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TECHNICAL REPORT

APOLLO 16 PHOTOGRAPHIC STANDARDS DOCUMENTATION

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Written by

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APOLLO 16 PHOTOGRAPHIC STANDARDS DOCUMENTATION

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ABSTRACT

This report documents the activities of the Photographic Technology Division, and particularly the Photo Science Office, the Precision Processing Laboratory, and the Motion Picture Laboratory, in connection with the scientific photography of the Apollo 16 manned space mission. It describes the preflight activities involved in establishing a standard process for each of the flight films, the manner in which flight films were handled upon arrival at the Manned Spacecraft Center in Houston, Texas, and how the flight films were processed and duplicated. The "tone reproduction" method of duplication is described. The specific sensitometric and chemical process controls are not included in this report, but are available on request.

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SECTION I

INTRODUCTION

This report documents the activities of the Photographic Technology Division (PTD), which includes the Photo Science Office (PSO), Precision Processing Laboratory (PPL), Motion Picture Laboratory (MPL), Still Laboratory (SL), and Quality Control (QC), in connection with the scientific photography of the Apollo 16 manned space mission.

In order to obtain a maximum amount of accurate information from the imagery produced, photography of optimum quality is essential. A large number of variables affect the quality of this imagery. The more variables that can be identified and controlled, the more reliable will be the resulting information. The purpose of this report is to identify and describe the method of dealing with some of the variables encountered in film selection and calibration, process control, and duplication and tone reproduction, as related to the Apollo 16 mission.

SECTION II

PREPARATIONS FOR FLIGHT FILM CONTROL

A. Chronology

The following is a timetable of the major events in the handling of Apollo 16 films; many of these events are detailed in this report.

DATE	EVENT
26 January 1972	NASA-contracted aircraft to Eastman Kodak for pickup of Apollo Mission Film (except SO-168, 70mm)
15 March 1972	SO-168 (70mm) picked up at Eastman Kodak
28 March 1972	NTB-3 for the S-201 Experiment hand-carried to PTD for sensitometry and returned to NRL for electronographic exposure calibration.
2 April 1972	Film spooled and premission sensitometry applied to CM and LM flight film, latent image control samples, and backup film
3 April 1972	Application of sensitometry on SIM Bay flight film.
5 April 1972	Flight film delivered to KSC
9 April 1972	NTB-3 delivered to KSC from NRL
10 to 11 April 1972	Magazines loaded at KSC, and cameras tested by exposing to resolution/color charts
15 April 1972	Magazines loaded on spacecraft
16 April 1972	Liftoff
16 to 27 April 1972	Cameras used for Apollo 16 photography; film exposed to space radiation environment.

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27 April 1972	Splashdown
29 April 1972	Films received at LRL, accounted for, and sent to PTD.
29 to 30 April 1972	Magazines inspected, condition documented, and film downloaded. Postmission sensitometry applied to flight film and latent image control samples.
18 May to 29 April 1972	Processing of flight film: 1. Processing of PTD sensitometric control film to certify processor control. 2. Processing of flight film, PTD sensitometric control film, latent image test control sample, resolution target friskets. 3. Visual inspection of flight film photographs.
5 June to 30 April 1972	Master and tone reproduction duplication of flight films involving densitometric analysis. Permanent storage in vault at PTD.

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B. DESCRIPTION OF MISSION FILMS

The following is a description of the physical and photographic characteristics of the film used on the Apollo 16 mission.

Type 2485 Film (Magazines HH, MM - 16mm; WW, XX, YY, ZZ, W, X Y - 35mm; SS, TT - 70mm):

This is an extremely high speed panchromatic film with extended red sensitivity. It is recommended for a wide variety of photorecording applications where very low exposure levels must be recorded. This film was used during the dim-light photographic experiments of Apollo 16. The emulsion is coated on a 4.0 mil Estar base and incorporates an antihalation undercoating and PX backing. Processing of the 16mm, 35mm, and 70mm film was accomplished in the Hi-Speed Motion Picture Processor using Kodak D-19 chemistry under the control limits specified in Section II, Paragraph D. Magazines WW and YY were not used.

Type 3400 Film (Metric Camera Cassette, 5-inch):

Panatomic-X Aerial Film is an intermediate speed, thin-base, high-altitude reconnaissance film. It is fully panchromatic with extended red sensitivity, and is coated on a 2.5 mil Estar base with a pelloid impregnated, dyed, antihalation gel backing. This film was used for orbital photography of the lunar surface, and for topographic photography of candidate exploration sites for future Apollo missions. Processing of the 5-inch film was accomplished in the Fultron Processor in MX-819-1 chemistry at 85°F. The resultant data was compared to predetermined control limits as specified in Section II, Paragraph D.

Type 3401 Film (Stellar Camera Cassette, 35mm; Magazines G, H, I, J, K, L, M, UU - 70mm):

Plus-X Aerial Film is a panchromatic negative camera film with high contrast, medium speed, high acutance, fine grain, and extended red sensitivity. It is coated on a 2.5 mil Estar base with dyed gel backing. On the Apollo 16 mission, this emulsion was used for stellar mapping, topographic, and geological survey photography.

Type 3414 Film (Panoramic Camera Cassette, 5-inch):

This film is a slow speed, high contrast, fine grain panchromatic emulsion with extended red sensitivity. The emulsion is coated on a 2.5 mil Estar base which has a dyed gel backing. Its resolution capability is 630 l/mm at 1000:1 target contrast and 250 l/mm at 1.6:1 target contrast. Its use during the mission was for candidate site exploration, transearth lunar photography, visibility at high sun angle experiments, and Command Service Module (CSM) orbital science photography experiments. Processing of the 5-inch film was accomplished in the Fultron processor in MX-819-1 chemistry at 85°F. The film process control limits are specified in Section II, Paragraph D, and in Attachment 1, "Special Processing of Apollo 16 Pan Camera Film".

Type SO-164 Film (Magazine II - 16mm):

Panatomic-X Recording Film is an intermediate speed, high contrast film with extended red sensitivity. It is coated on a 2.5 mil Estar base with a pelloid impregnated, dyed, antihalation backing. This film was used primarily for mass spectrometer boom photography. Processing was accomplished in the Houston Processor in D-19 chemistry.

Type SO-168 Film (Magazines JJ, LL - 16mm; A, B, C, D, E, F - 70mm: VV - 35mm):

This color reversal film is high speed (ASA = 160 with normal processing) Kodak Ektachrome FF emulsion. The high speed and long exposure range make this film suitable for lunar surface exposures where harsh lighting conditions produce dimly lit shadows and extremely bright highlights. Magazines JJ and VV were used to photograph Skylab food and meal preparation; Magazine LL was not used. Of the 70mm magazines, Magazine C was approximately 1 stop overexposed. No processing correction was attempted for this magazine since the exposure condition was not known until after the film was processed. The emulsion of .082 mil is coated on a 2.5 mil Estar base having an antihalation undercoating and PX backing. Processing for the 35mm and 70mm was accomplished on the Houston Processor in ME-4 chemistry (developer temperature at 98°F.) at 10.5 feet per minute. Processing for the 16mm film was done on the RAM Processor in ME-4 chemistry (developer temperature 98°F) at 60 feet per minute. The processing control limits are specified in Section II, Paragraph D. This film was used for documentation and public information photography.

Type SO-368 Film (Magazines AA, BB, CC, DD, EE, FF, GG, KK, N, O, P, Q, R, S, T, U - 16mm: NN, PP, QQ, RR, V - 70mm):

This reversal color photographic material was used on Apollo 16 for exterior photography. It has an ASA of 64 with normal processing. The film is coated on a 2.5 mil Estar base having an antihalation undercoating and a PX backing. This film was processed in the Motion Picture Laboratory Hi-Speed Processor with ME-2A chemistry at 75.5°F. to the control limits specified in Section II, Paragraph D. This film was used for documentation and public information photography. Magazines DD, KK, and U were not used.

<u>Type IIaO Film (Magazine OO - 70mm):</u>
This spectroscopic film is recommended for use in the ultraviolet for wavelengths shorter than 220nm. It is a panchromatic emulsion coated on a 4.0 mil triacetate base. On the Apollo 16 mission, this film was used for obtaining UV photography of the earth and moon for use in the study of planetary atmospheres and fur the investigation of short wavelength radiation from the lunar surface. Processing was accomplished in the Hi-Speed Processor in D-76 chemistry.

<u>Type NTB-3 Film (Emulsion thickness - 6μ; 35mm width unperforated):</u>
This nuclear track emulsion is used for recording Alpha particles, protons, deuterons, mesons, and fission fragments. It will record electron tracks with energies less than 30 Kev. The Apollo 16 6μ thick emulsion was coated on a 2.5 mil Estar base with nominal 1μ thick gel overcoat. It was used on the lunar surface for obtaining photographic imagery and spectroscopic data on celestial objects in the far ultraviolet region in order to detect and map the location of interplanetary, interstellar, and intergalactic hydrogen.

C. SENSITOMETRIC EXPOSURES

An Eastman I-B Intensity Scale Sensitometer was used in the PTD to simulate light incident upon or reflected from the surfaces of the earth and moon. To accomplish this simulation, the entire sensitometric system is calibrated in terms of absolute units for each situation. The components that must be considered are the source, light filtration, optical path length, and shutter mechanism. Each of these factors affects the spectral characteristics and quantity of radiant energy striking the photographic emulsion.

Photometric and spectroradiometric measurements are made to determine the desired operating color temperature of the illuminant. Spectrophotometric analysis is applied to all of the optical components to determine the effect of each on the system's spectral energy distribution. All data is derived in terms of radiometric units ($ergs/cm^2$) and then used to calculate the equivalent photometric units, where applicable, in terms of meter-candle-seconds.

With a knowledge of the exposure conditions planned for the mission photography, a test plan was developed by PTD photo-scientists to simulate these conditions. Table I in the Appendix lists the sensitometric exposure conditions for both process control strips and flight film documentation.

With the lamp burning at a color temperature of 2850°K, a Corning C-5900 glass filter, ground to a thickness of 4.15 mm, plus a Pittsburg 2043 filter, is used to simulate incident sunlight at 5500°K. A C-5900 filter, with a thickness of 3.63 mm is used to simulate reflected light at 4750°K.

D. CONTROL ESTABLISHMENT PROCEDURES

Since a photographic image is the result of the interaction of two major variables, exposure and processing, it was necessary to determine the control parameters for handling the original film. To accomplish this objective, conferences between the various users of Apollo 16 photography and the PTD Photo Science Office were conducted prior to the mission.

To establish "flight film control" conditions, each processing machine* was brought to an "in control" standard condition as determined by mechanical, chemical and sensitometric tests by the Photo Science Office. Samples of each mission film type, exposed as listed in Table 1, were processed until the results specified in the test plan were achieved. A standard control curve was then generated for each film type by making ten identically exposed sensitometric strips, aging them for one hour to

*Black and white films were processed in Kodak Versamat Model 11C-M and Fultron Processors; color materials were processed in the Houston and Ram Processors incorporating ME-4 chemistry, and the Hi-Speed Processor using ME-2A chemistry.

permit the latent image to stabilize, then processing them in a single group according to the previously determined conditions.

The ten strips were read on one of the PTD densitometers, and the resultant readings were averaged to yield the final process control curve. (Section F describes the manner in which these densities were used to generate the control curve.) The resultant curves from each of the mission film sensitometry were then used as the aim curves to establish control before the mission film was processed.

The additional photographic requirements placed on Apollo 16 in the SIM Bay (Panoramic, Metric and Stellar cameras) and the UV equipment areas, dictated the need for establishing special techniques in the handling and processing of the films involved.

The use of a Fultron, continuous spray/immersion type, processor was employed to handle the long lengths of film used in the Panoramic and Metric camera systems. The operationsl procedures employed wherever applicable for this mission were those described in the NASA Document MSC-05826 Procedures for Processing Scientific Instrumentation Bay (SIMBay) Films, April 1972. All processor readiness tests were conducted under actual mission handling, processing and operation procedures. During the course of these tests, in which over 200,000 feet of film were processed, sensitometric, chemical, mechanical and personnel readiness were proven to be within the control specifications. Procedures were defined by the Photo Science and Precision Laboratory. The tolerances placed on the process control curves for the Panoramic and Metric Camera Films were as follows:

	Optical Bar Camera Film Type 3414	Metric Camera Film Type 3400
Density	± .05	± .05
Fog	± .04	± .04

During the actual mission processing operation, exacting sensitometric control was maintained within the above limits.

Three problem areas were encountered during the actual mission and postflight film handling sequences. In the first instance, telemetry data from the Panoramic Camera indicated that the majority of the imagery would be from $1\frac{1}{2}$ to 2 stops overexposed due to a malfunction in the system's Automatic Exposure Control. Based on First Revolution telemetry data estimates, the overexposed portion of the imagery amounted to about 2/3 of the total imagery. The remaining imagery was estimated to be "normally" exposed.

As a result, PTD's Photo Science Office conducted a study to determine the feasibility of modifying the preestablished process (Control Curve PCD-D) to meet the following objectives:

1. Retain the toe speed for the "normally" exposed near-terminator photography.

2. Retain an "acceptable" density range for the overexposed imagery.

The test program (See attached Technical Note, "Special Processing of Apollo 16 Pan Camera Film") concluded that the objectives could be met. After evaluation of the test results by members of the NASA Photo Team and representatives from PTD/PSO, the following procedures were followed in processing the Pan camera film:

1. Two cuts were made from the TEI photographic portion of the flight roll. One was 310 feet long; the other was 200 feet long.

2. Postmission sensitometry was applied to a three-foot section of unexposed film from the head end of the roll (Figure 1).

3. The 310-foot section, along with the three-foot sensitometry section, was then processed according to the modified process control curve (Figure 2).

The processed imagery was densitometrically evaluated with a

MacBeth macrodensitometer, utilizing a 2mm aperture, and the densities were related to the sensitometric data obtained with the imagery. Figure 2 displays these results.

The plot depicts the density range representing the average of densities (Dmax and Dmin) for seven frames chosen at random. (Table 2 represents the actual densities as read from each frame of photography.)

By direction of the NASA Photo Team, the midscene value for the Pan Camera Automatic Exposure Control System was once again chosen to be at a Log E value of 1.50. Considering Point C, on Figure 2, as the central portion of the average density range on the modified process control curve, it can be seen that the difference in Log E units between the proposed and modified midscene values is now .34 units. Therefore, the imagery resulting from the modified process is approximately one stop overexposed.

In addition to the retention of an acceptable density range in the overexposed flight imagery, the Log Exposure range yet available is in the order of 0.60 to 0.90 Log E units before the curve shoulders and maximum density is achieved. This Log E range extension is depicted in Figure 2 by Curve A which represents the extension of Curve B from a density of 2.0.

Based on the above data and other data resulting from the test program, the decision was made to process the remaining portion of the Pan Camera Flight Film to the modified control curve.

The second problem was with the exposure of the lunar surface imagery on Film Type 3401. Due to the sun angle being higher than expected, the preestablished process for the flight film had to be modified to reduce the maximum density and extend the density range of the imagery. A test was conducted in the Fultron Processor with MX-819 chemistry utilizing sensitometric exposures and simulated lunar surface imagery exposed on 3401 film. The results of the test indicated that the objectives could be met with an increase in toe speed which would benefit the imagery within the lesser illuminated lunar surface subject areas. Figure 3 represents the modified process control curve for the lunar surface black and white photography.

During the processing preinspection of the Metric and Stellar Camera films the third major problem was discovered. A large quantity of metallic chips and shavings were found scattered throughout the surface areas of these flight films.

Due to the degrading potential that these chips would have on the emulsion and base if they adhered to the rollers as the film was being transported through the Fultron (Figure 4) and Hi-Speed processors, a mechanical cleaning device was designed to remove the chips before the films were fed into their respective processors. (Figures 5 & 6 depict this technique as applied on the Fultron Processor. A similar technique was applied to the Stellar film before entry into the Hi-Speed processor.) Upon postprocessing inspection of the Stellar and Metric camera films and examination of the pressure and drive rollers on the Fultron Processor, it was concluded that the mechanical cleaning technique did, in fact, remove the chips and shavings from the films. The inspections further revealed that these chips did not adversely degrade the flight imagery.

During the preflight investigations conducted to determine the optimum process and film handling techniques for the IIaO, 2485 and 3401 (Stellar) Apollo 15 flight films, it was determined that the Hi-Speed Motion Picture film processor should be used for processing these films. Again for Apollo 16 the need arose to employ the Hi-Speed processor for the IIaO film (Experiment S-177), the 3401 Stellar Camera film, film from the dim-light and Geghenschein experiments (Type 2485), and the S-201, UV Spectroscopic Camera experiment which utilized Film Type NTB-3.

The Photo Science Office provided basic assistance for the

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FIGURE 5

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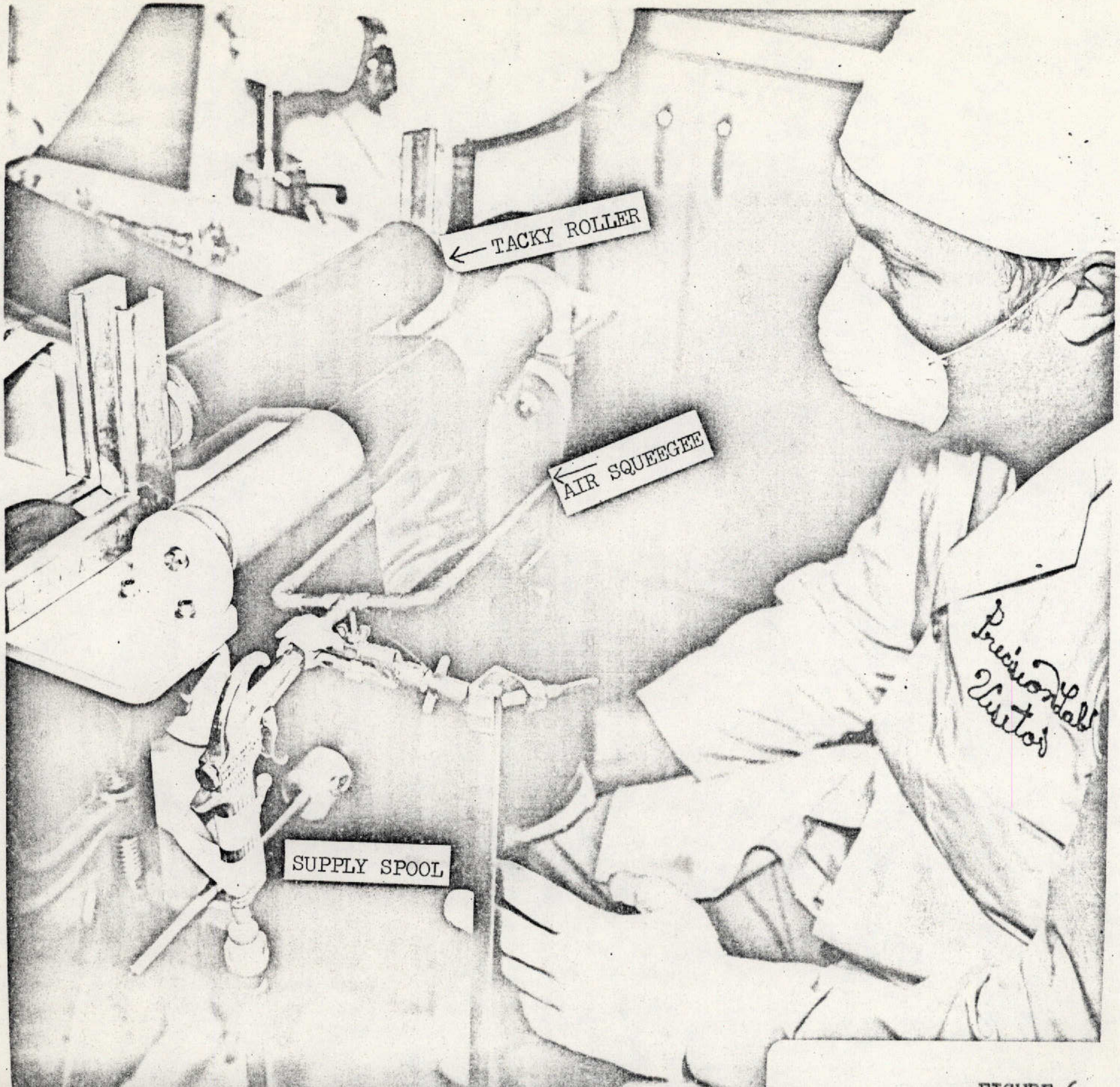

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FIGURE 6

Spectroscopic UV Camera (S-201) experiment, in establishing handling procedures, processing control, reproduction techniques, and the creation of colored density segments by use of Agfacontour Film for the NTB-3 film.

The characteristics of the NTB-3 film are such that extreme care had to be taken in the pre- and postmission handling of the flight film. Due to the emulsion being extremely pressure sensitive, flight film processing simulations were conducted to determine if any degradation to the emulsion would occur as the film was transported through the processor. Since the initial flight film certification tests dictated that the Fultron processor be used as the optimum processing configuration for NTB-3 flight film, the simulation was conducted on this machine.

Contact between the emulsion and the processor transport rollers resulted in abrasion marks over the entire length of the emulsion. This effect dictated a change in the proposed processor and processing configuration for the flight film. A secondary processing simulation was run utilizing the Hi-Speed Motion Picture Processor which does not have contact between the emulsion and the transport rollers. The results from this simulation dictated the use of this processor for processing the flight film. Figure 7 represents the final process control curve for the Apollo 16 NTB-3 flight film.

Special procedures were followed during the postmission handling of the NTB-3 flight film to determine the effects of the expected proton radiation fogging on the film during the course of the mission. Upon downloading the film from the "Film Transport Box", a piece of film, one inch in length, was cut, processed, and densitometrically evaluated. Since the base-plus-fog density of 0.13 (showing a radiation contribution of .06 density units) did not exceed the limiting value of .18 density units, it was decided to retain the preestablished processing technique for the flight film.

Consultations with the principal investigators provided assistance for many of their special photographic requirements. For example, premission fog level tests were conducted using the accelerator at Rice University. These tests enabled verification of mathematically predicted density levels, for base-plus-fog, under various doses of proton radiation.

In addition to the fog tests, special care has been given to the density separations which will be assembled to color code the gas concentrations surrounding the earth and various star clusters.

Figure 8 represents a result of the Agfacontour density slicing technique. To enhance the various tones rendered in the original image, four separations were made at different density levels. The image was then reconstructed using a prechosen spectral band for each of these density levels.

The red, green, and yellow colors represent three brightness levels of the Geocorona, while the blue color represents space.

Although different black and white chemistries and processor speeds were used to process each of the aforementioned film types, this processing system produced the desired results, with little measurable variability, regardless of developer activity, agitation rate or interaction of those two variables.

For all of the films involved in Apollo 16, control limits were established for gamma, density and speed (for color emulsion $\pm$ .04 Log E units for the yellow, magenta, and cyan layers).

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E. CHEMISTRY ANALYSIS PROCEDURES

During the establishment of processing control, a chemical analysis program was carried out by Quality Control technicians. This program monitored chemical parameters which, when within specific tolerances, signified the processing solutions as "in control". Chemistry checks included hydrogen ion content (pH) and specific gravity (SG). In addition, developers were tested for total reducing power (TRP) and bromide content (KBr). This information is available in the Photo Science Office of the Photographic Technology Division.

F. DENSITOMETRY

Several transmission type densitometers are utilized within the PTD for process control and analysis. A program of daily quality control assures that these instruments produce readings which agree with each other and with the calibrations of a Master NBS calibrated step tablet within $D = \pm 0.02$ in density range of 0 to 3.5, which more than covers the useful density range of these original materials.

SECTION III

FILM HANDLING PROCEDURES

The flight films were purchased from one to four months before the mission, certified and then refrigerated in the PTD until one week before liftoff. During that week, the majority of the film was thawed and spooled, sensitometric control strips were exposed on the end of each roll of flight and backup film.

Premission handling of the NTB-3 flight film involved procedural changes to the "normal" PTD plan.

After the premission sensitometry had been applied to two rolls of the flight film, the Principal Investigator loaded the prime and backup film transport boxes.

Upon completion of the preflight sensitometry and film loading procedures, the film transport mechanisms were returned to the Naval Research Laboratories where Electronographic and Spectrographic calibrations were made on the film. These calibrations are required for analysis of the mission imagery. Figure 9 depicts the NTB-3 Flight Film make-up.

For the NTB-3 and the other flight films, sensitometric exposures were made on control samples of the same emulsion batches. These samples (classified as "Houston Controls") were kept in the PTD in sealed film cans at room temperature, which approximated the conditions encountered by the flight film within the spacecraft. By comparing the D-Log E curves produced by these exposures with those produced by identical exposures made on the Houston Controls and on flight films just prior to processing the effect of latent image decay and the effects of the space environment on the flight film can be determined.

This is exemplified by the following:

Film Type	Format	Background Density		ΔD
		Control	Flight Film	
2485-107-2	70mm	.20	.58	.38
2485-107-2	35mm	.20	.55	.35
3401-378-6	70mm*	.09	.19	.10
3401-378-6	70mm	.15	.25	.10
3401-278-11/1	35mm	.10	.17	.07
IIaO-129771	70mm	.16	.30	.14
NTB-3-088-03-01	35mm	.06	.14	.08
3400-254-3	5 in.	.26	.30	.04
3414-16-5	5 in.	.21	.21	---
SO-168-9-1	70mm	R-3.14 G-3.10 B-3.20	R-2.95 G-2.92 B-5.00	R-.18 G-.18 B-.20
SO-368-18-32	70mm	R-2.90 G-3.25 B-3.76	R-2.78 G-3.05 B-3.50	R-.12 G-.20 B-.26

*Film Type 3401 (PCD-K) for Mag UU processed in Kodak B & W Versamat MX-641 chemistry: all other 3401 mags were processed in the Fultron Processor using MX-819 chemistry.

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The variations in density, when compared to a series of Cobalt$_{60}$ radiation tests conducted by PTD, indicated the film was exposed to $\approx$0.8 rad radiation dosage. The variations within the deltas for the same film types are attributed to the various storage locations within the spacecraft and the differences in shielding.

The films located in the SIM Bay showed little effect due to the environment. For Film Type 3414 the pre- and postsensitometry showed no rise in fog level due to environmental conditions. However, Film Types 3401 (Stellar camera film) and 3400 did display an increase of .07 and .04 density units, respectively. This increase was attributed to radiation fogging. The limited increase in fog did not adversely affect the resultant imagery and data analysis.

Resolution friskets were exposed onto most of the sensitometric strips (Master frisket Number 70505). Table 3 in the Appendix lists the resolution values of the target used and gives the modulation of each of the five rows.

After splashdown, the film magazines (including the SIM Bay camera magazines) were sent to Ellington Air Force Base. From Ellington, the film magazines were sent to the Lunar Receiving Laboratory (LRL). The magazines were delivered in Halliburton containers to PTD where they were downloaded and prepared for processing.

SECTION IV

FLIGHT FILM PROCESSING

Before the flight film was processed, chemical control was established to match the preflight control standards. Control strips were processed, read, averaged, and plotted according to the preestablished procedures. Based on the criteria established by the Photo Science Office, if the control densities were not within the tolerance limits, appropriate changes were made in processing speed, processing temperature, or chemistry, and the procedure was repeated until certification was accomplished. While these procedures were in process, sensitometric exposures were made on the flight film and on the latent image test control samples which had remained in the PTD during the flight.

With the processors "in control", a final mechanical certification was performed. Apollo simulated imagery was processed to check for scratches and macroscale density nonuniformities in all of the processing equipment.

Chemical checks were made on the machines, e.g., specific gravity and pH measurements were made on the developer solutions. If PSO recommended any changes, the corrective action was followed by additional control samples for verification of the action taken.

Once the processor was ready to process the flight film, it was spliced to a machine leader. A low-level infrared viewer aided the technicians in preinspection and splicing. Latent image tests, resolution friskets, and control sensitometry were processed at the same time. Figures 10 and 11 illustrate the sequence of elements composing the film roll on the processors.

In general, the film handling procedures were similar for all flight films. However, for the SIM Bay Systems, representatives from the NASA Photo Team, ASPO, and PTD met to decide whether the film would be processed in sections or as a continuous roll. (Refer to Section II-D for procedures used.)

Special handling and processing requirements requested by the Principal Investigator, were placed on the Type 2485 film. The 2485 flight film was divided into three format sizes, i.e. 16mm, 70mm, and 35mm. After processing, each group was reviewed by the Principal Investigator to assess the adequacy of star fields, imagery, and sensitometry.

SECTION V

APOLLO 16 PHOTOGRAPHIC TONE SCALE REPRODUCTION

The procedure of tone reproduction control was applied to the eleven rolls of 70mm black and white negative originals and to the individual parts of the Metric Camera and Pan Camera Flight Films. The densities in the processed original film represent a photographic measurement of the luminances existing in the scene at the time of exposure. From this negative, a second generation print, or master positive, is made using the film type, printing exposure, and processing condition best suited to accurate correspondence between master positive densities and original scene luminances.

Because the final use of the master positive will depend on whether a desirable visual appearance is needed or an actual physical density measurement is to be made, the selection of the printing and processing conditions must be controlled by the final requirement. The choice of printing levels is made on the basis of maximum and minimum densities of representative frames in the original processed negative.

The general aimpoint in printing the master positives is to render the negative Dmax to a positive print density of 0.40. If the positive density resulting from the exposure through the negative Dmin is too high, another print is made which is balanced for optimum rendition of that part of the negative information.

Tables 4 and 4A list the average minimum densities, positive density produced in printing from the negative Dmax, and the process gammas for each roll/cut of dried imagery.

SECTION VI

FLIGHT FILM DUPLICATION

As soon as the processing of all of the original film on hand had been completed, "quick look" positive duplicates were made. These were reviewed and frames selected for general news release. Negatives, internegatives, and/or transparencies of these frames were made from masters, and released to the news media directly or through prints made in the Still Laboratory.

When the urgent requirements of the news media had been satisfied, the task of providing scientific information was begun. Masters, tone reproduction masters, and direct negatives were produced as directed by the controlling distribution documents. To identify the various generations of black and white duplicates, the following terminology is used in the PTD.

Original - the film exposed in the camera. This is normally a "negative", in which the tonal values of the original scene are reversed. This is the "first generation".

2nd Generation Positive - a "master positive" made directly from the original negative by continuous printing. The tonal orientation corresponds to that of the original scene.

2nd Generation Tone Reproduction - a special "master" made under close sensitometric control of exposure and processing to permit the derivation of photometric information from this generation.

3rd Generation Negative - a "duplicate negative" printed from the 2nd generation positive or 2nd generation tone reproduction master with the intent of duplicating the original negative.

4th Generation Positive - a duplicate produced for viewing rather than photometric purposes. This is printed from a third generation, or duplicate negative, derived from the master positive.

2nd Generation Negative - a direct negative made from the original negative by using a blue-sensitive direct reversal material of high acutance. This material is intended for one-step duplication of aerial reconnaissance negatives of high definition. The results achieved through the use of this material represent the best method of original duplication, where subsequent reproductions will be made and where retention of image detail and acuity are important factors. This method of reproduction is highly recommended by PTD.

For duplicating Apollo 16 black and white negatives, Kodak types 2420, 2430, and 2422 films were used. The parameters which governed the making of tone reproduction masters and negatives, and an analysis of the tone reproduction system of duplication, are contained in Section V.

All original and duplicate color materials are processed by the reversal method, which produces a "positive" reproduction in each generation. The terminology employed for black and white duplication is followed in color duplication.

Color Original - the color film exposed in the camera. This is a positive image, the "first generation".

Color Master - a duplicate positive made directly from the color original by continuous contact printing. This is the "second generation".

Color Release Positive - a third (or higher) generation duplicate.

No tone reproduction duplicates were made from color originals. No technique is presently available which provides adequate sensitometric control of the reversal color process to the extent that sensitometrically controlled color duplicates are of consistently acceptable color balance and tonal reproduction.

All color duplicates are visually timed (density and color corrected) to the film from which they are printed to produce the best overall color quality.

Black and white original negatives were frame-numbered; masters were exposed on Kodak Film Types 2420 and 2430 on a Niagara continuous printer, then processed in a Fultron processor with MX-641 developer.

Masters were made from the original Type SO-168 film color transparencies by the MPL in order that frame numbers might be applied to the edge of the film by double printing on a Bell and Howell 70mm Model "C" motion picture continuous printer. (No problem was encountered in this operation on black and white film since unexposed areas, such as the film edge, have a low density and identifying numbers can be applied with opaque ink. Reversal color film, on the other hand, is opaque when unexposed.)

Once edge numbers had been applied, additional generations were printed on the B & H Model "C" in the MPL. Duplicates from Film Types SO-168 and SO-368 original were all made on Kodak Ektachrome Type 5389 Reversal Print Film.

SECTION VII

CONCLUSION

Due to the cooperation of experimenters and the combined efforts of NASA and Technicolor Graphic Services, Incorporated, the Apollo 16 photographic requirements were handled with a minimum of difficulty. A product of optimum quality was expeditiously delivered to investigators and news services.

Sensitometric information generated for the Apollo 16 mission, is on file in the Photo Science Office of the Photographic Technology Division. Since this specialized information may not be of value or interest to many of the readers of this report, it is being made available on a request basis. Requests may be directed to the Photo Science Office of the Photographic Technology Division (JL), National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, 77058.

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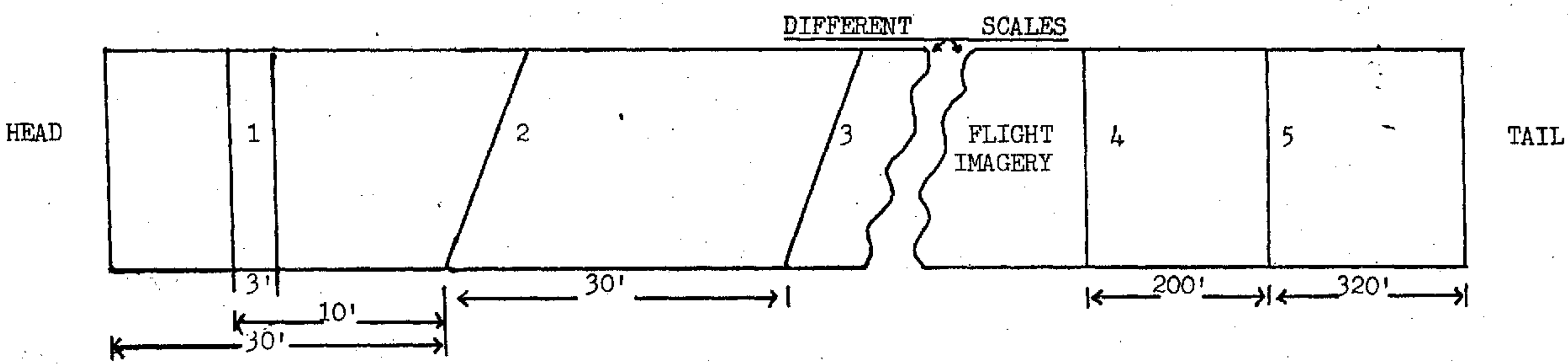
APPENDIX

APOLLO 16 SENSITOMETRIC EXPOSURE AND PROCESSING CONDITIONS

PCD	DESIGNATION	FILM	EMULSION NUMBER	SIZE	PROCESSOR	CHEMISTRY	FILTRATION	EXPOSURE TIME
A	BW	3400	254	5 in.	Fultron	MX-819	$4750^{\circ}K$ + Wr 12	1/50
B	HBW	3401	378-11/1	35mm	Hi-Speed	D-19	$5500^{\circ}K$	1/50
C	HBW	3401	378-6	70mm	Versamat	MX-641	$5500^{\circ}K$	1/50
D	LBW	3414	16	5 in.	Fultron	MX-819	$4750^{\circ}K$	1/25
E	VHBW	2485	107-2	70mm	Hi-Speed	D-19	$5500^{\circ}K$ + SCW + 1.0 ND	1/100
F	VHBW	2485	107-2	35mm	Hi-Speed	D-19	$5500^{\circ}K$ + SCW + 1.0 ND	1/100
G	VHBW	2485	107-02G	16mm	Hi-Speed	D-19	$5500^{\circ}K$ + SCW + 1.0 ND	1/100
H	BW164	SO-164	01-01	16mm	Houston	D-19	$5500^{\circ}K$	1/25
I	UV	IIaO*	129771	70mm	Hi-Speed	D-76	$3000^{\circ}K$ (3750 Å)	1/25
J	UVLS	NTB-3	088-03-01	35mm	Hi-Speed	D-19	$5500^{\circ}K$	1/10
K**	HBW	3401	378-6	70mm	Versamat	MX-641	$5500^{\circ}K$	1/50
L	CEX	SO-368	18-32	70mm	Hi-Speed	ME-2A	$5500^{\circ}K$	1/50
M	CEX	SO-368	16-31	16mm	Hi-Speed	ME-2A	$5500^{\circ}K$	1/50
N	HCEX	SO-168	009-1	70mm	Houston	ME-4	$5500^{\circ}K$	1/100
O	CIN	SO-168	009-1	35mm	Houston	ME-4	$5500^{\circ}K$	1/100
P	CIN	SO-168	007-31	16mm	RAM	ME-4	$5500^{\circ}K$	1/100

* Inconel Wedge to be used.
** Special Control (2.0 gamma) Magazine UU



1. Used for postmission sensitometry for test process.
2. Eastman Kodak Diagonal Splice.
3. Diagonal Splice after camera leader.
4. TEI section held for secondary testing, if found necessary.
5. TEI section used for primary test with Section 1 attached.

FIGURE 1 Special Handling: AS-16 Pan Camera Film

FLIGHT FILM

DATE 12 May 72 CONTROL # PostSensi. Pan TASK AS-16 PREPARED BY

FILM 3414 EMULSION # 16-5 MFG EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY	
SENSITOMETER I-B	PROCESSOR Fultron	INSTRUMENT MacBeth	SPEED ( )
ILLUMINANT 2850 K	CHEMISTRY MX-819	TYPE TD217DR	D-MAX 2.27
TIME ½ & 1/25 SEC.	SPEED TANKS 15 FPM	APERTURE SIZE 2 MM	GAMMA 1.44
FILTER 4750	TEMP °F 80.5 TIME	FILTER Visual	BASE + FOG .20

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

KBr

21	
20	
19	
18	
17	
16	
15	
14	
13	
12	
11	
10	
9	
8	
7	
6	
5	
4	
3	
2	
1	

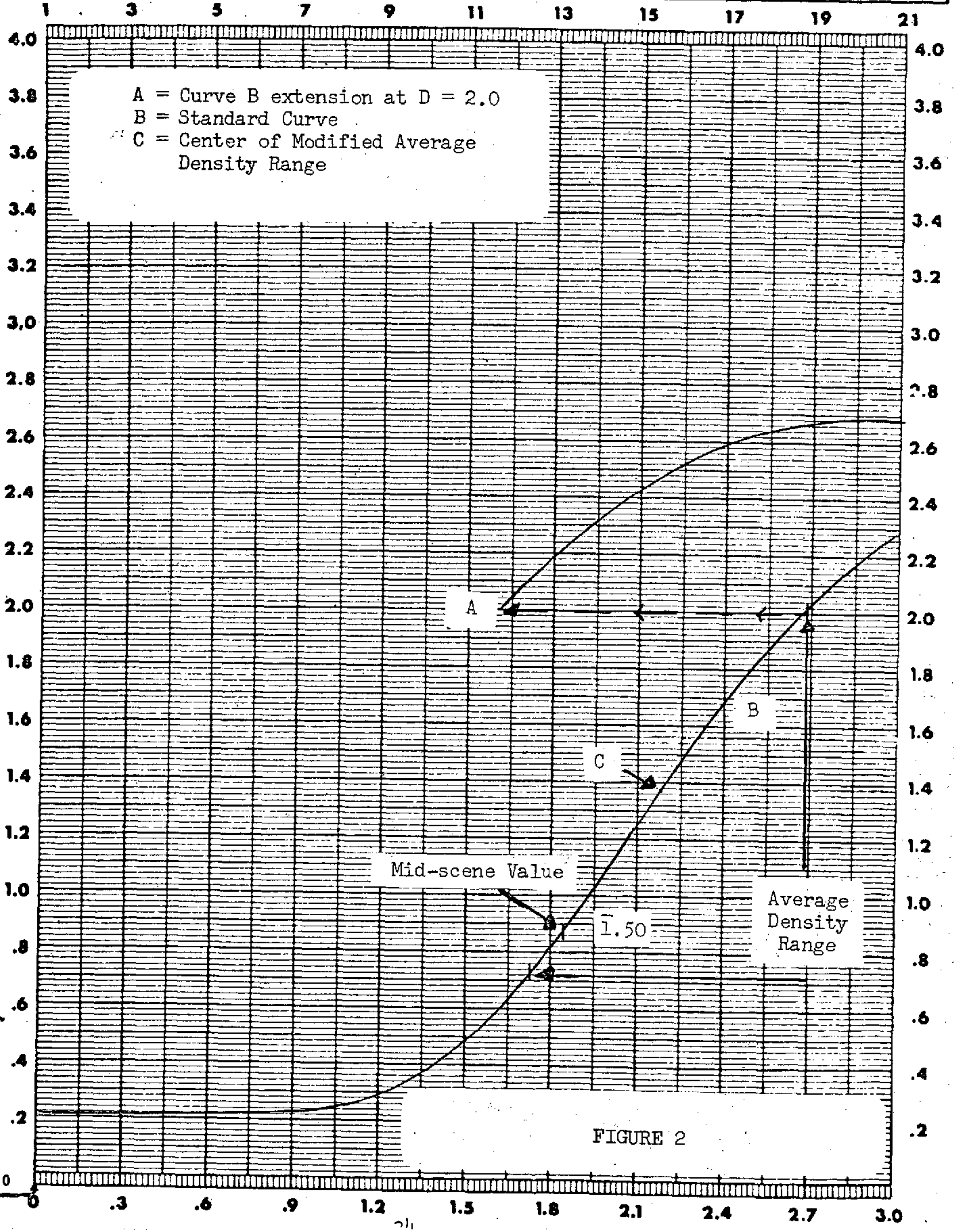


FIGURE 2

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Technicolor

ABSOLUTE LOG E AT R.L.E. - 0

A= 8.70 -10

T71-21 B= 7.67

DATE May 72 CONTROL # Modified C (70mm) TASK ______ PREPARED BY ______

FILM 3401 EMULSION # 378-6 MFG ______ EXPIRATION DATE ______

EXPOSURE DATA		PROCESSING DATA		DENSITOMETRY			
SENSITOMETER	I-B	PROCESSOR	Fultron #1	INSTRUMENT	MacBeth	SPEED ( )	
ILLUMINANT	2850 °K	CHEMISTRY	MX-819	TYPE	TD 403DD	D-MAX	
TIME	1/50 SEC.	SPEED ______ TANKS	8.25 FPM	APERTURE SIZE	2 MM	GAMMA	
FILTER	5500	TEMP °F	80 TIME	FILTER	Visual	BASE + FOG	

CHEMICAL ANALYSIS

______ SP GR

______ pH

______ TA

______ TRP

______ KB,

21	
20	
19	
18	
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3	
2	
1	

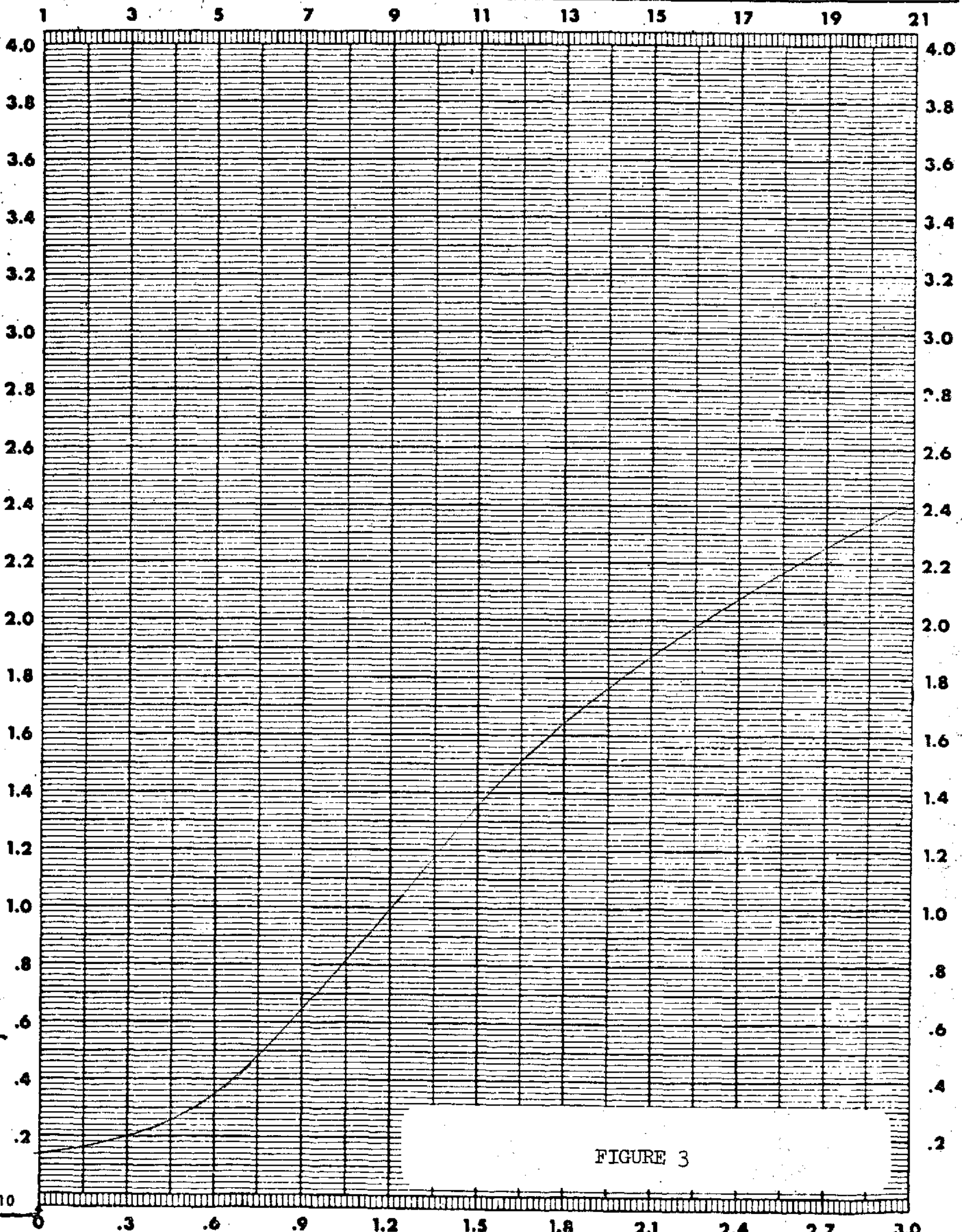

FIGURE 3

Technicolor

ABSOLUTE LOG E AT R.L.E. = 0

7.11 -10

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T71-21

DENSITOMETRIC ANALYSIS
Test Cut Apollo 16 Pan Camera 3414 Flight Film
(last 320 feet)

FRAME	Dmin	Dmax
5660	.49	1.94
	.57	1.94
	.60	2.08
	.78	2.05
5648	.72	1.96
	.76	2.06
	.59	2.03
5633	.67	1.98
	.83	2.05
	.87	1.99
5616	.73	2.01
	.83	2.01
	.77	2.01
5610	.59	1.99
	.37	1.78
	.65	2.07
	.77	2.13
	.71	1.94
5605	.94	2.00
	.68	2.07
	.63	1.99
5600	.86	2.06
	.80	1.92
	.80	2.05

TABLE 2

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TABLE 3 RESOLUTION FRISKET VALUES

G/E	1/mm	G/E	1/mm	G/E	1/mm	G/E	1/MM
4-1	16	5-1	32	6-1	64	7-1	128
2	18	2	36	2	72	2	144
3	20	3	40	3	81	3	161
4	23	4	45	4	90	4	181
5	25	5	51	5	102	5	203
6	28	6	57	6	114	6	228
						8-1	256

Lines per millimeter (1/mm) for each Group/Element (G/E) combination

Target	M
1	.95
2	.90
3	.76
4	.43
5	.26

Modulation (M) of target masters for each row

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APOLLO 16 TONE REPRODUCTION DATA

Magazine	Film Type/Emulsion	Roll Average Density Dmax	Roll Average Density Dmin	Positive Density Returned from Negative Dmax	Process Gamma
L	3401-378-6	1.50	.96	.40	1.0
I	3401-378-6	1.67	.73	.40	1.0
G	3401-378-6	1.72	.55	.40	1.0
H	3401-378-6	1.60	.79	.40	1.0
J	3401-378-6	1.99	1.15	.40	1.0
K	3401-378-6	1.90	1.12	.40	1.0
OO	IIaO-129771	1.34	.91	.40	1.0
UU	3401-378-6	1.88	.19	.40	1.0
TT	2485-107	----	----	---	1.0
SS	2485-107	1.95	.88	.40	1.0
M	3401-378-6	1.90	1.16	.40	1.0
Metric	3400-254	1.95	.88	.40	1.08

TABLE 4

TABLE 4A

APOLLO 16 PANORAMIC CAMERA TONE REPRODUCTION DATA

Cut	Original Average Density Dmax	Original Average Density Dmin	Positive Density Returned from Negative Dmax	Process Gamma
1	1.90	.34	.40	1.10
2	2.04	1.05	.40	1.50
3	1.95	1.29	.40	2.00
4	1.98	1.26	.40	2.00
5	1.82	1.18	.40	2.00
6	1.77	.64	.40	1.30
7*	1.70	.44	.40	1.00
	1.70	.44	.40	1.70
8	1.68	.44	.40	1.00
9*	1.76	1.01	.40	1.00
	1.76	1.01	.40	1.70
10*	1.67	1.41	.40	1.00
	1.67	1.41	.40	2.00
11*	1.95	.58	.40	1.75
	1.95	.58	.40	1.00

TABLE 4A Continued

APOLLO 16 PANORAMIC CAMERA TONE REPRODUCTION DATA

Cut	Original Average Density		Positive Density Returned from Negative	Process Gamma
	Dmax	Dmin	Dmax	
12	2.01	1.44	.40	2.00
13	1.95	1.42	.40	2.00
14	1.95	1.26	.40	2.00
15	1.86	1.30	.40	2.00
16	1.62	.66	.40	1.30
17	1.91	.45	.40	1.00
18	2.08	.41	.40	1.00

* To extend the density range of some frames within each cut, the cut was reprinted and processed to a higher gamma.

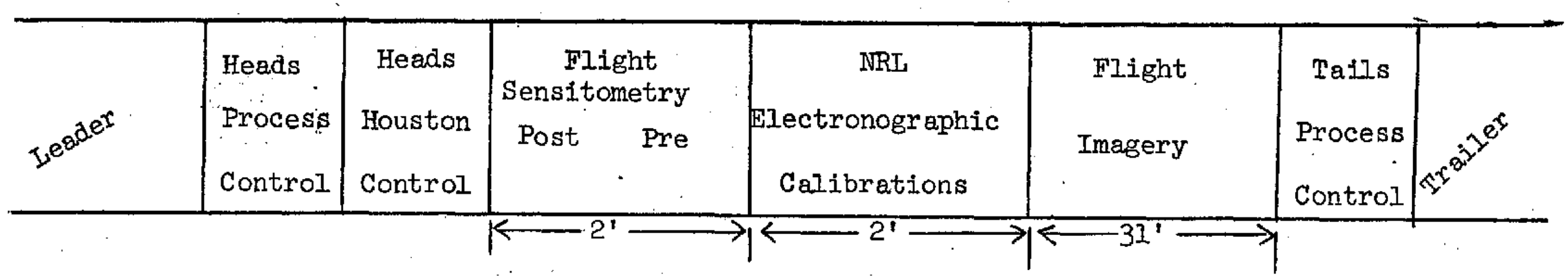

Figure 9 Make-Up NTB-3 Flight Film

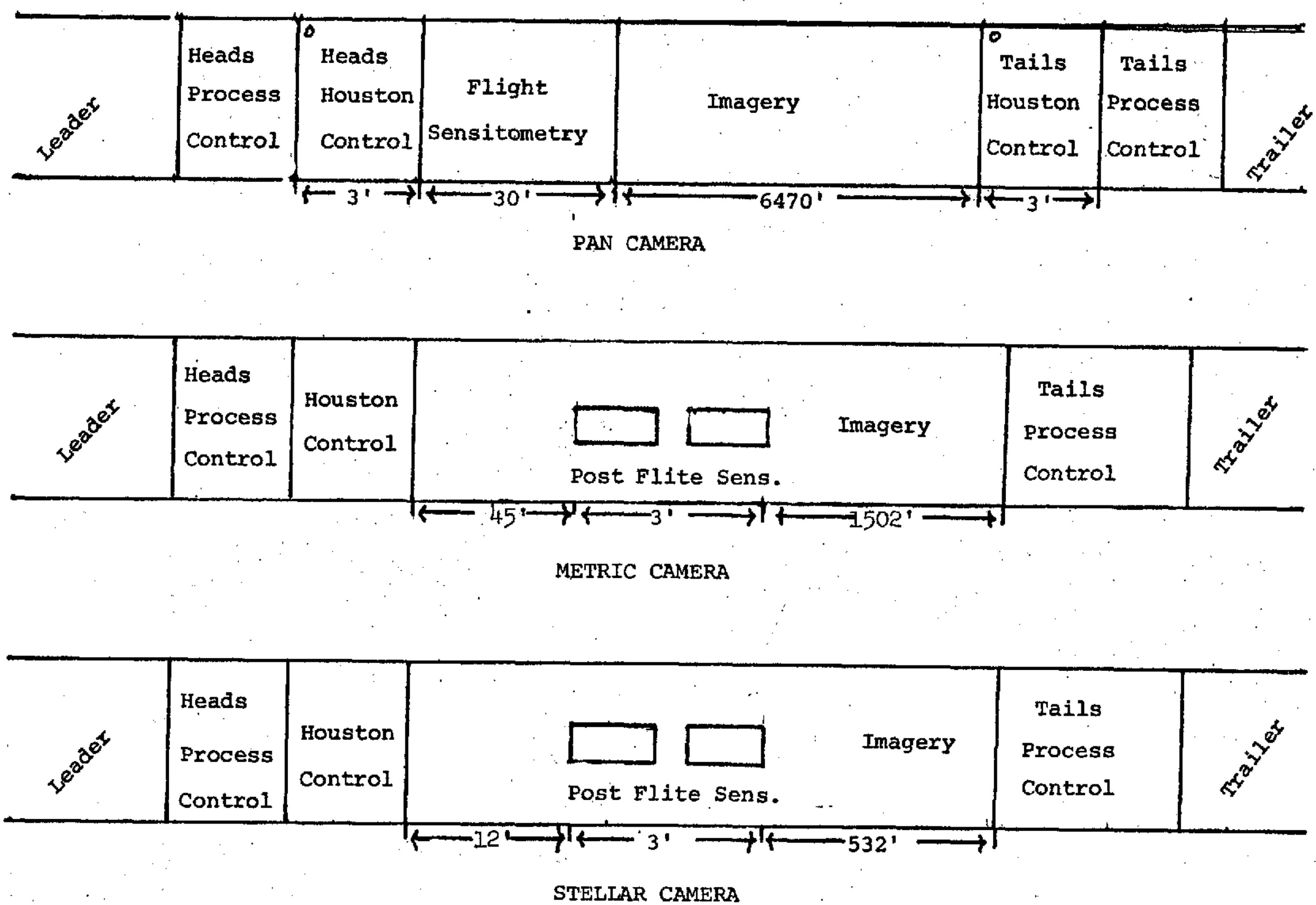

Figure 10 Preplanned Postflight Preparation of SIM Bay Films

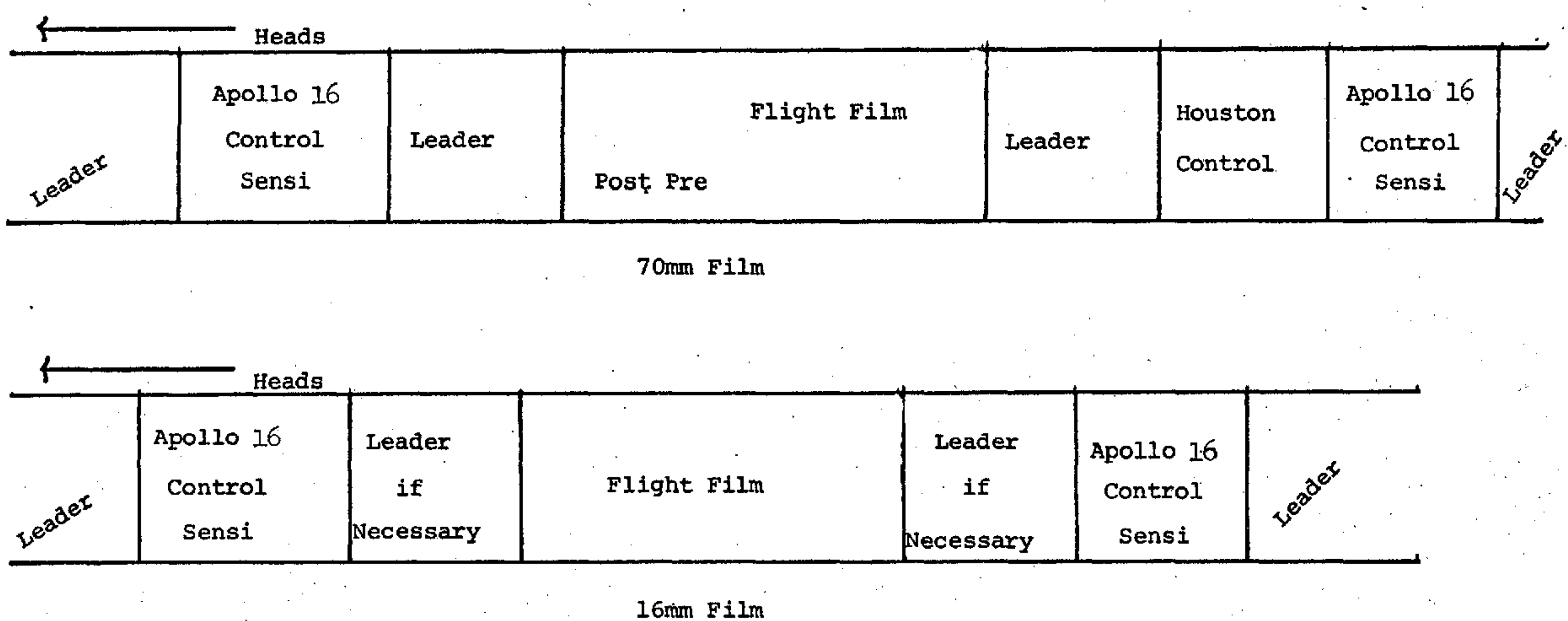

Figure 11 Preplanned Post Flight Preparation of 70mm and 16mm Flight Films

ABBREVIATIONS

The following abbreviations are in general use in the Photographic Technology Division, although all of them may not be used in this Report.

AEI	-	aerial exposure index
AH	-	antihalation
AHU	-	antihalation undercoating
ANSI	-	American National Standards Institute, Inc.
ASA	-	American Standards Association
ASPO	-	Apollo Systems Program Office
BW	-	black and white film
CEX	-	color exterior film
CIN	-	color interior film
CM	-	Command Module
$\cong$	-	congruent to (is)
CRT	-	cathode-ray tube
CSM	-	Command Service Module
D-log E	-	relation of density to logarithm of exposure
$^{\circ}$F	-	degrees Fahrenheit
$^{\circ}$K	-	degrees Kelvin
Dmax	-	maximum density
Dmin	-	minimum density
ergs/cm^2	-	radiometric unit of energy
EVA	-	extravehicular activity
fpm	-	feet per minute
γ	-	gamma
HBW	-	high speed black and white film
HCEX	-	high speed color exterior film
IR	-	infrared
KBr	-	potassium bromide
KSC	-	Kennedy Space Center
l/mm	-	lines per millimeter
LM	-	Lunar Module
log E	-	logarithm of exposure
LRL	-	Lunar Receiving Laboratory
m.c.s.	-	meter-candle-seconds
mil	-	1/100 inch
mm	-	millimeter
MBW	-	medium speed black and white film
μ	-	micron
MPL	-	Motion Picture Laboratory
MSC	-	Manned Spacecraft Center
MTF	-	modulation transfer function
NASA	-	National Aeronautics and Space Administration
NBS	-	National Bureau of Standards

ND	-	neutral density
nm	-	nanometer
NRL	-	Naval Research Laboratories
pH	-	the negative logarithm of the hydrogen ion concentration expressed in moles per liter
PPL	-	Precision Processing Laboratory
PSO	-	Photo Science Office
PTD	-	Photographic Technology Division
PX	-	Kodak code designation for fast-drying backing
QC	-	Quality Control
RH	-	relative humidity
RMS	-	root-mean-square
SCW	-	spacecraft window
SG	-	specific gravity
SIM Bay	-	Scientific Instrument Module. Area in Command Service Module containing the Panoramic, Stellar and Metric cameras.
SL	-	Still Laboratory
T	-	solution tanks
TEI	-	transearth injection
TRP	-	total reducing power
USASI	-	United States of America Standards Institute
UV	-	ultraviolet
VHBW	-	very high speed black and white film