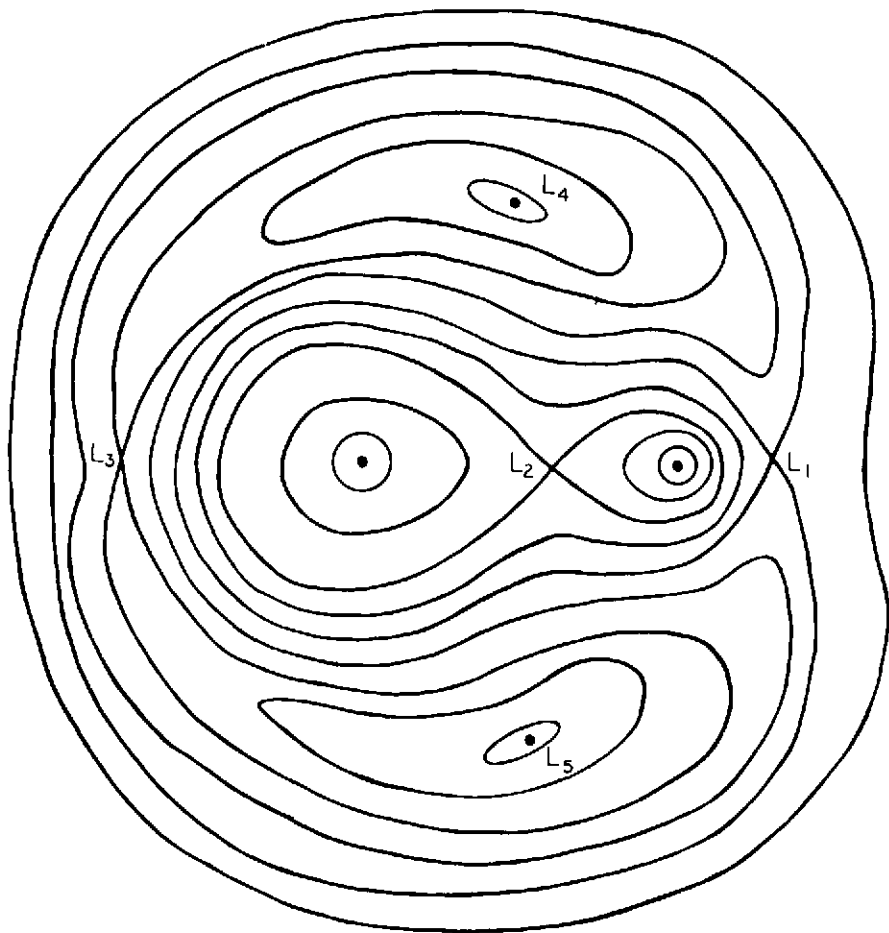
This work was made possible through the auspices of the Lunar Orbital Science Office of the Apollo Program Director, NASA Headquarters, which sponsors the Lunar Orbital Science Photographic Team. The Low-Light Level Working Group comes under that team. We are particularly appreciative of the individual efforts by people too numerous to name in the Apollo Program Office and the Divisions of Science Mission Support, Flight Crew Integration, Crew Procedures and Photographic Technology at the NASA Manned Spacecraft Center.

References

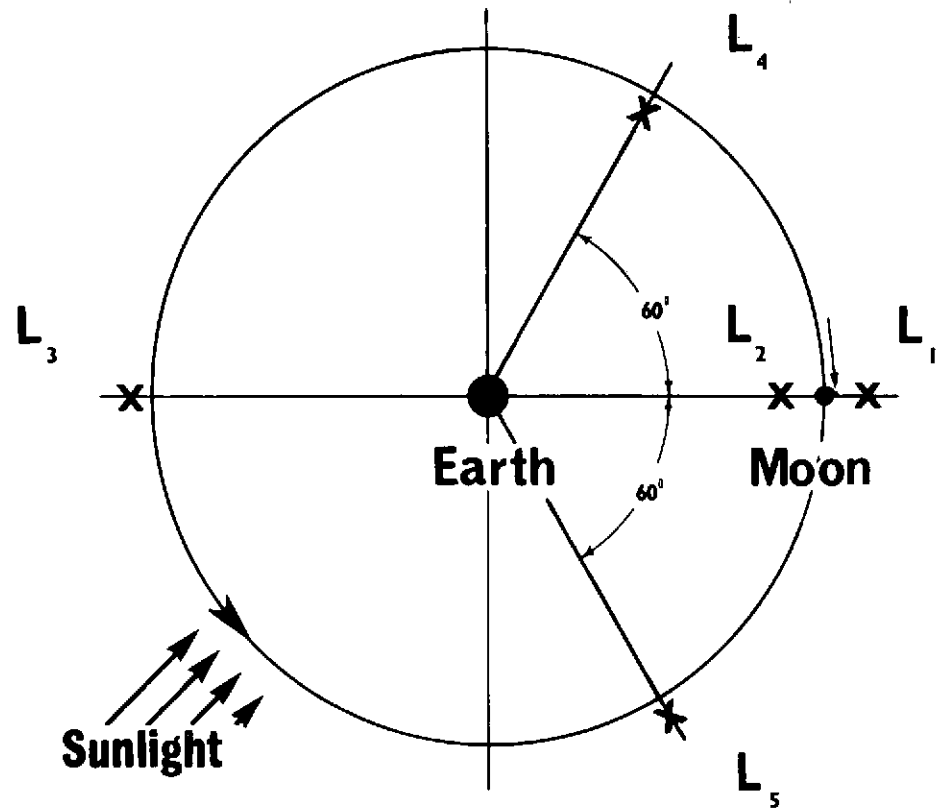
1. L. Dunkelman, J. A. O'Keefe, S. D. Soules, W. F. Huck, and P. D. Lowman, Jr., Mercury Project Summary (NASA SP-45, U. S. Government Printing Office), Chapter 19, 1963.
2. F. E. Roach, L. Dunkelman, J. R. Gill and R. D. Mercer, Gemini Midprogram Conference (NASA SP -121, U. S. Government Printing Office), Chapter 32, 315, 1966.
3. W.S. Cameron, L. Dunkelman, J.R. Gill, and P.D. Lowman, Jr., Man in Space, Introduction to Space Science, Chapter 14, Gordon and Buach, 1968.
4. R. D. Mercer, L. Dunkelman, and S. A. Roosa, Apollo 14 Preliminary Science Report (NASA SP-272, U. S. Government Printing Office), Part H, Section 18, 1971
5. V. Pizzo and J. T. Gosling, AAS Photo Bulletin, No. 1, 19, 1972.
6. R. M. McQueen, C. L. Ross, R. T. Hansen, A. Dollfus, Z. Mouradian, and A. Worden, AAS Solar Physics Division Meeting, College Park, Maryland (USA), April 1972.

Phenomenon	B/B_{\odot}	Luminance (Stilbs) Cd cm^{-2}
Sun	1	2.2×10^5
Sunlit Earth	8.5×10^{-6}	1.8
Full Moon	2.4×10^{-6}	5×10^{-1}
Solar Corona at 2 Ro	2.4×10^{-8}	5×10^{-3}
Total Eclipse Zenith Sky (at sea level) Also Solar Corona at 8 Ro	2.8×10^{-10}	6×10^{-5}
Zodiacal light 20° Elongation	3×10^{-12}	5×10^{-7}
Brightest Milky Way Also Zodiacal at 33° Elongation	5.5×10^{-13}	1.1×10^{-7}
Continuum Airglow Zenith	2×10^{-14}	4.2×10^{-9}
Threshold Apollo 15 Photography with Nikon f/1.2 at 4 min Kodak 2485 Film	7×10^{-15}	1.5×10^{-9}

Table 1



RESTRICTED THREE-BODY PROBLEM FORCE
FIELD CONTOURS ON SMALL MASS



APOLLO 15 EARTH-MOON GEOMETRY
SHOWING THE SUNLIGHTING AND
REGION OF DOUBLE UMBRA

Figure 1

Figure 2

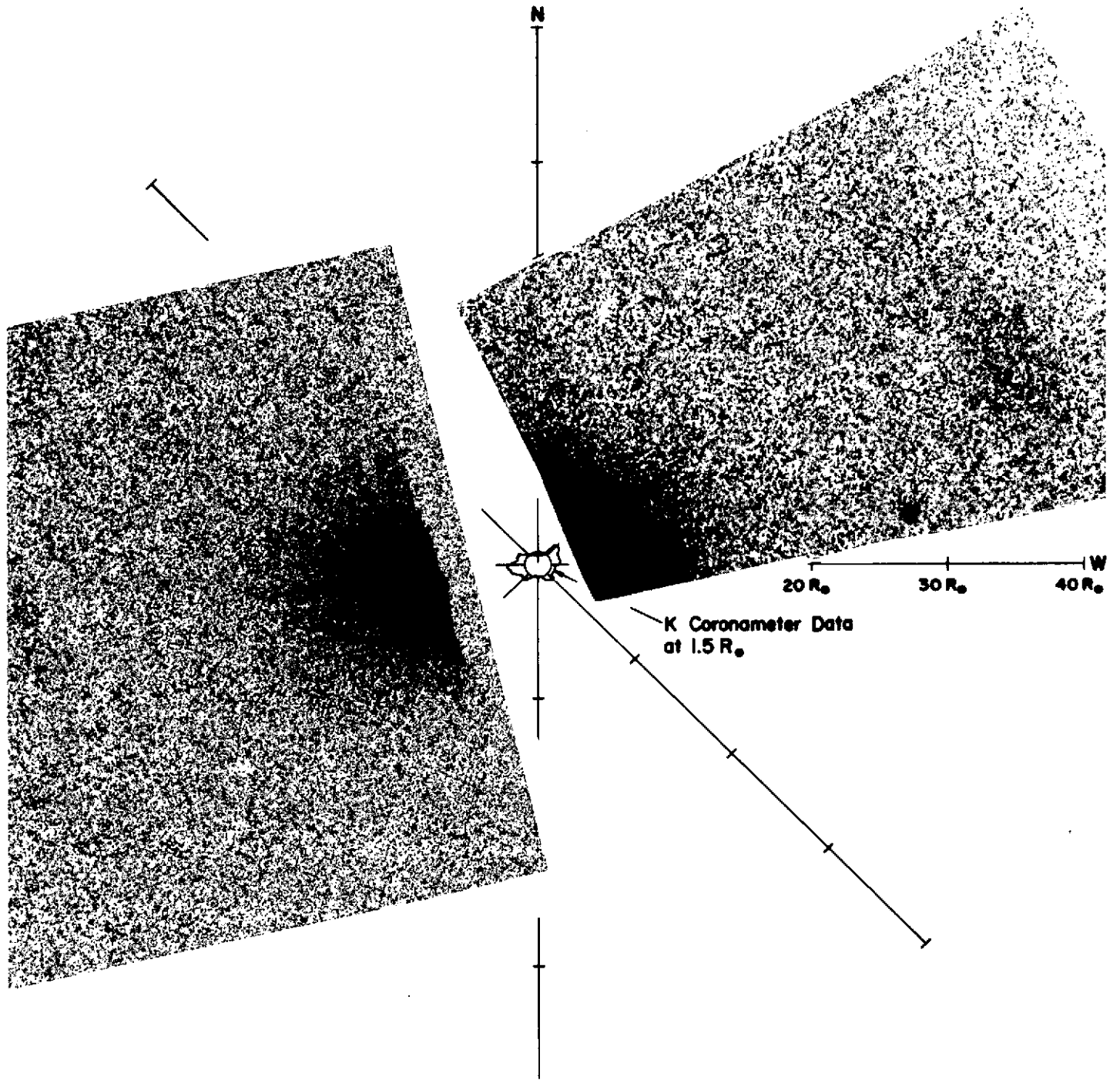


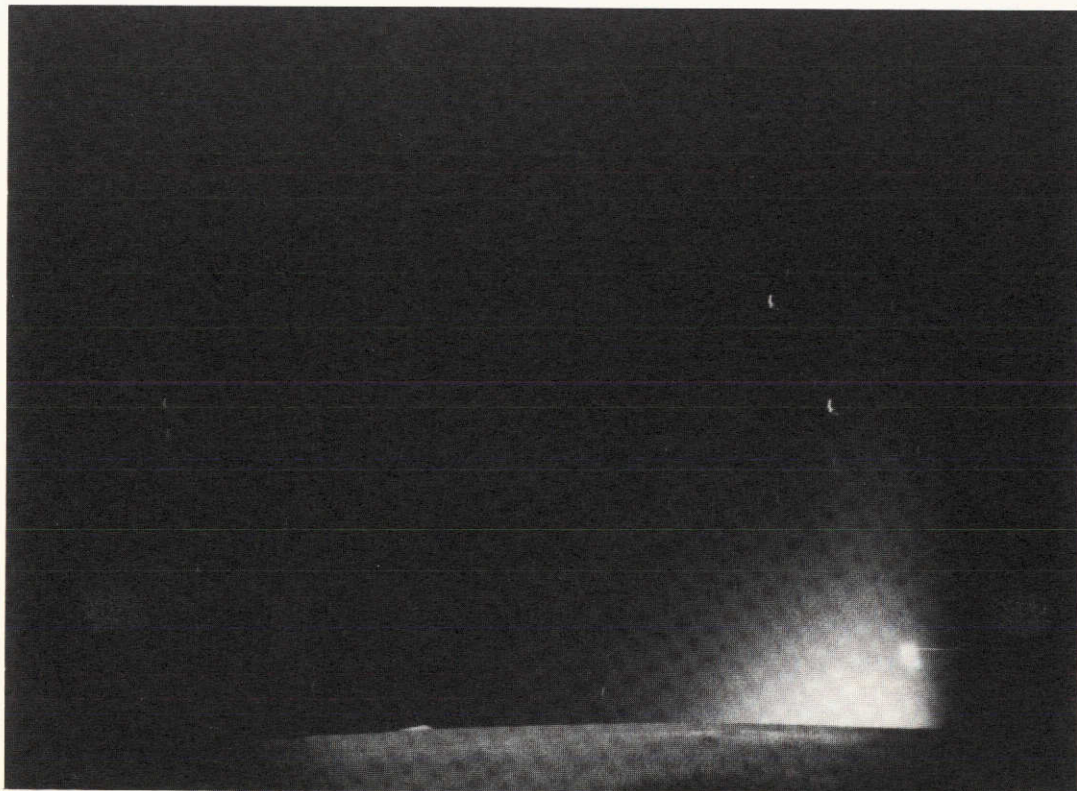
Figure 3

APOLLO 15 SOLAR CORONA PHOTOGRAPHY

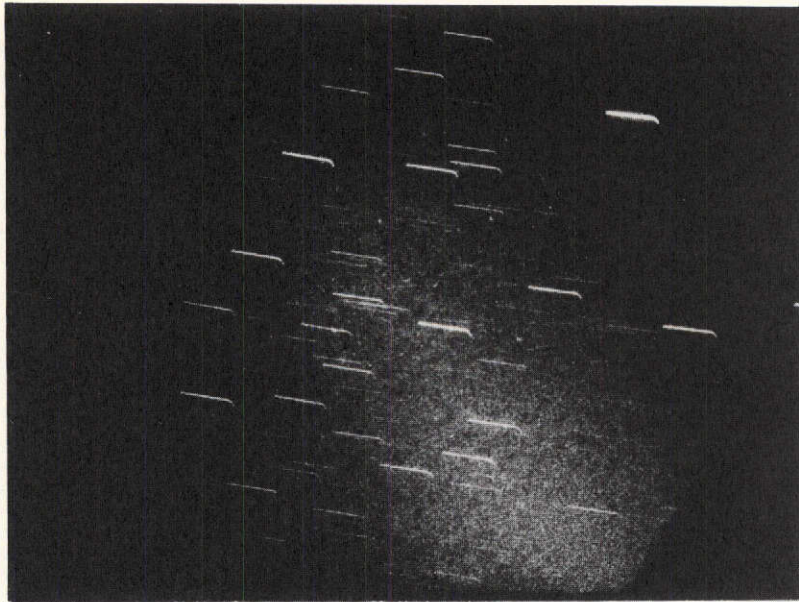
70mm Hasselblad Electric Camera, 80mm fl lens, f/2.8, Kodak 2485 film



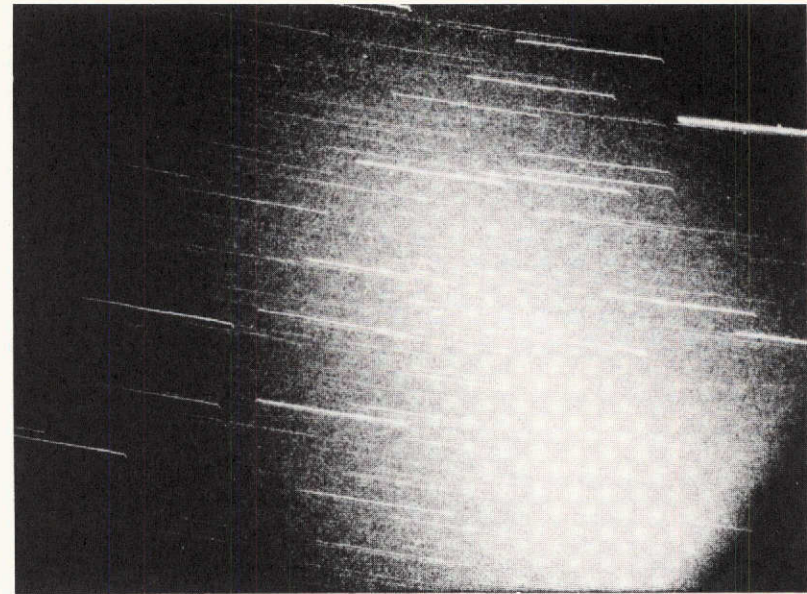
Sunrise F-corona extends 20° above lunar limb with Sun 3° below. Mercury at top is 28° from sun with Regulus directly below.



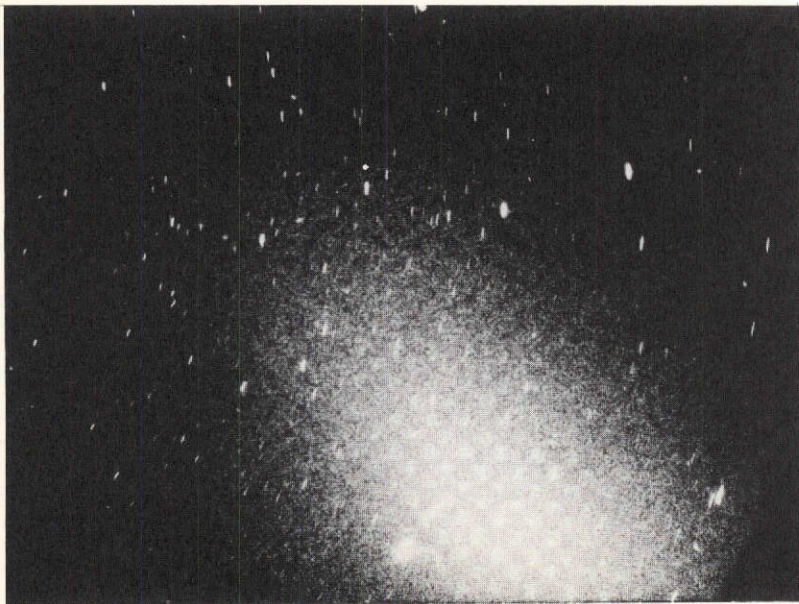
Sunset F-corona extends along ecliptic toward Pollux and Castor. Venus appears as bright object on right. Earthshine illuminates lunar mare showing large crater and highland peaks on horizon.



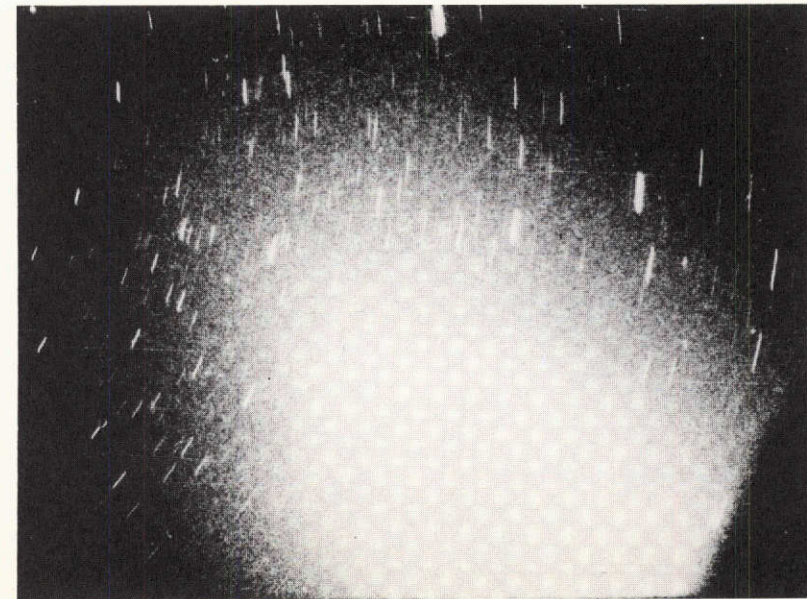
20 sec exposure along ecliptic 45° from sun;
dark lunar limb in lower right 25° from sun.



60 sec exposure along ecliptic 45° from sun;
dark lunar limb in lower right 25° from sun.



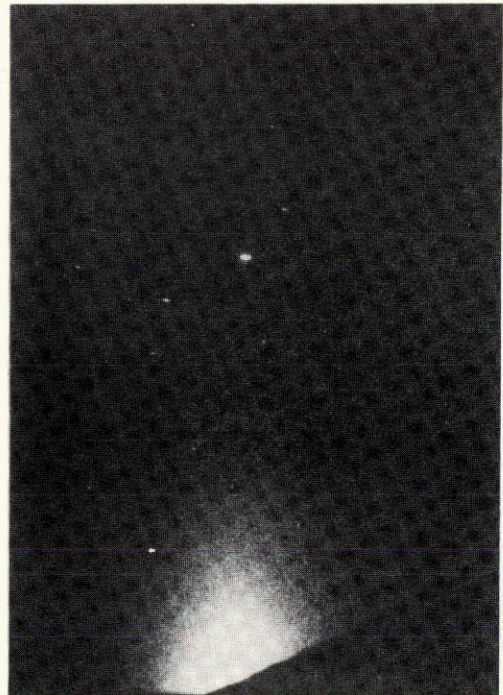
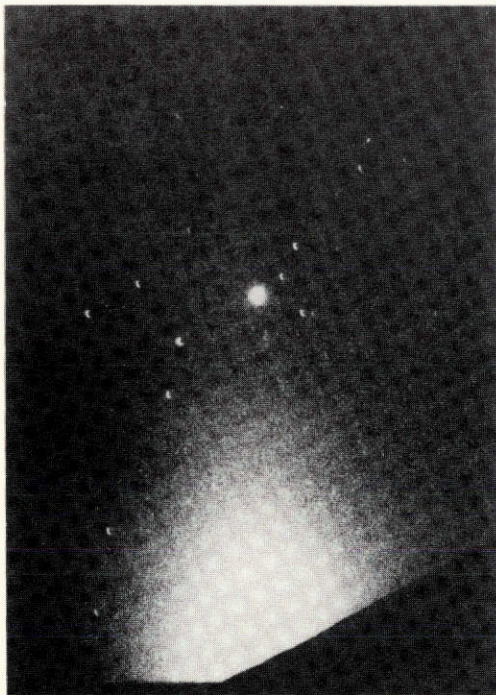
10 sec exposure along ecliptic 35° from sun;
dark lunar limb in lower right 15° from sun.



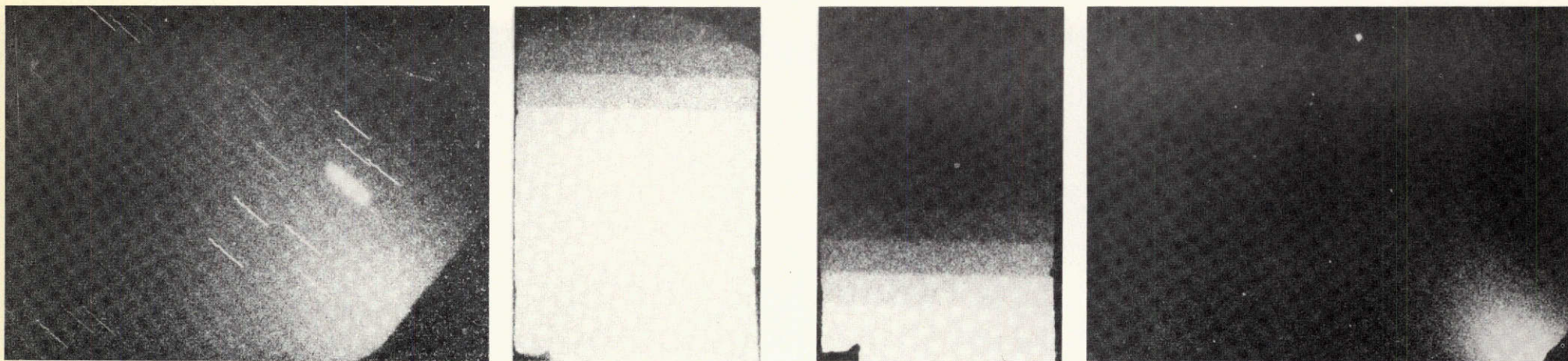
30 sec exposure along ecliptic 35° from sun;
dark lunar limb in lower right 15° from sun.



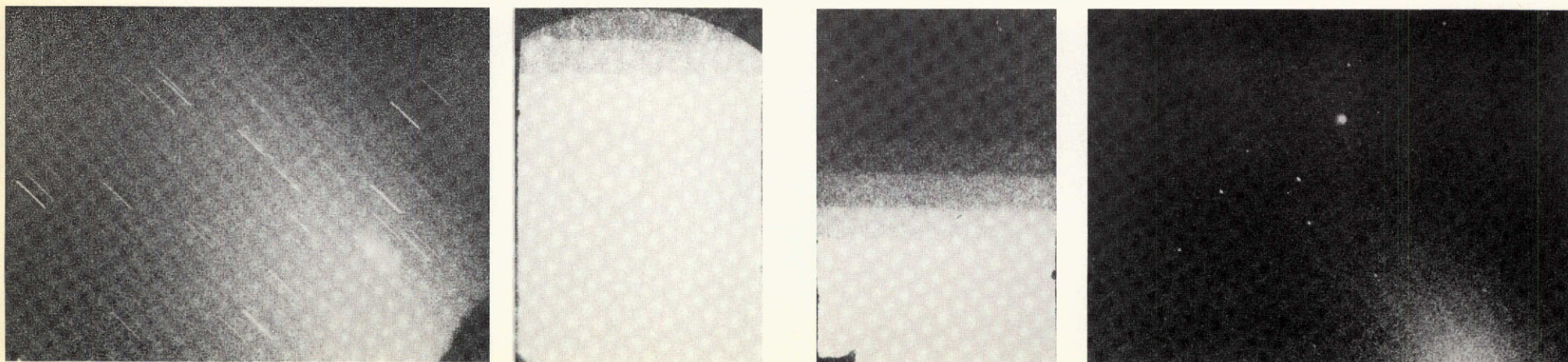
Solar corona and zodiacal light sketched by Commander Cernan as it appeared visually from lunar orbit two minutes and again at one minute prior to sunrise.



Photographs of outer corona and inner zodiacal light in plane-polarized, white light using the 35mm Nikon camera, 55mm lens set at f/1.2 and Kodak 2485 high-speed recording film. Exposures of 5-seconds on left and 1-second on right were taken at two minutes and at seventy seconds prior to sunrise.



Red ($\sim 620-700$ nm) zodiacal light scenes located eastward on ecliptic with corresponding calibration wedges. 40 sec. exposure on left is centered at 35° elongation, with sun 15° below lunar limb at lower right corner; 2 sec. exposure on right centered at 25° elongation with sun 3.5° below lunar limb (AS17-159-23908 & 23912).



Blue ($\sim 420-510$ nm) zodiacal light scenes located eastward on ecliptic with corresponding calibration wedges. 40 sec. exposure on left is centered at 35° elongation, with sun 15° below lunar limb at lower right corner; 2 sec. exposure on right centered at 25° elongation with sun 3.5° below lunar limb (AS17-159-23937 & 23941).

CSM LOW LIGHT LEVEL ASTRONOMY

Obtain photographs of low brightness astronomical sources.

Purpose

The purpose is to obtain high-speed, black and white photographs of low brightness astronomical sources.

The functional test objectives are as follows:

- FTO 1) Obtain photographs of diffuse galactic light of four celestial subjects.
- FTO 2) Obtain photographs of zodiacal light as the CSM approaches sunrise.
- FTO 3) Obtain photographs of solar corona after CSM sunset and prior to CSM sunrise.
- FTO 4) Obtain photographs of the lunar libration region, L_4 .
- FTO 5) Obtain photographs through the CM sextant of the earth's darkside.
- FTO 6) Obtain earth limb photographs during solar eclipse by the earth; and comet photography, if appropriate trajectory and celestial conditions exist.

Test Conditions

- FTO 1) Accomplishment of all test objectives will require two (2)
 - FTO 2) Data Acquisition Camera (DAC) magazines and one (1) Hasselblad
 - FTO 3) magazine, all containing Type 2485 film. Each magazine will
 - FTO 4) have a set of special low light level calibration exposures
 - FTO 5) along with the standard calibrations performed pre- and post-
 - FTO 6) flight. Control film strips are required from the flight film stock for similar calibrations, for assessment of best development processing and for analysis of emulsion base fog levels.
-
- FTO 1) Internal spacecraft lighting above 3×10^{-14} of the sun's surface brightness ($= 2 \times 10^{-9}$ lamberts) will be excluded from the camera's field-of-view. Consequently, a camera hood or a dark cabin with window shades will be used. Forward firing thrusters must not be actuated while the camera shutter is open, and in
 - FTO 2)
 - FTO 4) FTO 1) all thrusters will be off. Photographs will be taken from lunar orbit when both sun and earth are below the horizon.

These tasks will use the 16 mm DAC system mounted in the appropriate CM window with mode selector on "Time" and with shutter speed and operation button actuations as specified below. The 18 mm lens will be attached with aperture set to "T1" and focus at infinity. About a foot of "protective" film will be advanced through the magazine just prior to and just after each series of sequential exposures in order to insure that inadvertent exposures to high brightness will not fog data frames. CSM attitude deadbands will be maintained within ± 0.5 for FTO 1) and FTO 4).

FTO 3) Internal lighting above 3×10^{-12} of the sun's surface brightness
 FTO 5) ($= 2 \times 10^{-7}$ lamberts) will be excluded from the cameras field of
 FTO 6) view by means of hood systems or a dark cabin with window shades. It is desirable that forward firing thrusters not be used if the required attitudes can be maintained without them. All three of these tasks will require the 16 mm DAC system with protective film advance and calibration data specified above. The 18 mm lens will be attached with aperture set to "T1" and focus at infinity. In addition, FTO 3) and FTO 6) will require the 70 mm Electric Hasselblad with the 80 mm lens using the technique of protective film advance of 3 frames just before and after a photographic series for data collection. CSM attitude deadbands will be maintained within $\pm 0.5^\circ$.

FTO 1) Twelve galactic survey photographs will be obtained. Each of four points on the celestial sphere will be photographed three times. These photographs will have 20-second exposures for the first two photographs of a celestial target, followed by one 5-second exposure. These exposure times will be repeated for each of the four celestial targets. CSM attitude will be allowed to settle down automatically for five minutes after each target acquisition. If the spacecraft attitude rates exceed $0.2^\circ/\text{sec}$. in any axis, it is highly desirable that an additional 60 seconds of automatic rate damping be performed and a second set of photographs be taken of that same target. During exposures all attitude thrusters will be disabled. The aiming points will be as follows:

<u>Celestial Subject</u>	<u>Right Ascension</u>	<u>Declination</u>
North Galactic Pole	$12^{\text{h}} 40^{\text{m}}$	$+28.0^\circ$
North Ecliptic Pole	$18^{\text{h}} 0^{\text{m}}$	$+66.5^\circ$
North Celestial Pole	-	$+90.0^\circ$
Northernmost Milky Way	$0^{\text{h}} 40^{\text{m}}$	$+60.0^\circ$

FTO 2) A series of 25 photographs will be taken as the CSM approaches sunrise. At the beginning of the series when the zodiacal light levels are lowest, sets of three time exposures taken one after the other will be used to bracket the expected light

levels. Near sunrise the automatic exposure duration provided by the shutter speed selector will be used to compensate for the rapidly increasing light levels. The CSM attitude will be matched to the lunar orbital rate ($\approx 3^\circ/\text{min}$) to hold the X-axis aligned near to the forward-looking local horizontal such that approximately one-eighth of the camera's field-of-view is fixed on the lunar surface. The CSM will be pitched at the orbital rate and the CSM attitude deadband will be maintained within $\pm 5.0^\circ$. Times for initiation of each exposure set and their durations are as follows:

<u>Time from CSM Sunrise</u> <u>(Min:Sec)</u>	<u>Exposure Durations</u> <u>(Sec)</u>
-25:00	20, 10, 5
-21:40	20, 10, 5
-18:20	16, 8, 4
-15:00	16, 8, 4
-11:40	8, 4, 2
- 8:20	8, 4, 2
- 5:00	4, 2, 1
- 1:00	1/60
- 0:45	1/125
- 0:30	1/250
- 0:15	1/500

FTO 3) Two series of solar corona photographs will be made: one after CSM sunset and one prior to CSM sunrise. Each series will consist of seven Electric Hasselblad photographs with the 80 mm lens set at f/2.8 and infinity, and approximately 180 DAC frames with the camera running at one frame per second (fps). For the sunrise series of photographs, the CSM attitude will be matched to the lunar orbital rate ($\approx 3^\circ/\text{min}$) to hold the X-axis aligned near to the forward-looking local horizontal such that approximately one-eighth of the camera's field-of-view is fixed on the lunar surface.

The CSM will be pitched at the orbital rate and the CSM attitude deadbands will be maintained within $\pm 5.0^\circ$. For the sunset series of photographs, attitude and rates will be as specified above, except that the X-axis will be pointing approximately backward along the trajectory line of travel. Data Acquisition Camera exposure periods and shutter speeds are as follows:

<u>Time From CSM Sunset (Sec)</u>	<u>DAC Shutter ON/OFF Speeds</u>	<u>Time Prior to CSM Sunrise (Sec)</u>	<u>DAC Shutter ON/OFF Speeds</u>
0 to 80	ON 1/500	-180 to -80	ON 1/125
80 to 180	ON 1/125	- 80 to 0	ON 1/500
180	OFF -	0	OFF -

Exposure periods and shutter speeds for the Electric Hasselblad Camera are as follows:

<u>Time From CSM Sunset (Sec)</u>	<u>Time Prior To CSM Sunrise (Sec)</u>	<u>Electric Hasselblad Exposure Occurrence & Shutter Speeds</u>
0	0	-
10	-10	1/125
20	-20	1/60
30	-30	1/30
40	-40	1/15
50	-50	1/8
60	-60	1/4
70	-70	1.0

- FTO 4) A series of four photographs will be made of the lunar libration region, L_4 . Exposure times will be one at 60 seconds, two each at 20 seconds, and the last at 5 seconds. The libration point will be located at $10^h 10^m$ right ascension and $+10^\circ$ declination. CSM inertial attitude will be maintained within $\pm 0.5^\circ$.
- FTO 5) Two series of time exposure darkside earth photographs will be attempted with the DAC connected by optical adapter to the CM sextant optics. Each series will consist of three photographs sequentially in time at 60 seconds, 20 seconds, and 5 seconds exposure durations. The first series of photographs will be obtained during translunar flight near the mid-distance point when spacecraft rotation for Passive Thermal Control is not scheduled. Vehicle attitude and sextant shaft and trunnion angles will be selected to shadow the optics from direct or reflected sunlight. Camera pointing through the CSM sextant optics shall be stationary at some point on the dark portion, and arranged so that earth terminator will not drift into the field-of-view during the exposure periods. CSM attitude deadbands will be maintained within $\pm 0.5^\circ$. The second series of photographs will be obtained under the same conditions during transearth flight.

FTO 6) If the CSM transearth trajectory passes through the earth's umbra, two series of Electric Hasselblad and DAC photographs will be taken. The first series will begin when the sun appears to set and the second series will begin three minutes prior to computed sunrise. Photography requirements consist of seven Electric Hasselblad photographs with the 80 mm lens set at f/2.8 and infinity, and approximately 180 DAC frames with the camera running at 1 fps.

If a comet is in favorable celestial position, time exposure DAC photographs through the sextant will be obtained. Three photographs, sequentially in time at 60 seconds, 20 seconds, and 5 seconds exposure duration are required. In addition, window mounted DAC and Electric Hasselblad photographs will be attempted from lunar orbit when the sun and earth are not in view.

Success Criteria

FTO 1) Photographs and supporting data defined under the Test Conditions
 FTO 2) shall be acquired and returned to earth for processing and evaluation.
 FTO 3)
 FTO 4)
 FTO 5)
 FTO 6)

Evaluation

FTO 1) The photographic and supporting data will be evaluated by the
 FTO 2) Low Light Level Astronomy Working Group of the Apollo Orbital
 FTO 3) Science Photographic Team for general scientific interest.
 FTO 4) (Astronaut records, photographs, BET, and CG 0001 V)
 FTO 5)
 FTO 6)

Data Requirements

1) Telemetry Measurements:

<u>Measurement Number</u>	<u>Description</u>	<u>TM</u>	<u>Mode</u>	<u>Priority</u>
CG 0001 V	Computer Digital Data 40 Bits	PCMD+	2	M*

*This measurement will be recorded by the onboard tape recorder during film exposure periods in lunar orbit between LOS and AOS, and will be dumped to the MSFN at the next opportunity.

2) Astronaut Logs and Voice Records: (M)

Record of GET, magazine number, frame number, exposure anomalies, inadvertent or planned changes in the CSM optical environment, or any occurrences of thruster activity during photo sequences.

3) Photographs: (M)

Photographs of all phenomena specified in FTO 1) through FTO 5) inclusive, and whatever is available during the flight period under FTO 6) performed in the manner described in the Test Conditions.

4) Trajectory Data: (M)

Best estimate of trajectory (BET), covering periods when photographs were obtained.

CSM LOW LIGHT LEVEL ASTRONOMY

Background and Justification

Investigations to study these phenomena photographically and visually from manned spacecraft were begun in the Mercury Program starting with MA-6 and continued throughout the remainder of the program. An experiment on Zodiacal Light and Gegenschein used a specially modified, fast camera system to successfully collect data on MA-9. This and similar investigations were carried out on the Gemini Program using flight qualified camera systems, with faster films as they become available. A second experiment, entitled Dim Light Photography, was accomplished on several later Gemini missions with partial success. Related work has also been performed on rocket, balloons, and unmanned orbiting vehicles.

Apollo missions provide unique opportunities for investigating the near earth-moon phenomena by parallax enhancement and by using the extremely dark observational vantage point afforded by the double lunar umbra region, i.e., the low lunar orbit region shadowed from both sunlight and earthshine.

Degradation of data collected on previous manned spaceflights, of low intensity astronomical sources, are attributed to several factors. The more obvious of these are spacecraft window cleanliness and transmission qualities, light scattering effluents from spacecraft purges, dumps, ventings and depressurizations, etc. A more subtle problem is the difficulty of avoiding extremely low level, stray light in the spacecraft cabin and from vehicle thruster firings during attitude changes and stabilization. The flight crew must literally work in the dark during periods of data collection to avoid these problems which would swamp the phenomenon under study. In some cases, these contaminating light levels are well below the crew's visual threshold and their presence goes

undetected. The phenomena under investigation are equally as dim, and the crew must use computed attitudes or secondary aiming points. Furthermore a darkened cabin makes almost impossible the use of clocks, attitude indicators and written checklists. This complicates the data collection procedures and hampers the acquisition of necessary supporting data to the accuracy desired.

The double umbra region penetrated by the lunar orbiting spacecraft presents man with the darkest region ever experienced. Furthermore, future manned flight programs beyond Apollo missions do not now call for trajectories through this region.

Previous Flight Objectives

<u>Objective Number</u>	<u>Title</u>	<u>Mission</u>
20.115	Lunar Mission Photography from the CSM	8

CREW PROCEDURES CHANGE REQUEST

INITIATED BY R.D. Mercer/S.N. Hardee	ORGANIZATION Ap. Lun. Orb. Pho. Sci. Tm./TD2	DATE 21 June 1971
CHANGE NUMBER	S/C EFFECTIVITY	

DOCUMENT AFFECTED

TITLE	DOCUMENT NO.	PAGE NO.	BASIC OR CHANGE DATE	TIME OR STEP NO.
Low Light Level Photography	Checklists & Flight Plan	See Attach.	For Flt. Pln Ch. B	See Attachments

DETAIL CHANGE IN EXACT WORDING

Attachments show desired wording for CM Photo Procedures - Apollo 15 which is the basis for CMP Checklists and appropriate Flight Plan entrees. Changes from 7 May 1971 Procedures are noted by black bar in right-hand margin with numbers corresponding to reasons for change noted below.

Procedures affected are:

1. Geggenschein (Experiment S-178)
2. Zodiacal Light
3. Lunar Libration
4. Solar Corona
5. Earthshine
6. DAC/SXT Photo Test
7. Lunar Eclipse

REASON: (In order of first occurrence in attachments with type and priority of change indicated below.)

1. "...wo/fwd firing jets..." implies WITHOUT forward firing jets just as "...w/optics..." implies WITH optics. This clarification is PREFERRED.
2. "1/1000" is the minimum shutter speed on the Nikon as opposed to "1/500". Use of 1/1000 will further limit possible light excess on protect frames. In addition, the 1/1000 detent on the Shutter Speed Select Knob is directly adjacent to the clockwise rotation stop on that knob. This change will allow easier operation by the crew when the set-by-feel method is required, particularly when the cabin is dark, time is crucial and the camera is mounted on the window bracket. This modification is HIGHLY DESIRABLE. (See Continuation Sheet)

REMARKS: Changes noted herein reflect NO discredit on efforts of flight and procedure planners. Their initial detailing of procedures from PI requirements while avoiding operational constraints will greatly improve the scientific data to be obtained. In particular, we wish to single out the clever efforts of Mr. W. Kalvert (TRW) in devising the safest and most consistent method for executing "protect" frames whether the cameras are hand-held or bracket mounted - a procedure with which we heartily concur.

<input type="checkbox"/> APPROVED	COORDINATOR'S SIGNATURE	DATE
<input type="checkbox"/> DISAPPROVED		

FINAL DISPOSITION

<input type="checkbox"/> APPROVED	FCOD SIGNATURE	DATE SIGNED	SUSPENSE DATE
<input type="checkbox"/> DISAPPROVED			

Reason:

3. The eight additional frames are required as a spacer on 35mm cassette "T" to separate Lunar Libration photography from Earthshine. This guarantees that no data frames will be destroyed when the film is cut postflight to allow separate and different development processing for each of these phenomena to properly enhance their scientific data content. Sufficient frames are available on cassette "T" to fulfill this requirement, including the preflight and postflight calibration exposures for Earthshine, and still have up to ten spare frames. This revision is MANDATORY.
4. The change in celestial coordinates for Lunar Libration Region L₄ Targeting Point is necessary to correct, in part, earlier calculations using a different lift-off time and a different execution time of this task than carried in the current Flight Plan. Also, an additional shift of 4° to the west in the plane of lunar orbit has been included to purposely offset the L₄ point from center frame (camera line-of-sight) in order to simplify the extraction of scientific data from the lens vignetting function. Since the L₄ position has a considerable shift from day-to-day (approximately 13°/day), its targeting point is given for the one-day-later-lift-off. This revision is MANDATORY.
5. The two "protect" frames, one before and one after, surrounding scientific data collection tasks using the EL camera with VHBW film must be eliminated from all Terminator (under Earthshine) photography and from the Solar Corona Window Calibration. This will decrease the number of frames used for each Terminator photographic pass from eight to six and for the Solar Corona Window Calibration from five to three. In addition, settings of shutter speeds for these tasks will be correspondingly affected. This change is required to properly utilize the limited number of frames available on the single VHBW EL magazine approved for flight. The only alternative to this procedural change is to fight for the addition of a second VHBW EL magazine - literally an impossibility at this point in time. Therefore, this revision is MANDATORY.
6. "1/1000" is the minimum shutter speed on the DAC as opposed to "1/500". Use of 1/1000 will further limit possible light excess on protect frames. In addition, the 1/1000 detent on the Shutter Speed Selector is also the clockwise rotation stop on that knob. This change will allow easier operation by the crew when the set-by-feel method is required, particularly when the cabin is dark, time is crucial and the camera is mounted on the window bracket. This change may, in turn, necessitate other changes to the Shutter Speed Selector switching procedures. This modification is HIGHLY DESIRABLE.
7. This is a correction in a designation and/or the inclusion or an omission in the procedures. These modifications are MANDATORY.

MSC Form 482 Continuation Sheet - Mercer/Hardee, 21 June 1971

Reason:

8. These word changes are suggested to simplify and clarify an understanding of the task details. This clarification is PREFERRED.
9. This is a correction in the start of the two-minute EL exposure using a CEX magazine so that the exposure staddles equally the moment the moon just begins to leave the earth's umbra. It then corresponds exactly, but in reverse order, with the procedure used when the moon just completes its entry into the umbra. A shuffling of line items in the procedure is also required to complete this change. This modification is MANDATORY.

CM PHOTO PROCEDURES - APOLLO 15

I. GEGENSCHNEIN

A. Pad (None required)

B. Constraints

- o Photos taken in double umbra
- o Forward firing thrusters disabled
- o Two photographs of each target desired
- o SC exterior lights to be off
- o Interior lighting to be minimized
- o Cycle protective frame before and after photo sequence
- o Use window shade
- o Use 0.5° DB when SC is holding inertially on target
- o CSM to be undocked
- o Damp rates for five minutes prior to disabling total attitude hold control.

C. Data Requirements

- o LBR data mandatory
- o Record of start and stop of photo sequence
- o Magazines, frames used
- o Targets:

	<u>RA</u>	<u>Decl</u>
ANTISOLAR	20 ^h 20 ^m	-19° 30'
MIDWAY	21 ^h 0 ^m	-17° 00'
MOULTON	21 ^h 45 ^m	-13° 30'

D. Procedures with the following additional assumptions:

- o Six jet authority w/fwd firing jets
- o Experiments in Sim Bay operating

1. CONFIGURE CAMERA: (GEGENSCHIEIN)
INSTALL CAMERA SHIELD
CM4/NK/55/VHBW-BRKT (f 1.2, 1/1000,∞) (12 FR)
MAG () _____, FR# _____

2 | []

2. V49 MNVR TO (ANTI SOLAR PT)
(MIDWAY PT)
(MOULTON PT) ATT (:)

Note: If time prohibits photos of all three tgts, photograph only the last two tgts.

3. DAMP RATES:
VERIFY FDAI SCALE 5/1
WAIT 5 MIN FOR RATES TO DAMP
VERIFY RATES ON FDAI ARE <0.2°/SEC IN ALL AXES
CMC MODE - FREE

4. DIM INTERIOR LIGHTS
CYCLE 1 FRAME, CHANGE SHUTTER TO T
1 FRAME, EXP TIME 1 MIN
1 FRAME, EXP TIME 3 MIN
CHANGE SHUTTER TO 1/1000
CYCLE 1 FRAME, LIGHTS UP
CMC MODE - AUTO

2 | []

5. REPEAT STEPS 2, 3, AND 4 FOR SECOND AND THIRD PTS

6. RECORD FR# _____

7. STOW CAMERA
REMOVE CAMERA SHIELD

E. Procedures with the following assumptions
o All jets enabled initially

1. CONFIGURE CAMERA: (GEGENSCHIEIN)
INSTALL CAMERA SHIELD
CM4/NK/55/VHBW-BRKT (f 1.2, 1/1000,∞) (12 FR)
MAG () _____, FR# _____

2 | []

2. V49 MNVR TO (ANTI SOLAR PT)
(MIDWAY PT)
(MOULTON PT) ATT (:)
(, ,)

3. DISABLE JETS A3, C4, B3, D4

4. DIM INTERIOR LIGHTS
CYCLE 1 FRAME, CHANGE SHUTTER TO T
1 FRAME, EXP TIME 1 MIN
1 FRAME, EXP TIME 3 MIN
CHANGE SHUTTER TO 1/1000
CYCLE 1 FRAME
LIGHTS UP

2 | []

5. REPEAT STEPS 2 AND 4 FOR THE SECOND AND THIRD PTS
6. RECORD FR# _____
7. ENABLE ALL JETS
8. STOW CAMERA
REMOVE CAMERA SHIELD

F. Gegenschein Calibration Procedure with the following assumptions:

- o Camera handheld \perp to window
 - o Experiments in Sim Bay running
 - o 6 jet authority w/fwd firing jets |
1. CONFIGURE CAMERA: (GEGENSCHIEIN CALIBRATION)
CM5/NK/55/VHBW (f 1.2, 1/1000, ∞) (4 FR)
MAG () _____, FR# _____
 2. V49 MNVR TO MIDWAY PT (:)
(, ,)
 3. REMOVE CM5 WINDOW COVER
DAMP RATES
VERIFY FDAI SCALE 5/1
WAIT 5 MIN FOR RATES TO DAMP
VERIFY RATES ARE $<0.2^{\circ}/\text{SEC}$ IN ALL AXES
CMC MODE - FREE
 4. DIM INTERIOR LIGHTS
CYCLE 1 FRAME, CHANGE SHUTTER TO T
1 FRAME, EXP TIME 1 MIN
1 FRAME, EXP TIME 3 MIN
CHANGE SHUTTER TO 1/1000
CYCLE 1| FRAMES, LIGHTS UP
CMC MODE - AUTO
 5. RECORD FR# _____
STOW CAMERA
REPLACE CM5 WINDOW COVER

1 | 

2 | 

2 | 

II. ZODIACAL LIGHT

ZODIACAL LIGHT PHOTO PAD
T START ____:____:____
START DET AT SUNRISE-30 MIN

A. Pad

B. Constraints

- o SC to be in 5.0° DB
- o SC in orbital rate
- o Use window shade
- o Forward firing thrusters disabled
- o Photos in double umbra
- o Camera FOV to cover portion of lunar horizon
- o Interior lighting to be minimized
- o Cycle protective frame before and after photo sequence

C. Data Requirements

- o LBR data mandatory
- o Record of start and stop of photos
- o Magazine, frames used

D. Procedures

- o Assumes CSM in Sim Bay ATT with single jet authority
- o Assumes P20 in operation
- o Assumes orb rate can be maintained for ~15 min while in free mode

1. CONFIGURE CAMERA: (ZODIACAL LIGHT)

INSTALL CAMERA SHIELD

CM4/NK/VHBW-BRKT (f 1.2, 1/1000,∞) (27 FR)

MAG ()____, FR#____

2

2. PHOTO SEQUENCE

0:00 - MISSION TIMER, RESET/START (T START) (SR-30 MIN)

CMC MODE FREE

DIM INTERIOR LIGHTS

CYCLE 1 FRAME, CHANGE SHUTTER TO T

5:00 - 1 FRAME, EXP TIME 120 SEC (SR-25:00 MIN)

1 FRAME, EXP TIME 30 SEC

8:20 - 1 FRAME, EXP TIME 120 SEC (SR-21:40 MIN)

1 FRAME, EXP TIME 30 SEC

11:40 - 1 FRAME, EXP TIME 90 SEC (SR-18:20 MIN)
1 FRAME, EXP TIME 30 SEC
1 FRAME, EXP TIME 10 SEC
15:00 - 1 FRAME, EXP TIME 90 SEC (SR-15 MIN)
1 FRAME, EXP TIME 30 SEC
1 FRAME, EXP TIME 10 SEC
CHANGE SHUTTER TO 1/1000, CYCLE 1 FRAME

2

CMC MODE - AUTO
MONITOR ADJUSTMENT OF RATES (IF RATES HAVE NOT SETTLED-
DELETE PHOTO SEQUENCE AT 18:20)

CMC MODE - FREE
CYCLE 1 FRAME, CHANGE SHUTTER TO T
18:20 - 1 FRAME, EXP TIME 60 SEC
1 FRAME, EXP TIME 20 SEC
1 FRAME, EXP TIME 8 SEC
21:40 - 1 FRAME, EXP TIME 60 SEC
1 FRAME, EXP TIME 20 SEC
1 FRAME, EXP TIME 8 SEC
25:00 - 1 FRAME, EXP TIME 30 SEC
1 FRAME, EXP TIME 10 SEC
1 FRAME, EXP TIME 4 SEC
29:00 - 1 FRAME, EXP TIME 1/8
29:15 - 1 FRAME, EXP TIME 1/15
29:30 - 1 FRAME, EXP TIME 1/30
29:45 - 1 FRAME, EXP TIME 1/60
CHANGE SHUTTER TO 1/1000
CYCLE 1 FRAME, LIGHTS UP

2

3. CMC MODE - AUTO
RECORD FR# _____
STOW CAMERA
REMOVE CAMERA SHIELD

III. LUNAR LIBRATION

A. Pad (None required)

B. Constraints

- o Use window shade
- o Dim interior lights
- o Maintain DB of 0.5°
- o Cycle protective frame before and after photo sequence
- o Photos taken in double umbra
- o Fwd firing thrusters disabled

C. Data Requirements

- o LBR data mandatory
- o Record of start and stop of photo sequence
- o Magazine, frames used
- o Target location:

For 1334Z 26 Jul 71 lift-off

For 1337Z 27 Jul 71 lift-off

RA = $23^{\text{h}} 13^{\text{m}}$

RA = $23^{\text{h}} 59^{\text{m}}$

Decl = -1.827°

Decl = $+4.107^{\circ}$

D. Procedures

- o Assumes all jets enabled except fwd firing (A3, G4, B3, D4)

1. CONFIGURE CAMERA: (LUNAR LIBRATION)

INSTALL CAMERA SHIELD

CM4/NK/55/VHBW-BRKT, (f 1.2, 1/1000, ∞) (6 FR)

MAG () _____, FR# _____

2. V49 MNVR TO L4 ATT (:)

(, ,)

3. DIM INTERIOR LIGHTS

CYCLE 1 FRAME, CHANGE SHUTTER TO T

1 FRAME, EXP TIME 4 MIN

2 FRAMES, EXP TIME 90 SEC

1 FRAME, EXP TIME 30 SEC

CHANGE SHUTTER TO 1/1000

CYCLE 9 FRAME, LIGHTS UP

4. RECORD FR# _____

STOW CAMERA

REMOVE CAMERA SHIELD

IV SOLAR CORONA

A. Pads

SOLAR CORONA PHOTO PAD (SR) T START ____ : ____ : ____ START DET AT SUNRISE - 8 MIN

SOLAR CORONA PHOTO PAD (SS) T START ____ : ____ : ____ START DET AT SUNSET - 5 MIN
--

B. Constraints

- o SC to maintain orbital rate
- o SC to be in 5.0° DB
- o SC will be pitched down WRT the local horizontal so that camera FOV includes part of the lunar surface
- o (+) X axis or (-) X axis pointing along the velocity vector
- o Fwd firing thrusters disabled
- o Interior lighting to be minimized
- o Both cameras to have protective film advance before and after each photo sequence

5

C. Data Requirements

- o HBR mandatory for EL
- o Record of start and stop of photo sequence
- o Magazine, frames used

D. Procedures - Sunset Solar Corona

Note: Assumes all jets enabled

1. CONFIGURE CAMERAS: (SUNSET SOLAR CORONA)
CM4/DAC/18/VHBW-BRKT, MIR (T1, 1/1000, ∞) 24 fps (7% MAG)
MAG () _____, MAG% _____
UTILITY PWR-ON
DAC-ON AT 24 fps FOR 2 SEC (COVER LENS)
CHANGE SHUTTER TO 1/500 AND FRAME RATE TO 1 fps

CM4/EL/80/VHBW-BRKT (f2.8, 1/500, ∞) (9FR)
PCM CABLE
MAG () _____, FR# _____
COVER LENS, CYCLE 1 FRAME
CHANGE SHUTTER TO 1/125

6

6

2. P20 OPT 5 (SS SOLAR CORONA ATT) (:)

N78 (+000.00)

(-082.00)

(+180.00)

N79 (+005.00)

N70 (00050)

(, ___/ ,) HGA P___, Y___

NOTE: HEADS UP, LHLV

7

3. 0:00 - MISSION TIMER, RESET/START (T START) (SS-5 MIN)

PCM BIT RATE - HIGH

DISABLE JETS A3, C4, B3, D4

DIM INTERIOR LIGHTS

5:00 - DAC - ON

5:10 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/60

5:20 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/30

5:30 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/15

5:40 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/8

5:50 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/4

6:00 - 1 FRAME EL, CHANGE EL SHUTTER TO 1.0

6:10 - 1 FRAME EL

6:20 - CHANGE DAC SHUTTER TO 1/125

8:00 - DAC - OFF

CHANGE EL SHUTTER TO 1/500

CHANGE DAC SHUTTER TO 1/1000

6

4. REMOVE EL FROM WINDOW, COVER LENS, AND CYCLE 1 FRAME

REMOVE DAC FROM WINDOW, COVER LENS, AND RUN AT 24 fps FOR 2 SEC.

6

LIGHTS UP

ENABLE ALL JETS

PCM BIT RATE - LOW

RECORD MAG % _____, FR# _____

E. Procedures - Sunrise Solar Corona

Note: Assumes all jets enabled

1. CONFIGURE CAMERAS: (SUNRISE SOLAR CORONA)

CM4/DAC/18/VHBW-BRKT, MIR (T1, 1/1000, ∞) 24 fps (7% MAG)

MAG () _____, MAG% _____

UTILITY PWR-ON

DAC-ON AT 24 fps FOR 2 SEC (COVER LENS)

CHANGE SHUTTER TO 1/125 AND FRAME RATE TO 1 fps

6

CM4/EL/80/VHBW-BRKT (f 2.8, 1/500, ∞) (9 FR)

PCM CABLE

MAG () _____, FR# _____

COVER LENS, CYCLE 1 FRAME

CHANGE SHUTTER TO 1 SEC

2. P20 OPT 5 (SR SOLAR CORONA ATT.) (:)

N78 (+000.00)

(-082.00)

(+000.00)

N79 (+005.00)

N70 (00050)

(, _____ / ,)

NOTE: HEADS UP, LHLV

3. 0:00 - MISSION TIMER, RESET/START (T START) (SR-8 MIN)

PCM BIT RATE - HIGH

DISABLE JETS A3, C4, B3, D4

DIM INTERIOR LIGHTS

5:00 - DAC-ON

6:40 - CHANGE DAC SHUTTER TO 1/500

6:50 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/4

7:00 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/8

7:10 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/15

7:20 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/30

7:30 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/60

7:40 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/125

7:50 - 1 FRAME EL, CHANGE EL SHUTTER TO 1/500

8:00 - DAC - OFF

4. REMOVE EL FROM WINDOW, COVER LENS, AND CYCLE 1 FRAME
REMOVE DAC FROM WINDOW, COVER LENS, AND RUN AT 24 fps
AND SHUTTER SPEED 1/1000 FOR 2 SEC

LIGHTS UP

ENABLE ALL JETS

PCM BIT RATE - LOW

RECORD MAG % _____, FR# _____

F. Procedures | Sunrise Solar Corona

o Assumes SC in 40° S. Oblique Att (Map Camera)

o Assumes 6 jet authority, w/fwd firing jets

1. CONFIGURE CAMERAS SAME AS SUNRISE SOLAR CORONA

2. SAME PROCEDURE AS STEP 3 | OF SUNRISE SOLAR CORONA EXCEPT
ALL JETS ARE DISABLED (CMC MODE-FREE) AND TLM HAS
PREVIOUSLY BEEN CONFIGURED HBR)

3. SAME AS STEP 4 OF SUNRISE SOLAR CORONA EXCEPT PCM REMAINS HBR
AND 6 JET AUTHORITY IS RESELECTED (CMC MODE - AUTO)

G. Procedures - Corona Window Calibration

- o Photos taken during TEC
- o Assumes all jets enabled
- o 5.0° DB during photos
- o Camera pointed to moon

1. CONFIGURE CAMERA : (CORONA WINDOW CALIBRATION)
CM4/EL/80/VHBW-BRKT (f 2.8, 1/500, ∞) (5FR)
MAG () , FR#
2. V49 MNVR TO CORONA WINDOW CALIBRATION ATT (:)
(, ,) HGA P , Y
3. INHIBIT JETS A3, C4, B3, D4
CYCLE 1 FRAME, CHANGE SHUTTER TO 1/125
1 FRAME, CHANGE SHUTTER TO 1/60
1 FRAME, CHANGE SHUTTER TO 1/30
1 FRAME, CHANGE SHUTTER TO 1/500
CYCLE 1 FRAME
RECORD FR#
ENABLE JETS

5

5

5

V. EARTHSHINE

A. Pad

EARTHSHINE PHOTO PAD T START ____ : ____ : ____ START DET AT SUNSET -5MIN

B. Constraints

- o SC to be in orbital rate
- o Interior lighting to be minimized
- o Camera to be pointed vertically to lunar surface
- o Protective film advance before and after photo sequence

C. Data Requirements

- o Record of start and stop of photo sequence
- o Magazine and frame used

D. Procedure - Earthshine

- o Assumes SC in Sim Bay Att
- o Camera handheld
- o CM5 window cover is not removed

1. CONFIGURE CAMERA : (EARTHSHINE)
CM5/NK/55/VHBW (f 1.2, 1/1000, ∞) (20FR)
MAG () _____, FR# _____
2. 0:00 MISSION TIMER: RESET/START (T START) (SS TERM -5)
DIM INTERIOR LIGHTS
COVER LENS, CYCLE 1 FRAME, CHANGE SHUTTER TO 1/125
4:00 - 4 FRAMES AT 30 SEC INTERVALS
CHANGE SHUTTER TO 1/15 SEC
6:00 - 4 FRAMES AT 30 SEC INTERVALS
CHANGE SHUTTER TO 1/8 SEC
8:00 - 10 FRAMES AT 30 SEC INTERVALS
CHANGE SHUTTER TO 1/1000, COVER LENS, CYCLE 1 FRAME
3. LIGHTS UP
RECORD FR# _____

E. Terminator Procedure

- o Taken at terminator when Sim cameras are operating
 - o Forty seconds on dark side of terminator, one minute on daylight side
 - o Handheld
 - o Photos will be time tagged to Pan/Map Camera start and stop times
1. CONFIGURE CAMERA: (TERMINATOR PHOTOS)
CM5/EL/80/VH BW, IVL (f 2.8, 1/125, ∞) (6FR) 5
PCM CABLE 5
MAG () _____, FR# _____
 2. EL - ON (T START -40 SEC)
EL - OFF (T START +1 MIN) 5
RECORD FR# _____

Note: Step 2 above is for sunrise terminator

VII. DAC/SXT PHOTO TEST

A. Pad (Not Required)

B. Constraints

- o Take 2 sequences, once during TLC, once during TEC
- o Use same star field both times
- o Use auto optics out of zero-zero position
- o Power off reticle light
- o Each sequence will require 2 sets of photos
 - one w/optics at $\sim 90^\circ$ to sun line
 - one w/optics shaded by SC
- d SC to be in $.5^\circ$ DB for photos
- o FWD firing jets to be disabled during photo sequence

C. Data Requirements

- o Record of Mag & % Mag used

D. Procedures DAC/SXT Photo Test

- o Assumes all jets enabled initially

1. CONFIGURE CAMERA: (SXT PHOTO TEST)

CM/DAC/SXT/VHBW (EXP 1/1000) 24 fps (5% MAG)
MAG () _____, MAG % _____
PCM CABLE
UTILITY PWR - ON

2. V49 MNVR TO SXT PHOTO TEST ATT (:)
(, ,) HGA P _____, Y _____

3. DISABLE JETS A3, C4, B3, D4
P52 (NO MARKS)
N70 ()

4. VERIFY THRU SXT THAT OPTICS BORESIGHTED ON TARGET
G&N PWR (AC) - OFF (PNL5)
MOUNT DAC ON SXT
DIM INTERIOR LIGHTS, DAC ON AT 24 fps FOR 2 SEC
CHANGE TO TIME AND 1/60

1 FRAME - EXP TIME 60 SEC
1 FRAME - EXP TIME 20 SEC
1 FRAME - EXP TIME 5 SEC
1 FRAME - EXP TIME 1 SEC
CHANGE TO 24 fps & 1/1000
RUN DAC FOR 2 SEC, LIGHTS UP

6

5. V49 MNVR TO SXT PHOTO TEST ATT (:)
(, ,) HGA P___, Y___

6. P52 (NO MARKS)
N70 ()

7. REMOVE DAC
VERIFY THRU SXT THAT OPTICS BORESIGHTED ON TARGET
MOUNT DAC ON SXT
DIM INTERIOR LIGHTS, DAC ON AT 24 fps FOR 2 SEC
CHANGE TO TIME & 1/60

7

7

1 FRAME - EXP TIME 60 SEC
1 FRAME - EXP TIME 20 SEC
1 FRAME - EXP TIME 5 SEC
1 FRAME - EXP TIME 1 SEC

CHANGE TO 24 fps & 1/1000
RUN DAC FOR 2 SEC, LIGHTS UP

6

8. RECORD MAG % _____
REMOVE & STOW DAC
G & N PWR - AC1 or AC 2 (PNL 5)

IX. LUNAR ECLIPSE

A. Pad

LUNAR ECLIPSE PHOTO PAD T START _____ : _____ : _____ MOON ENTERS EARTH UMBRA-20 MIN
--

LUNAR ECLIPSE PHOTO PAD T START _____ : _____ : _____ MOON LEAVES EARTH UMBRA-10 MIN
--

B. Constraints

- o Taken during transearth coast
- o Use window shade with NK in CM4
- o Use one frame protective film advance
- o Forward firing thrusters disabled
- o Interior lighting to be minimized
- o EL to be handheld in CM2
- o Use 0.5° when SC is holding inertially on target

C. Data Requirements

- o HBR data required for EL shutter closures
- o Need 2 sets of 6 frames for each camera
- o Mag and frame used
- o Record of start and stop of photo sequence

D. Procedure

1. CONFIGURE CAMERA: (LUNAR ECLIPSE)

INSTALL CAMERA SHIELD

CM4/NK/55/VHBW, BRKT (f 1.2, 1/1000, ∞) (16 FR)

MAG () _____, FR# _____

CM2/EL/250/CEX (f5.6, 1/500, ∞) (16 FR)

PCM CABLE

MAG () _____, FR# _____

2, 7

2. V49 MNVR TO LUNAR ECLIPSE ATT (:)
(, ,) HGA P___, Y___

3. PHOTO SEQUENCE (for moon entering earth's umbra)

0:00 - MISSION TIMER, RESET/START (T START)
DISABLE JETS A3, C4, B3, D4
DIM INTERIOR LIGHTS
COVER EL LENS, CYCLE 1 FRAME
CHANGE EL SHUTTER TO 1 SEC

5:00 - 1 FRAME EL
CHANGE EL SHUTTER TO B

8:00 - 1 FRAME EL, EXP TIME 2 SEC
CHANGE to 80mm LENS AND f2.8
CHANGE EL SHUTTER TO 1 SEC

11:00 - 1 FRAME EL
CHANGE EL SHUTTER TO B

14:00 - 1 FRAME EL, EXP TIME 2 SEC

17:00 - 1 FRAME EL, EXP TIME 10 SEC
CYCLE NK 1 FRAME, CHANGE NK SHUTTER TO T

19:00 - 1 FRAME EL, EXP TIME 2 MIN
1 FRAME NK, EXP TIME 2 SEC

20:00 - 1 FRAME NK, EXP TIME 4 SEC

21:00 - 1 FRAME NK, EXP TIME 8 SEC

22:00 - 1 FRAME NK, EXP TIME 15 SEC

23:00 - 1 FRAME NK, EXP TIME 30 SEC

24:00 - 1 FRAME NK, EXP TIME 60 SEC
CHANGE NK SHUTTER TO 1/1000 SEC
CYCLE NK 1 FRAME
CHANGE EL SHUTTER TO 1/500
COVER EL LENS, CYCLE 1 FRAME

LIGHTS UP, ENABLE JETS
RECORD EL FR# _____
RECORD NK FR# _____

Note: This procedure assumes
that Step 4 follows Step 3
with no intervening use of
the NK and EL.

4. PHOTO SEQUENCE (for moon leaving earth's umbra)

0:00 - DET, RESET/START (T START)
DISABLE JETS A3, C4, B3, D4
DIM INTERIOR LIGHTS
CYCLE NK 1 FRAME, CHANGE NK SHUTTER TO T

6:00 - 1 FRAME NK, EXP TIME 60 SEC

7:00 - 1 FRAME NK, EXP TIME 30 SEC

8:00 - 1 FRAME NK, EXP TIME 15 SEC
COVER EL LENS, CYCLE 1 FRAME
CHANGE EL SHUTTER TO B

9:00 - 1 FRAME EL, EXP TIME 2 MIN
1 FRAME NK, EXP TIME 8 SEC

10:00 - 1 FRAME NK, EXP TIME 4 SEC

11:00 - 1 FRAME NK, EXP TIME 2 SEC
13:00 - 1 FRAME EL, EXP TIME 10 SEC
16:00 - 1 FRAME EL, EXP TIME 2 SEC
CHANGE EL SHUTTER TO 1 SEC
19:00 - 1 FRAME EL
CHANGE TO 250mm LENS AND f5.6
CHANGE EL SHUTTER TO B
22:00 - 1 FRAME EL, EXP TIME 2 SEC
CHANGE EL SHUTTER TO 1 SEC
25:00 - 1 FRAME EL
CHANGE EL SHUTTER TO 1/500 SEC
COVER EL LENS, CYCLE 1 FRAME
CHANGE NK SHUTTER TO 1/1000 SEC
CYCLE NK 1 FRAME

LIGHTS UP, ENABLE JETS
RECORD EL FR# _____
RECORD NK FR# _____
STOW CAMERAS
REMOVE CAMERA SHIELD

CREW PROCEDURES CHANGE REQUEST

INITIATED BY D. Mercer/S.N. Hardee	ORGANIZATION Ap.Lun.Orb.Pho.Sci.Tm/TD2	DATE 25 June 1971
CHANGE NUMBER	S/C EFFECTIVITY	

DOCUMENT AFFECTED

TITLE Apollo 15 Checklist&Flt. Plan	DOCUMENT NO. Change A	PAGE NO. 3-38, 39,380,381	BASIC OR CHANGE DATE 1 June 1971	TIME OR STEP NO. 32:00/270:00
--	--------------------------	------------------------------	-------------------------------------	----------------------------------

DETAIL CHANGE IN EXACT WORDING

Star field to be used must be changed to a region near Shaula (λ Scorpii, Navigation Star 61₁₀ (75₈)). The exact unit vector for pointing at the celestial sphere should be:

$$\begin{aligned} x &= -0.10820 \\ y &= -0.79037 \\ z &= -0.60300 \end{aligned}$$

Centering of optics showing crewman's and DAC's fields-of-view is shown on attached star map.

REASON:

Information recently furnished in Apollo 15 Star Chart and Trajectory Documents show that the Earth will be too close to the original star field chosen near Hamal (α Arietis, Navigation Star 38₁₀ (46₈)). Earthshine on the sextant optics would be detrimental to the desired results. In addition, the position denoted above will provide a richer star field having a wider range of stellar magnitudes available for interpretation of results.

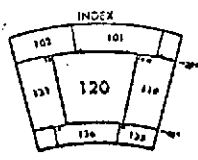
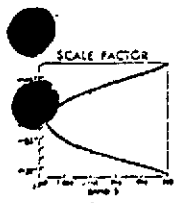
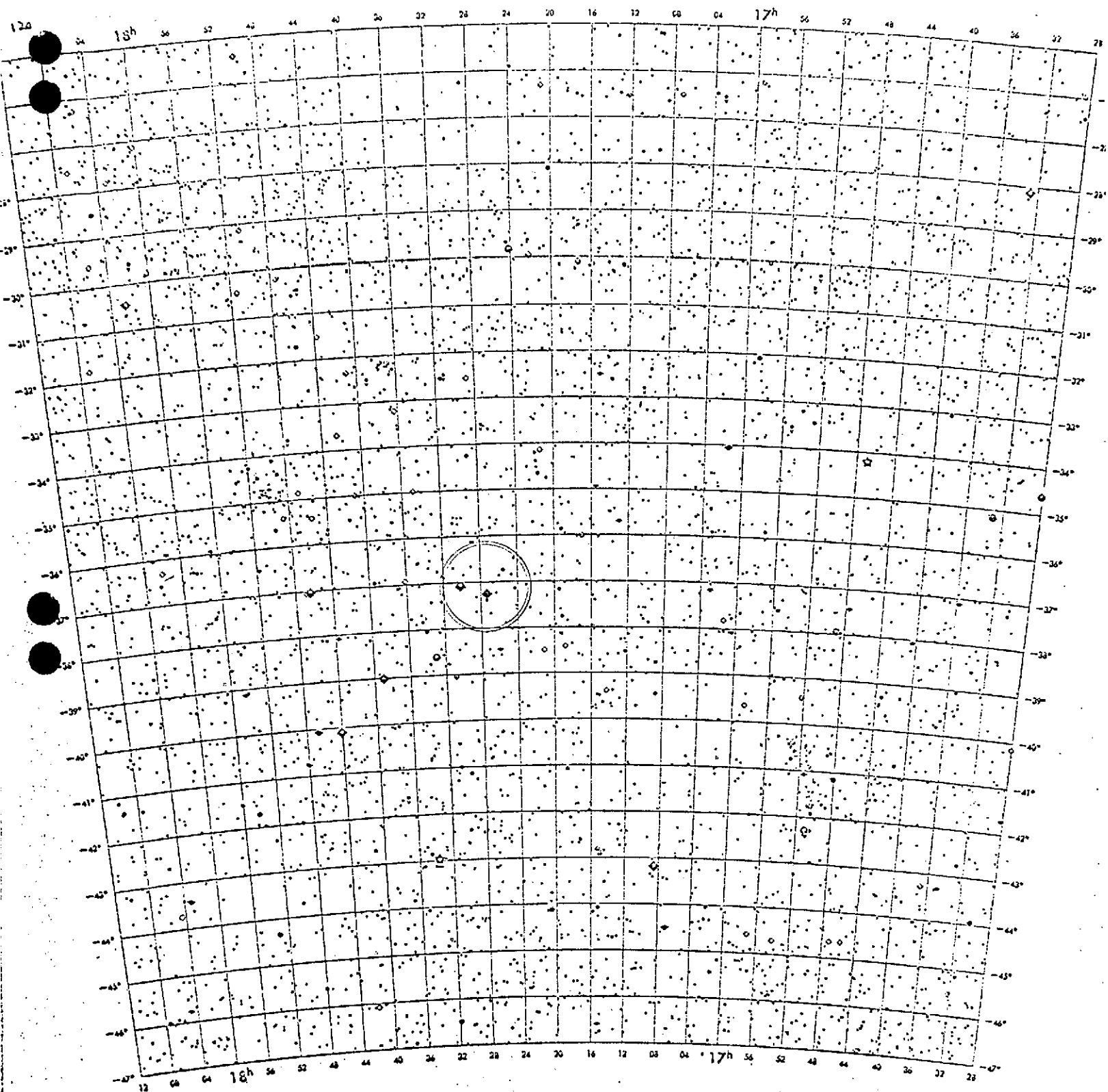
REMARKS:

None.

<input type="checkbox"/> APPROVED	COORDINATOR'S SIGNATURE	DATE
<input type="checkbox"/> DISAPPROVED		

FINAL DISPOSITION

<input type="checkbox"/> APPROVED	FCOD SIGNATURE	DATE SIGNED	SUSPENSE DATE
<input type="checkbox"/> DISAPPROVED			



MAGNITUDES

m	1	2	3	4	5	6	7	8	9
NORMAL STARS	☆	☆	◇	◇	◇	◇	◇	◇	◇
DOUBLE STARS	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
STARS WITH OUT KNOWN PROPER MOTIONS	●	●	●	●	●	●	●	●	●
Variable Stars	○	○	○	○	○	○	○	○	○

NON-STELLAR OBJECTS

☉	♃	♄	♅	♆	♁
SUN	JUPITER	SATURN	URANUS	NEPTUNE	PLOUTO

SAO STAR CHART - 1967
 EQUINOX AND EPOCH 1950.0
 FK4 SYSTEM
 LAMBERT CONIC PROJECTION
 SCALE 6195/in.
 STANDARD PARALLEL 34° 44'

CREW PROCEDURES CHANGE REQUEST

INITIATED BY R. D. Mercer/S.N. Hardee	ORGANIZATION Ap. Lun. Orb. Pho. Sci Tm./TD2	DATE 25 June 1971
CHANGE NUMBER	S/C EFFECTIVITY	

DOCUMENT AFFECTED

TITLE Apollo 15 Checklist & Flight Plan	DOCUMENT NO.	PAGE NO. As appropriate	BASIC OR CHANGE DATE Flt. Pln. Ch. B	TIME OR STEP NO. As appropriate
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DETAIL CHANGE IN EXACT WORDING

Add the following phrase, or words to the same effect, to the appropriate procedures in preparing the 16mm Data Acquisition Camera for Solar Corona Photography,

"COVER DAC SHUTTER INDICATOR LIGHT WITH LIGHT-TIGHT TAPE."

Also add a related procedure after completion of the Solar Corona Photography to the effect,

"REMOVE TAPE FROM DAC SHUTTER INDICATOR LIGHT."

REASON:

The EL and DAC will be used concurrently through the CM4 window with no window shade. The DAC will be operating at 1 fps and the cabin will be dark to avoid stray internal light being reflected back from the window panes into the camera optics - particularly into the EL camera which is prime for this Detailed Objective. If the DAC shutter light is not taped it may destroy the opportunity for collecting Solar Corona data on the EL.

REMARKS:

None

<input type="checkbox"/> APPROVED	COORDINATOR'S SIGNATURE	DATE
<input type="checkbox"/> DISAPPROVED		

FINAL DISPOSITION

<input type="checkbox"/> APPROVED	FCOD SIGNATURE	DATE SIGNED	SUSPENSE DATE
<input type="checkbox"/> DISAPPROVED			

APOLLO 15 PREFLIGHT CREW BRIEFING AGENDA

1. Introduce People (Addresses, Phone numbers) Associations & Expertise
2. Subjects: S178 Gegenschein/Moulton Region
Low Light Level Photography - Mostly from Lunar Orbit but also TLC/TEC

In Order of Priorities

Internal Priorities

- | | |
|---|--|
| <ol style="list-style-type: none"> 1. Gegenschein/Moulton Region 2. Solar Corona 3. Lunar Eclipse 4. Sextant Photo Tests 5. Libration Point L₄ 6. Zodiacal Light | <ol style="list-style-type: none"> 2 SRise, SSet, Calib Either 2nd or 3rd TEC, TLC Late, Early, Middle |
|---|--|

3. Zodiacal Light, Gegenschein, Lunar Libration Point Explanation of Basic Geometry, Timing (Double Umbra), and Improved Viewing from Moon. (Mercer and Dunkelmann with photos and diagrams)
4. Gegenschein/Moulton Region (S-178) Scientific Objectives, History of Attempts, Special Viewing Advantages from Lunar Orbit, AS-14 Results, etc. (Dunkelman)
5. Solar Corona - Same as Item 4 plus Pre-In-Postflight calibrations (Ross)
6. Zodiacal Light, Libration Point, Lunar Eclipse, and Sextant Tests - Same as Item 4 (Mercer)
7. Discuss internal priorities of tasks (50% Film can =>50% Science) (All)
8. General details affecting Science (All)
 - A. Supporting data and problems in acquisition and interpretation - Voice and Logs.
 - B. Review Training (Past and Future) peculiar to these Tasks.
 - C. Camera - Lighting - Stabilization Problems including specific details on individual Camera Equipments Operation, Setting, Film loading/ Changing, Vignetting, etc.
 - D. Supporting and Noteworthy Visual Observations.
 - E. Questions and Crew Preferences.
9. General details affecting operational procedures (All)
 - A. Flight Plan - Nominal and Non-nominal
 - B. Procedures - Nominal and Non-nominal
 - C. Pads and Ground Support for Timing and Trajectory Variations.
 - D. Questions and Crew Preferences
10. Postflight Debriefings, Reporting and Publication
11. Press, PAO, and Justifications for Science, Manned Flight and Apollo

VHFW (2485) FILM BUDGET FOR APOLLO 15

CAMERA SYSTEM		35 mm NIKON				70 mm HEL				16 mm DAC			
FRAME USAGE					FRM CNT				FRM CNT				% FILM
TASK	TIME	DATA	PRTCT	MAG	INDICATE	DATA	PRTCT	MAG	INDICATE	DATA	PRTCT	MAG	REMAIN
Preflight Sensitometry	--	6 ²	0	T	--	7 ²	0	R	--	26 ²	60	H	95
Preflight Sensitometry	--	32 ²	1	W	--	--	--	--	--	--	--	--	--
Sextant Test	32:00	--	--	--	--	--	--	--	--	8	192	H	89
Near Terminator Rev 2	81:44	--	--	--	--	6	0	R	6	--	--	--	--
Far Terminator Rev 3	84:40	--	--	--	--	6	0	R	12	--	--	--	--
Sunrise Solar Corona	123:19	--	--	--	--	7	2	R	21	180	96	H	82
Sunset Solar Corona	124:36	--	--	--	--	7	2	R	30	180	96	H	75
Lunar Libration L4	125:07	4	10	T	14	--	--	--	--	--	--	--	--
Earthshine	144:13	18	2	T	34	--	--	--	--	--	--	--	--
Gegenschein/Moulton Cal	146:41	2	2	U	4	--	--	--	--	--	--	--	--
Zodiacal Light	148:39	23	4	U	31	--	--	--	--	--	--	--	--
Gegenschein/Moulton	168:21	6	6	U	43	--	--	--	--	--	--	--	--
Far Terminator Rev 58	190:35	--	--	--	--	6	0	R	36	--	--	--	--
Near Terminator Rev 58	191:36	--	--	--	--	6	0	R	42	--	--	--	--
Gegenschein/Moulton	195:53	6	6	V	12	--	--	--	--	--	--	--	--
Near Terminator Rev 62	199:28	--	--	--	--	6	0	R	48	--	--	--	--
Near Terminator Rev 63	201:26	--	--	--	--	6	0	R	54	--	--	--	--
Far Terminator Rev 70	214:15	--	--	--	--	6	0	R	60	--	--	--	--
Sunrise Solar Corona	216:05	--	--	--	--	7	2	R	69	180	96	H	67
Far Terminator Rev 72	218:12	--	--	--	--	6	0	R	75	--	--	--	--
Near Terminator Rev 72	219:11	--	--	--	--	6	0	R	81	--	--	--	--
Far Terminator Rev 73	220:12	--	--	--	--	6	0	R	87	--	--	--	--
Solar Corona Window Cal	239:05	--	--	--	--	3	2	R	92	--	--	--	--
Lunar Eclipse 2nd Contact	269:05	6	2	V	20	(6) ¹	(2) ¹	P	(64) ¹	--	--	--	--
Sextant Test	270:00	--	--	--	--	--	--	--	--	8	192	H	62
Lunar Eclipse 3rd Contact	270:55	6	2	V	28	(6) ¹	(2) ¹	P	(80) ¹	--	--	--	--

CAMERA SYSTEM		FRM CNT				FRM CNT				% FILM			
FRAME USAGE		DATA	PRTCT	MAG	INDICATE	DATA	PRTCT	MAG	INDICATE	DATA	PRTCT	MAG	REMAIN
TASK	TIME												
Postflight Sensitometry	--	6	0	T	--	7 ²	0	R	--	26 ²	60	H	60
Postflight Sensitometry	--	17 ²	0	V	--	--	--	--	--	--	--	--	--
Postflight Sensitometry	--	15 ²	0	W	--	--	--	--	--	--	--	--	--
Column Frame Totals for VHBW		147	35	T+U+V		98	8	R		608	792	H	
Camera Frame Totals for VHBW		182		T+U+V		106		R		1400 = 35 ft.		H	
Extra Frames of VHBW		6, 9, 3		T,U,V		6		R		2280 = 57 ft.		H	

1. CEX (SO 368) type film; not summed in with VHBW
2. Does not include frames for identification and preflight/postflight processing sensitometer used by Photographic Technology Laboratory after which the following frames are available:

Camera Type	MAG	Usable Frames
35mm NIKON	T	52
" "	U	52
" "	V	48
" "	W	48
70mm HEL	R (P) ¹	112 (155) ¹
16mm DAC	H	3680

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1.0 PURPOSE

The purpose of this procedure is to establish known light standard on flight film so the film can be evaluated upon completion of experiment. This procedure must be worked concurrently with procedure _____ "Film Loading Procedure for the 35mm Flight Camera System".

2.0 APPLICATION

This procedure applies only to film 2485 and 2484 identified by a label (VHBW) on the film cassette. Verification of procedure is recorded in Section 6.0 of this report.

3.0 EQUIPMENT REQUIREMENTS

QUANTITY (IN ADDITION TO THE REQUIREMENTS OF TPS _____)

1 HAO-ATM Sensitometer Box

The above equipment shall be supplied and operated by the principal investigator photo team member or his representative. No calibration stickers or calibration by NASA is required of this equipment.

1 35mm Nikon Camera _____

4.0 IDENTIFICATION PROCEDURE

NOTE: All photography must be accomplished in a dark room under controlled light conditions.

4.1 Inspect cassette per TPS _____.

4.2 Darken dark room

4.3 Load film cassette with film type 2485 or 2484 per TPS _____ paragraph(s) _____. Protect unused film stock from exposure by placing surplus in double, light-tight cans and maintain under strict control for postflight tests.

4.4 Install cassette loaded with 2485 or 2484 type film on the camera.

4.5 Perform identification photograph per TPS _____ paragraph(s) _____.

-
- 4.6 Photo team representative will hook-up power supply, set controls and turn on Sensitometer Box. This procedure will require approximately ten minutes which includes equipment warm-up time.
 - 4.7 Mount camera body without lens on Sensitometer Box.
 - 4.8 Verify neutral density filter is in Sensitometer Box and camera focused on step wedge using reflex viewer.
 - 4.9 Set camera shutter speed to TIME and expose two frames, each for 240 sec. $\pm 2.0\%$
 - 4.10 Expose two frames, each for 180 sec. $\pm 2.0\%$.
 - 4.11 Expose two frames, each for 120 sec. $\pm 2.5\%$.
 - 4.12 Expose two frames, each for 90 sec. $\pm 4.0\%$.
 - 4.13 Expose two frames, each for 60 sec. $\pm 5.0\%$.
 - 4.14 Expose two frames, each for 30 sec. $\pm 5.0\%$.
 - 4.15 Expose two frames, each for 20 sec. $\pm 5.0\%$.
 - 4.16 Expose two frames, each for 15 sec. $\pm 5.0\%$.
 - 4.17 Expose two frames, each for 10 sec. $\pm 5.0\%$.
 - 4.18 Expose two frames, each for 8 sec. $\pm 6.5\%$
 - 4.19 Expose two frames, each for 4 sec. $\pm 10.0\%$
 - 4.20 Expose two frames, each for 2 sec. $\pm 20.0\%$
 - 4.21 Set camera shutter speed to 1/8 and expose two frames.
 - 4.22 Set camera shutter speed to 1/15 and expose two frames.
 - 4.23 Set camera shutter speed to 1/30 and expose two frames.
 - 4.24 Set camera shutter speed to 1/60 and expose two frames.
 - 4.25 Turn off Sensitometer Box and reset aperture to minimum opening.
 - 4.26 Set camera shutter speed to 1/1000, expose frame and do not advance film.

-
- 4.27 Open camera back, mark last frame and close camera back.
- 4.28 Rewind film into cassette per TPS _____ paragraph(s) _____ and mark as cassette "W". Verify cassette working.
- 4.29 Turn up darkroom lights and reconfigure Sensitometer Box by changing to cover plate without neutral density filter holder and filters. Verify plate changed.
- 4.30 Repeat paragraphs 4.1 through 4.5.
- 4.31 Advance film onto take-up spool until six frames from end of cassette film load or from tail end identification frames. Verify film properly positioned.
- 4.32 Repeat paragraphs 4.6 through 4.8
- 4.33 Set camera shutter speed to 1/8 and expose two frames.
- 4.34 Set camera shutter speed to 1/15 and expose two frames.
- 4.35 Set camera shutter speed to 1/125 and expose two frames.
- 4.36 Turn off Sensitometer Box.
- 4.37 Rewind film into cassette per TPS _____ paragraph(s) _____ and mark as cassette "T". Verify cassette marking.
- 5.0 UNLOADING PROCEDURES
- 5.1 Cassette "W" and "T" will contain additional film purposely left unexposed so that postflight Sensitometer Box exposures can be accomplished.
- 5.2 Darken dark room.
- 5.3 Install cassette "W" in the camera.
- 5.4 Transport film onto take-up spool until marked frame of paragraph 4.27 just passes image plane and close camera back.
- 5.5 Perform paragraphs 4.6 through 4.24 or as much as remaining film will allow.
- 5.6 Rewind film into cassette, remove cassette and unload film per TPS _____ paragraph(s) _____.
- 5.7 Install cassette "V" in the camera.

- 5.8 Transport film by counting frames onto take-up spool until second of remaining, unused frames is positioned over image plane.
- 5.9 Perform exposures not completed under paragraph 5.5 or as much as remaining film will allow.
- 5.10 Rewind film into cassette, remove cassette and unload film per TPS _____ paragraph(s) _____.
- 5.11 If required, install cassette "U" in the camera and perform paragraphs 5-8 through 5.10.
- 5.12 Install cassette "T" in the camera.
- 5.13 Repeat paragraphs 4.1 through 4.5.
- 5.14 Advance film onto take-up spool until twelve frames from end of cassette film load or from tail end identification frames. Verify film properly positioned.
- 5.15 Repeat paragraphs 4.6 through 4.8.
- 5.16 Repeat paragraphs 4.33 through 4.36.
- 5.17 Rewind film into cassette, remove cassette and unload film per TPS _____ paragraph(s) _____.
- 6.0 DATA SHEET

INSPECTION
VERIFICATION

- 6.1 Surplus film stock protected from exposure per paragraph 4.3 _____
- 6.2 Paragraphs 4.8 _____
- 4.9 _____
- 4.10 _____
- 4.11 _____
- 4.12 _____
- 4.13 _____
- 4.14 _____
- 4.15 _____
- 4.16 _____

✓

6.2 Paragraphs 4.17

4.18

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4.37

6.3 Paragraphs 5.14

5.15

5.16

DATE _____

INSPECTION _____

APOLLO LUNAR ORBITAL, ASTRONOMICAL PHOTOGRAPHIC TASKS

Proposed Procedures for NASA Support of Data Analyses for Each Flight

1. Preparation of "Preliminary Data Package" by NASA MSC and Apollo Lunar Orbital Photographic Science Team containing the following information:
 - a. A list of Astronomical Photography including
 - 1) Time of exposure
 - 2) Duration of exposure
 - 3) Film type and processing specification
 - 4) Camera type and settings
 - 5) Lens type, settings, and field-of-view size
 - 6) Celestial/lunar/earth location of frame center and orientation.
 - b. A set of duplicate negatives of astronomical exposures with a set of development H&D curves for the original negatives.
 - c. Isodensitraces and/or lines-of-interest sensitometry measurements for the best or for a representative example frame from each astronomical subject photographed.
 - d. Pertinent, quick-look supporting data on trajectory, crew comments, post-flight technical debriefings, etc. that might be available early.
2. Principal Investigator Analysts review the "Preliminary Data Package" and specify in writing to the NASA Data Analyses Manager what data may be of interest including the extent of their further participation in the final data reduction.
3. NASA Data Analyses Manager will do the following:
 - a. Collect and organize the individual expressions of interest in further data reduction from the PI Analysts.
 - b. Determine the extent of funding necessary and of NASA facilities required to support the Analyst PI efforts.
 - c. Coordinate directly with appropriate Analyst PI's as to the time and place for a Data Review Session with the PI's in attendance.

4. The Data Review Session will be held at the appropriate facility (probably MSC) chaired by the NASA Data Analyses Manager with the invited Analyst PI's, the required NASA personnel and their specified contractors. Purpose of this meeting will be to:
 - a. Review all flight data from astronomical tasks and the supporting information in order to prepare exact procedures before continuing with handling of the original photographic material.
 - b. Continue with specified, additional densitometry and/or special reproductions from flight negatives, with Analyst PI's in attendance.
 - c. Perform additional or special post-flight calibration measurements on:
 - 1) Flight hardware such as cameras, lenses, spacecraft windows, etc.
 - 2) NASA data handling and processing equipments used for initial work including photographic processing equipment, densitometers, light sources, etc. This work will include cross-calibration procedures to relate Analyst PI's standards and laboratory calibrations with those used by NASA..
5. A series of separate meetings will be held between the NASA Data Analyses Manager and each Analyst PI after the Data Review Session and its associated work. These meetings will:
 - a. Review the Analyst PI's original proposal to NASA and his expression of interest for the current flight data so that a specific plan for data analysis can be rewritten as necessary.
 - b. Determine exactly how NASA facilities and personnel will work with the Analyst PI and visa-versa.
 - c. Specify as completely as possible on the part of the Analyst PI:
 - 1) Final requirements for original flight material.
 - 2) Procedures for data handling outside NASA facilities.
 - 3) Schedules for completing work on key portions of the data analyses.
 - 4) Methods and formats for reporting results.
 - 5) Contacts and coordination procedures with the appropriate NASA groups with whom the Analyst PI must work.