SKYLAB PROGRAM

EARTH RESOURCES EXPERIMENT PACKAGE

SENSOR PERFORMANCE REPORT
VOLUME VII (S190B)
SL2, SL3 AND SL4 EVALUATION

OCTOBER 25, 1974

CONTRACT NAS8-24000

AMMENDMENT JSC-14S

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

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SENSOR PERFORMANCE REPORT
VOL. VII (S190B)
(SL2, SL3 and SL4 EVALUATIONS)

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Submitted by: Gerald P. Kenney
Gerald P. Kenney
Skylab/EREP Sensor Performance
Evaluation Manager, JSC/HC

Technical
Review by: Kenneth J. Demel
Kenneth J. Demel
S190B Project Scientist, JSC/TF

Approved: Richard A. Moke
Richard A. Moke
Manager, Systems Analysis and
Integration Office, JSC/HC

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Amendment JSC-14S

Skylab Program
Lyndon B. Johnson Space Center

FOREWORD

This document is submitted by MMC in accordance with the requirements of Annex I to Exhibit A, Statement of Work, Part I, Data Requirements List (DRL), of Contract NAS8-24000, Amendment JSC-14S, Line Item 319 (JSC-05529, Reference Paragraph 3.1.4d) and was performed under WBS 02216.

The document was edited and compiled by Martin Marietta Corporation based on information from all the organizations involved in performing the EREP sensor performance tasks. The organizations providing inputs to this S190B Performance Report were Johnson Space Center, Orbital Assembly Project Office (JSC/KW), Science and Applications Directorate (JSC/S&AD), and Photographic Technology Division (JSC/PTD), and the Itek Corporation. The portions for which each organization was responsible are indicated in the Table of Contents and at the head of each section. The contact points for inquiries concerning the data presented are as follows:

JSC/KW	J. Prim	(713) 483-5961
JSC/S&AD	W. E. Hensley	(713) 483-2772
	K. J. Demel	(713) 483-2071
JSC/PTD	N. Lamar	(713) 483-4141
Itek Corporation	R. Colins	(617) 276-4691
Martin Marietta Corporation	W. O. Nobles	(303) 794-5211 X7306

The contributors to this document for each of the organizations were:

JSC/KW	D. Denais
	R. Castille
JSC/S&AD	R. Albrizio
	P. Lloyd
	R. Davis
	F. Collin
Itek Corporation	H. Alpaugh
	F. Corbet
	R. Collins
JSC/PTD	N. Lamar
	L. Perry
	J. Sauer
	M. Weinstein
	G. Martinez
	T. Aubry
	J. Retzlaff

After January 1, 1975, inquiries concerning this document should be addressed to NASA/JSC, Earth Resources Program Office, Mail Code HA.

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ABBREVIATIONS

EREP	Earth Resources Experiment Package
ETC	Earth Terrain Camera
GRD	Ground Resolved Distance
JSC	Johnson Space Center
KW	Skylab Program Office - Orbital Assembly Project Office
LOSAT	Lunar Orbiter Strip Analytical Triangulation
MMC	Martin Marietta Corporation
NASA	National Aeronautics and Space Administration
PTD	Photographic Technology Division
PTL	Photographic Technology Laboratory
RMS	Root Mean Square
S&AD	Science and Applications Directorate
SAL	Scientific Air Lock
SL	Skylab
SPE	Sensor Performance Evaluation
SPO	Skylab Program Office
TBS	To Be Supplied
VIE	Visual Image Evaluation

1. INTRODUCTION

1.1 Purpose - The purpose of this document is to provide a compilation of data defining the flight performance of the Skylab Experiment S190B, the Earth Terrain Camera (ETC) of the Earth Resources Experiment Package (EREP).

The objective of this document is to provide that Skylab Mission Performance data required by both the EREP Principle Investigators for scientific evaluation of flight data and the NASA evaluation teams for monitoring and evaluating EREP hardware performance.

1.2 Scope - The material contained in this document presents the performance data of the S190B experiment obtained and analyzed from the three Skylab missions. This document has been updated after each Skylab mission following the engineering evaluation of the data from that mission.

1.3 Summary

1.3.1 SL2 Summary - The S190B Earth Terrain Camera (ETC) operated acceptably for all of its scheduled EREP passes throughout the SL2 mission. The crew reported no problems in unstowing the camera, changing filters, installing the ETC window in the SAL, or installing the camera onto the window. The ETC was operated for a total of seven times with no failures. The clock on the ETC was checked on DOY 170 (June 19, 1973) and was found to be 30 min. and 58 sec. slower than GMT. The change in time was expected since a similar circumstance was experienced during ETC qualification testing for launch vibration. A leak existed in the seal of the spare magazine to the camera vacuum interface. For EREP passes 08 and 10, black-and-white film EK 3414 (roll #82) was installed in this spare magazine. Since there was an audible "hiss", the vacuum hose was not connected to the camera. This caused the vacuum platen to be inoperable, resulting in some degradation in resolution for this roll of film.

The vegetation of the South American jungle areas proved to be much darker than vegetation found in the United States, and was consequently about 1/2 stop underexposed in all cases.

The film sensitometric data for SL2 was provided under separate cover and is, therefore, not included in this report. The reference documents are, however, listed.

1.3.2 SL3 Summary - The S190B hardware operated acceptably during SL3. Special vacuum seals were installed which eliminated the loss of vacuum on the platten reported on SL2. Frame spacing on all color film exposed in the primary magazines was consistent and averaged 4.92 inches. Frame spacing on the B/W and color IR film exposed in the spare magazine was consistent and averaged 4.90 inches. Readability and exposure of the clock was satisfactory for most of the frames. Mechanical image anomalies were identified on five frames of roll SO-242 color film and one roll of infrared film showed some damage in the copies attributable to the duplication procedure. Resolution of the camera was equal to or better than specifications except for frames 303 through 375 of Roll 88. This was the result of the vacuum hose for the platen not being connected during this pass. Fogging of about 35 frames resulted when magazines were removed from the camera. The overall exposure accuracy for SL3 was generally better than that of SL2. Overexposure was evident in all solar inertial passes due to increased reflection inherent with looking along the solar azimuth. A one half stop increase over SL2 exposure settings for the South American rain forest areas did not produce any noticable improvement in that target imagery. An increase in exposure for coastal areas during SL3 resulted in overexposure with little gain in detail. Ground positioning errors resulting from photo triangulation of SL3 images were consistent with SL2 triangulation. The RMS error of the photo residuals was 8.5 micrometers vs 8.2 for SL2. The orientation of S190B relative to S190A resulted in a pointing displacement of 2821 meters for the SL3 frame as compared with 3176 meters for the SL2 frame evaluated.

1.3.3 SL4 Summary - The S190B hardware operated in an acceptable manner during the SL4 mission. A new clock installed on the ETC did not function as precisely as expected and its overall accuracy was no better than the original clock. Frame spacing on all color film exposed in the prime magazine was consistent and averaged 4.9 inches. The frame spacing on the B/W film exposed in the spare magazine varied for the first 89 frames from 5.38 inches to a minimum of 4.75 inches. The average spacing for the remainder of the roll was 4.90 inches. The IR color film frame spacing averaged 4.92 inches. No sensitometry data was lost or degraded on SL4. Clock exposure and legibility was good on all frames except 34 exposures on roll 90. Since the clock exposure was independent of the data format, no ground imagery was degraded. No mechanical image anomalies were identified during this mission. Resolution was equal to or better than specifications with no identified exceptions. During SL4, 97% of the 2159 frames were within $\pm$ one half stop of normal. This showed a significant improvement

compared with the results of the previous two missions. Less than 1% of the frames had exposures exceeding ± 1 full stop from normal. Snow scenes and the South American rain forests were still a problem on SL4. LOSAT triangulations were consistent with the previous missions with RMS errors of the photo residuals ranging between 8 and 9 micrometers. The orientation of S190B relative to S190A resulted in a pointing displacement of 2637 meters.

2. REFERENCE DOCUMENTS

MSC-04947	Film Handling Procedures for Manned Space Flights.
JL12-502	SL/2 Sensitometric Data Package, JSC/PTD, 26 July 1973.
JL12-503	SL/3 Sensitometric Data Package, JSC/PTD, 23 November 1973.
MSC-01549 (Vol. 1) Rev. A	S190 Operational Data Book
TR73-3	Skylab I(1/2) Sensitometric Summary, JSC/PTD, 26 June 1973.
TR73-4	Skylab II (3) Sensitometric Summary, JSC/PTD, November 1973.
	Methods for Analyzing the Photographic System, Including the effects of Non-linearity and Spatial Frequency Response; G. C. Higgins, Photographic Science and Engineering; 15, 2, March/April 1971.
	The Use of Edge Gradients in Determining Modulation - Transfer Functions; F. Scott, R. M. Scott, R. V. Shack; Photographic Science & Engineering; 7, 6, Nov./Dec. 1963.
	G. C. Higgins and F. H. Perrin, Photographic Science & Engineering; 2; 66 (1958).
JOSA, 55 1586	Determination of the Spread Function From Noisy Edge Scans; R. A. Jones; (1965)
SAMSO-TR-72-66, AD739550	A New Technique for Estimating the Modulation Transfer, Function of An Imaging System from Its Edge Response; P. L. Smith.

ATR68-27	Recovery of System Transfer Functions From Noisy Photographic Records; E. S. Blackman; Itek Technical Report, December 1968.
	Statistics, An Introduction; Rickmers, A. D.; and Todd H. N.; McGraw-Hill, N. Y. 1967.
AFAL-TR-66-343	Study of Image Evaluation Techniques; W. L. Attaya, G. C. Brock et al.; Itek Corporation, 1966.
AF 33 (600) 43383 Final Report	Photographic Image Enhancement Through Superimposition of Multiple Images; Itek Corporation, 1961.
JL 12-505	SL4 Sensitometric Data Package, JSC/PTD, June 1974.
TR 74-2	Skylab III(4) Sensitometric Summary, JSC/PTD, June 1974.

3. FUNCTION/LIMIT VERIFICATION (SPE-S190B-001, JSC/KW)

The Function/Limit Verification task for S190B consisted of evaluations of the S190B photography and an evaluation of the experiment operational data. The photographic evaluation was comprised of a review of the returned photographic film data, and an analysis of this data for frame spacing, sensitometric data, shifts in resolution, proper exposure and legibility of the clock, mechanical damage to the film, and an inspection of each frame for general image quality.

The verification of experiment operational data consisted of reviwing air-ground transcripts, crew logs, and postmission crew debriefings for pertinent crew comments, problems, or anomalies affecting the S190B experiment operation.

3.1 Photographic Evaluation (SL2) - The S190B photographic evaluations were performed using master positive film (second generation contact positive transparencies). When necessary the original films were used to determine the cause of certain anomalies found on the master positives. Anomalies may appear in reproductions made from the second generation film that are not covered by this report.

3.1.1 SL2 Photographic Review - The Earth Terrain Camera (S190B) and its supporting systems were used on six EREP passes and one Lunar Calibration pass on Skylab 2. A total of 775 exposures were made using two canisters of film, one color, and one black and white. The canister of color film, SO242 (CT07), roll number 81, was launched in the SL2 Command Module to replace color film that had been damaged by the high temperature environment of the orbital workshop. Two canisters of color SO242 film (CT01 and CT02), and one canister of color infrared film 3443, (IR01) were discarded due to the excessive thermal environment of the OWS.

The black and white film 3414 (BW01), roll number 82, was launched on SL1 in the orbital workshop (OWS), but was not damaged by the thermal environment and did not require replacement.

Table 3.1.1-1 lists the combinations of film, magazines, and filters used on Skylab 2.

3.1.2 SL2 Frame Spacing - The frame spacing on each canister of film was reviewed to verify that no double exposures were made and that the spacing between frames did not decrease or increase excessively. Frame spacing was measured between corresponding fiducial marks located at the top and bottom center of each frame outside of the normal data frame. The expected frame spacing based on design specification was 5.20 $\pm$ 0.45 inches.

The frame spacing on canister CT07, roll #81, was consistent and averaged 4.92 inches. The frame spacing for the first 40 frames of canister BW01, roll #82, varied erratically between 4.85 and 5.35 inches, with no data loss. After frame 40 the frame spacing of roll #82 was consistent, averaging 4.89 inches for the remainder of the roll. The erratic frame spacing was caused by loose winding of film on the supply spool, and did not indicate a hardware malfunction.

3.1.3 SL2 Sensitometry Review - Pre- and postflight sensitometry strips were placed on the film by the NASA/JSC Photographic Technology Division. Punch holes were put in the film leader to identify the location of the sensitometry.

Both canisters of film returned from SL2 had exposures in the location of the sensitometry. In each case the first exposure was not numbered and contained no data other than an image of the clock. This exposure was caused by testing the camera operation prior to opening the scientific airlock. The clock was double exposed in the sensitometry strips on both canisters. Frame 001 of roll #82 overlapped the sensitometry completely and the clock was not visible because of the double exposure. Loss of data in this frame was approximately 25 percent. Frame 003 of roll 82 had two punch marks resulting in less than a 2 percent data loss. Frame 001 of canister roll 81 overlapped the sensitometry by 75%. Forty percent of the data on this frame was lost or degraded. Frame 002 of roll 81 had three punch marks resulting in less than a 2% loss of data.

Imagery overlapping the sensitometry was caused by insufficient film advance during the loading of the film. A procedural change was made for Skylab 3 and Skylab 4 to advance additional film. No mechanical damage was identified on the film in either canister.

3.1.4 SL2 Clock Exposure and Legibility - The film was reviewed for proper exposure and readability of the reference clock and the indicated time was checked to verify that the

clock was operating. The legibility and exposure were satisfactory on all data frames of roll 81. The legibility of roll 82 was not as good as roll 81 because the vacuum platen was not activated when this canister was used in flight. The exposure of the clock was adequate on all data frames on roll 82, clock operation was verified as normal on all frames.

3.1.5 SL2 Mechanical Image Anomalies - Second generation film was reviewed to determine if any mechanical damage to the film, such as holes or scratches, occurred. No mechanical anomalies were found on the SL2 film.

3.1.6 SL2 Resolution Evaluation - Random frames from each data pass were reviewed for shifts in resolution or obvious differences in frames. Absolute resolution was not determined in this review. The resolution expected from this system with the respective film, filter combinations for a 2:1 ground contrast were:

18" Apochromatic lens, B & W 3414, Wratten 12 filter - 11.5 meters
18" Apochromatic lens, SO242 Hi-resolution color - 13.1 meters

The resolution of the color film examined (roll 81) was within the specifications. Resolution of all photographs on the black and white film, roll 82, was degraded appreciably because the vacuum platen was not activated for this magazine.

3.1.7 SL2 Individual Frame Analysis - Each frame of film exposed with S190B on SL2 (rolls 81 and 82) was reviewed for quality and image. Table 3.1.7-1 lists the individual frames that contained image defects, and the cause of the defects.

Normal procedures require that 3 frames be advanced singly before the magazine is removed from the camera and that 2 frames be advanced singly before the start of each data pass. Those frames that were exposed to preclude fogging of the planned data are also listed in Table 3.1.7-1.

3.2 Experiment Operational Data (SL2) - The following paragraphs refer to operational problems or crew comments regarding the performance of the Earth Terrain Camera system. This information has been gathered from a review of air-ground transcripts, crew logs, and postmission crew debriefings.

3.2.1 Air-Ground Transcripts - The S190B clock was set February 28, 1973 and at that time was 1.5 seconds fast. The clock was checked for errors only once during the SL2 mission. On June 19, 1973 (DOY 170) it was determined to be 30 minutes and 02 seconds slow. The clock was expected to develop an error during launch vibration, and some error did occur. The clock time shown in S190B photographs indicates the sequence in which the photographs were taken, but does not define the precise exposure time of any photograph.

Film magazine BW01, roll 82, was used for the first time on EREP pass #8. During the preparation for this pass, the science pilot noted an audible vacuum leak in the magazine to camera body vacuum connector. EREP passes #8 and 10 were made without the vacuum hose being attached to the camera. The effect of not having the vacuum hose connected was the operational loss of the vacuum platen and a consequent degradation of photograph resolution. The vacuum platen is necessary to assure that the film is flat and in the focal plane of the lens. A new seal was launched on SL3 to correct this vacuum leak.

3.2.2 Crew Logs and Postmission Crew Debriefing - Review of the crew logs and postmission crew debriefings did not reveal any further problems or anomalies.

3.3 SL3 Photographic Evaluation

3.3.1 SL3 Photographic Review - One thousand, four hundred and ninety six (1496) color, 415 black and white and 412 infrared pictures were taken during this mission. The ETC was operated during 34 EREP passes, 2 lunar calibrations, 4 special passes, and 1 solar inertial pass. Exposure settings were good, and all hardware operated normally.

Six canisters of film were launched and returned on SL3. Four canisters of SO242 color film (CT 03, CT 04, CT 08, CT 09) were exposed. One canister of 3414 black and white film (BW 02) and one canister of 3443 color infrared film (IR 02) completed the quantity of film. Special vacuum seals were carried on this mission to reduce the loss of vacuum between the camera body and the spare magazine. Installation of one of these seals eliminated the "hiss" reported by the Skylab 2 crew. Table 3.3.1-1 lists the combinations of film, magazines and filters used on Skylab 3. Exposure values for pictures taken during Skylab 3 were based on Skylab 2 experience. Exposures were good on this mission although it was not possible to accommodate all exposure settings potentially required during a data pass.

3.3.2 SL3 Frame Spacing - Frame spacing on all color film exposed in the prime magazine was consistent and averaged 4.92 inches. Frame spacing on the black and white and color IR film exposed in the spare magazine was consistent and averaged 4.90 inches.

3.3.3 SL3 Sensitometry Review - No scientific or sensitometry data was lost or degraded on any of the Skylab 3 film. One canister of film, CT 09, had punch marks in the first unnumbered frame of that roll. This frame had a clock exposure and a black background indicating that it was taken with the scientific airlock closed to verify operation of the camera prior to a data pass. No mechanical damage was identified on the leader of any canister used on this mission.

3.3.4 SL3 Clock Exposure and Legibility - Legibility and exposure of the clock on all data frames was verified as satisfactory with the following exceptions: one data pass recorded on canister CT 08 (frames 125-199) was made with an improper data block exposure control setting and therefore the clock is difficult to read. Exposure control for the clock is independent of the exposure of the image format and no degradation of scientific data was caused by this error. Double exposure of the clock was experienced on 3 frames. CT 08 frame 125 and BW 03 frames 249 and 341. This condition was caused by a power transient when the camera was turned on. Power was applied to the camera approximately one minute prior to start of data take, and the latest time shown should be used as the reference. The data format was not double exposed because of this power-up transient.

3.3.5 SL3 Mechanical Image Anomalies - No mechanical image anomalies have been identified on canisters CT 03, CT 08, CT 09, and BW 02. Canister CT 04, S0242 color film had small vertical scratches on frames 002, 003, 004, and horizontal scratches on frames 005 and 006. Processing of the film was the most probable cause of the scratches. The infrared film, IR 02, showed general damage in all reproductions. This damage was generated when the original was copied, and it varied from one copy to another. The damage appeared as very small red dots or teardrop shapes. The emulsion of the 3443 IR film was very soft and was susceptible to damage of this type. Yellow streaking was prevalent throughout canister CT 04, S0242 color film, but this was not a mechanical defect. This yellow streaking consisted of one streak, 2mm wide, CC05 to CC10 yellow in color primarily in frames 239 to 385. This streak oscillates in a 2 cm path at about 1/2 oscillations per frame. Blue streaking was prevalent throughout canister IR 02, 3443 infrared color film, but this also was not a

mechanical defect. This blue streaking consisted of one to two plus density streaks, 1 to 2mm wide, CC05 to CC10 cyan in color along the roll from head to roll end. The streaks oscillate randomly at 1/2 to 2 cycles per frame. In-frame visibility depends on scene color and content. In both cases, the condition was related to the original film and existed in all copies.

3.3.6 SL3 Resolution Evaluation - Resolution of the camera system was equal to or better than the system specification with one exception: frames 303 through 375 of canister CT 09 were degraded because the vacuum hose was not attached and therefore the vacuum platen was not functioning when these frames were taken.

3.3.7 SL3 Individual Frame Analysis - Normal operational procedures were followed for all data passes. Single frame advancement of film with the scientific airlock open exposed a data frame. Some fogging occurred on data frames preceding magazine removal from the camera. Individual frame analysis is listed in Table 3.3.7-1. No attempt has been made to list all frames that contain color streaking since this condition existed throughout all of the canisters CT 04 (color film) and IR 02 (color infrared film).

3.4 SL3 Experiment Operational Data

3.4.1 Air-Ground Transcripts - As was the case for SL2, the clock photograph should be used only for the sequences of the ground scenes.

3.4.2 Crew Logs and Postmission Crew Debriefings - Information from the crew debriefing confirmed that the camera was operated for a period with the vacuum hose disconnected. The reduction in resolution was discussed in section 3.3.6. No other anomalies were identified.

3.5 SL4 Photographic Evaluation

3.5.1 SL4 Photographic Review - One thousand seven hundred and eighty five (1785) color, 456 black and white and 406 infrared pictures were taken on this mission. The ETC was operated during 33 EREP passes, 1 lunar calibration and 3 special passes. Exposure settings were good and all hardware operated normally.

A new clock and locking knob was flown up to support the ETC for SL4. The replacement clock and locking knob were installed on the camera before any use of ETC on SL4. The replacement clock did not function as precisely as expected and its overall accuracy was no better than the first clock. The six canisters

of film exposed on this mission were flown up in the command module. Four canisters of SO-242 color film (CT 10, CT 11, CT 12, CT 13), one canister of 3414 black and white film (BW 03) and one canister of SO-131 color infrared film (IR 03) were exposed on this mission. Table 3.5.1-1 lists the combinations of film magazines and filters used on each data pass for SL4.

3.5.2 SL4 Frame Spacing - The frame spacing on all color film exposed in the prime magazine was consistent and averaged 4.9 inches. The black and white film (BW 03) exposed in the spare magazine varied for the first 89 frames from a maximum of 5.38 inches to a minimum of 4.75 inches. This same type of variance was observed on SL2. This variance is within specification for the camera system and no frames overlapped. The average frame spacing for the remainder of the roll was 4.90 inches. The infrared color film frame spacing averaged 4.92 inches.

3.5.3 SL4 Sensitometry Review - No sensitometry data was lost or degraded on SL4, no mechanical damage was identified on the film leader of any canister on this mission.

3.5.4 SL4 Clock Exposure and Legibility - Clock exposures and readability was good on all frames with the following exception. Frames 86 through 120 of color film CT 10 had bad clock exposures and could not be read.

The most probable cause of this poor exposure is associated with the request to voice record clock time. It is believed that the clock was not firmly repositioned after the time was recorded or was read during the data collection period. Clock exposures were independent of data format and, therefore, no ground target data were degraded.

3.5.5 SL4 Mechanical Image Anomalies - No mechanical image anomalies have been identified on canisters CT 10, CT 11, CT 12, CT 13, or BW 03. Five frames of canister IR 03 have blue streaking in them and is not a mechanical defect. See Table 3.5.7-1 for frames affected.

3.5.6 SL4 Resolution Evaluation - Resolution of the camera system was equal to or better than the system specification with no identified exceptions.

3.5.7 SL4 Individual Frame Analysis - Normal operational procedures were followed for all data passes. Single frame advancement of film with the scientific airlock open exposed one

data frame. Black data frames with a clock exposure indicated that the airlock was closed. Some fogging occurred on data frames preceding magazine removal from the camera. Individual frame analysis is listed in Table 3.5.7-1. Canister CT 10 has less than the normal number of exposures. This condition was caused by advancing film for approximately 6 seconds before the first data exposures were made in addition to the normal film advance after loading the film in the magazine. The last exposure on each canister also had tape marks and light fog due to normal processing conditions.

3.6 SL4 Experiment Operational Data

3.6.1 Air-Ground Transcripts - No useful information to the data recipient was identified in review of transcripts.

3.6.2 Crew Logs and Postmission Crew Debriefings - No additional information was identified from crew logs or debriefings.

Table 3.1.1-1 Operational Configuration for Skylab 2

Film Canister[a]	Magazine	EREP Pass	Frames Used	Filter Number
CT 07, Roll 81 S0242 Color	Prime	05	1 - 125	5
		06	126 - 268	5
		07	269 - 375	5
		11	377 - 384	5
		Lunar Cal	385 - 403	5
BW 01, Roll 82 3414 Black and White	Spare	08[b]	1 - 135	1
		10[b]	136 - 372	1

NOTES: a. Film canisters CT 01, CT02, and IR 01 were thermally damaged and not used.
b. Vacuum hose was not connected.

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Table 3.1.7-1 Individual Frame Analysis for SL2

Film Identification	Anomaly or Condition	Cause
Canister CT 07, Roll 61		
Frame #Unnumbered	No image/double exposure	a,d
#1	Double exposure over sensitometry	d
#2	3 Punch marks	d
#120, 121, 122	Single Frame Advance	b
#123	Fogged Frame	c
#124, 125	Black frame/no image	a
#263, 264, 265	Single Frame Advance	b
#625	38mm Wide fog band	c
#266	Fogged Frame	c
#267, 268	Black frame/no image	a
#371, 372, 373	Single Frame advance	b
#373	33mm wide fog band	c
#374	Fogged frame	c
#375, 376	Black frame/no image	a
Canister BW 01, Roll 82		
Frame Unnumbered	No image	a,d
#1	Double exposure over sensitometry	d
#3	2 Punch marks in frame	d
#131, 132	13mm band of fog extends outside of data frame	c
#134, 135	Wide band of fog	c
3 unnumbered frames	1 fogged 2 black	c, a

a. Normal prepass operation to check operation of camera.
b. Normal postpass operation to advance film to protect data from light fog.
c. Frame fogged due to magazine removal from camera.
d. Insufficient film advance.
e. Processing generated condition.
f. Vacuum hose not connected.
g. Defective film.
h. Power on transient.
i. Improper data block exposure control setting.
j. Unnecessary film advance.
k. Improper position of clock.

Table 3.3.1-1 Operational Configuration for Skylab 3

FILM CANISTER	MAGAZINE	EREP PASS	FRAMES USED	FILTER NUMBERS
CT 03 (Roll 83) S0242 Color	Prime	12	001--116	5
		13	117--176	5
		14	177--284	5
		15	285--373	5
CT 04 (Roll 84) S0242 Color	Prime	18	001--087	5
		19	088--152	5
		Special Pass	153--159	5
		21	160--232	5
		22	233--312	5
		23	313--336	5
		25	337--385	5
CT 08 (Roll 86) S0242 Color	Prime	27	001--051	5
		29	052--124	5
		Special Pass	125--199	5
		32	200--214	5
		Lunal Cal	215--220	5
		34	221--244	5
		35	245--276	5
		36	277--315	5
		37	316--345	5
		Solar Inertial	346--363	5

Table 3.3.1-1 Operational Configuration for Skylab 3 (Continued)

FILM CANISTER	MAGAZINE	EREP PASS	FRAMES USED	FILTER NUMBER
CT 09 (Roll 88) S0242 Color	Prime	39 44 45 46 47 48 50 40(a)	001--034 035--092 093--132 133--180 181--207 208--235 236--302 303--375	5 5 5 5 5 5 5 5
BW 02 (Roll 85) Black and White 3414	Spare	20 Lunar Cal Special Pass Special Pass 29 30 31	001--130 131--142 143--173 174--194 195--248 249--315 316--415	1 1 1 1 1 1 1
IR 02 (Roll 87) Infrared film 3443	Spare	38 42 43 49 52	001--029 030--109 110--186 187--241 242--412	4 4 4 4 3

Notes: (a) Vacuum hose not connected.

Table 3.3.7-1 SL3 Individual Frame Analysis

FILM IDENTIFICATION	ANOMALY OR CONDITION	CAUSE*
Canister CT 03		
Frame # Unnumbered	Black Frame/Clock only	a
# 114, 115, 116	Single Frame	b
# 116	Fogging above clock area	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 282, 283, 284	Single Frame	b
# 284	Fogging above clock area	c
# Unnumbered	Fogged	c
# 285	Single frame advance	a
Canister CT 04		
Frame # Unnumbered	Black Frame/Clock only	a
# 002	Small Vertical scratches above clock	e
# 003, 004	" " " Lower 1/3 of frame	e
# 005, 006	" Horizontal " " " " "	e
# 085, 086, 087	Single Frame	b
# 087	Fogged area in data frame	c
# Unnumbered	Fogged	c
2 Unnumbered	Black frame/Clock only	a
# 150, 151, 152	Single Frame	b
# 152	Fogged area in data frame	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 159 + 3 Unnumbered	Black frame/Clock only	b
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 232 + 3 Unnumbered	Black frame/Clock only	b
3 Unnumbered	1 Fogged, 2 Black/clock only	c,a
# 310, 311, 312	Single frame	b
# 312	Fogged area in data frame	c
3 Unnumbered	1 Fogged, 2 Black/clock only	c,a
# 334, 335, 336	Single frame	b
# 336	Fogged area in data frame	c
3 Unnumbered	1 Fogged, 2 Black/clock only	c,a
All frames	Yellow streaking	g

* See page 3-9 for cause legend.

Table 3.3.7-1 Individual Frame Analysis (Continued)

FILM IDENTIFICATION	ANOMALY OR CONDITION	CAUSE *
Canister CT 08		
Frame Unnumbered	Black frame/Clock only	a
# 049, 050, 051	Single frame	b
# 051	Narrow fog band	c
Unnumbered	Fogged	c
2 Unnumbered	Black frame/Clock only	a
# 122, 123, 124	Single frame	b
# 124	Narrow fog band	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 125	Double Exposure of clock	h
# 125--199	Poor Exposure of clock	i
# 197, 198, 199	Single frame	b
# 199	Narrow fog band	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 215 + 3 Unnumbered	Black frame/Clock only	b
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 242, 243, 244	Single frame	b
# 244	Narrow fog band	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 343, 344, 345	Single frame	b
# 345	Narrow fog band	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
Canister CT 09		
Frame Unnumbered	Punch holes in frame, Black with clock only	d,a
# 032, 033, 034	Single frame	b
# 034	Wide band of fog	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 130, 131, 132	Single frame	b
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 178, 179, 180	Single frame	b
# 180	Wide band of fog	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 205, 206, 207	Single frame	b
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 233, 234, 235	Single frame	b
# 235	Wide band of fog	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 300, 301, 302	Single frame	b
# 302	Wide band of fog	c
3 Unnumbered	1 Fogged, 2 Black with clock only	c,a
# 303--375	Reduced Resolution	f

* See page 3-9 for cause legend.

Table 3.3.7-1 SL3 Individual Frame Analysis (Continued)

FILM IDENTIFICATION	ANOMALY OR CONDITION	CAUSE *
Canister BW 02		
Frame Unnumbered	Black frame/Clock only	a
# 140, 141, 142	Single frame	b
# 142	Fogged area in data	c
3 Unnumbered	1 Fogged, 2 Black/Clock only	c,a
# 171, 172, 173	Single frame	b
# 173	Wide fog band in data	c
3 Unnumbered	1 Fogged, 2 Black/Clock only	c,a
# 192, 193, 194	Single frame	b
3 Unnumbered	1 Fogged, 2 Black/Clock only	c,a
# 246, 247, 248	Single frame	b
# 248	Wide fog band in data	c
3 Unnumbered	1 Fogged, 2 Black/Clock only	c,a
# 313, 314, 315	Single frame	b
3 Unnumbered	1 Fogged, 2 Black/Clock only	c,a
# 341	Double exposure of clock	h
# 249	Double exposure of clock	h
Canister IR 02		
Frame Unnumbered	Black frame/Clock only	a
All	Blue streaks throughout	g
All	Red dots throughout	e
# 027, 028, 029	Single frame	b
# 029	Narrow fog band	c
3 Unnumbered	1 Fogged, 2 Black/Clock only	c,a
# 184, 185, 186	Single frame	b
# 186	Wide fog band	c
3 Unnumbered	1 Fogged, 2 Black/Clock only	c,a
# 239, 240, 241	Single frame	b
# 241	Wide fog band	c
3 Unnumbered	1 Fogged, 2 Black/Clock only	c

* See page 3-9 for cause legend.

Table 3.5.1-1 Operating Configuration For Skylab 4

FILM CANISTER	MAGAZINE	EREP PASS	FRAMES USED	FILTER NUMBER
CT 10 (Roll 90) SO242 Color	Prime	54	001--085	5
		55	086--139	5
		56	140--173	5
		57	174--209	5
		single frames	210--211	5
		58	212--244	5
		59	245--288	5
		single frames	289--291	5
		60	292--364	5
CT 11 (Roll 91) SO242 Color	Prime	61	001--090	5
		62	091--179	5
		64	180--249	5
		65	250--289	5
		73	290--334	5
		single frames	335--336	5
		74	337--403	5
CT 12 (Roll 92) SO242 Color	Prime	lunar cal	001--012	5
		81	013--091	5
		82	092--152	none
		85	153--224	none
		86	225--252	none
		87	253--332	5
		91	333--400	5

Table 3.5.1-1 Operational Configuration For Skylab 4 (Continued)

FILM CANISTER	MAGAZINE	EREP PASS	FRAMES USED	FILTER NUMBER
CT 13 (Roll 94) S0242 Color	Prime	93 single frames 95 single frames 96 98	001--067 068--069 070--146 147-- 148--200 201--418	5 5 5 5 5 5
BW 03 (Roll 89) 3414	Spare	53 special pass 1 special pass 2 special pass 3 76 lunar cal 78 single frames 80	001--048 049--090 091--124 125--164 165--243 244--245 246--379 380--381 382--456	2 1 2 2 1 unknown 1 1 1
IR 03 (Roll 93) S0131	Spare	82 83 single frames 88 89 single frames 92 94	001--050 051--113 114--116 117--200 201--238 239--240 241--302 303--406	none none 5 5 5 5 5 5

Table 3.5.7-1 SL4 Individual Frame Analysis

FILM IDENTIFICATION	ANOMALY OR CONDITION	CAUSE *
Canister CT 10		
Frame # 3 Unnumbered	Black Frame/Clock only	a
12 feet of film	No exposure - no clock	j
# Unnumbered	Black Frame/Clock only	a
# 86 thru 120	Clock exposure bad	k
# 139 & Unnumbered	Black Frame/Clock only, Fogged Frame	b,c,a
# 203 & 4 Unnumbered	Black Frame/Clock only, Fogged Frame	b,c
# 210, 211	Single Frame advance, SAL open	a
# 289, 290, 291	Single Frame advance, SAL open	b
# 291 & 3 Unnumbered	Fogged Frame, Black Frame/Clock only	c,a
# 363, 364	Band of Fog, Tape on Film	c, e
Canister CT 11		
Frame # Unnumbered	Black Frame/Clock only	a
# 88, 89, 90	Single Frame advance, SAL open	b
# Unnumbered	Fogged	c
Blank	No data	j
# 3 Unnumbered	Black Frame/Clock only	a
# 179 & 6 Unnumbered	Black Frame/Clock only Fogged Black Frame/Clock only	a,c,b
# 249 & 6 Unnumbered	Black Frame/Clock only, Fogged, Black Frame/Clock only	a,c,b
# 287, 288, 289	Single Frame advance SAL open Fogged area on 289	a,c,b
# 334	Fogged area 2.5 MM wide	c
# Unnumbered	Fogged frame	c
# 335, 336	Single Frame advance SAL open	a
# 337	Clock exposure bad	k
# 402	4 MM fog band	c
# 403	Light fog and tape on film	c,e

* See page 3-9 for cause legend.

Table 3.5.7-1 SL4 Individual Frame Analysis (Cont)

FILM IDENTIFICATION	ANOMALY OR CONDITION	CAUSE *
Canister CT 12		
Frame # Unnumbered	Black Frame/Clock only	a
# 12	1.5 MM fogged band	c
# 3 Unnumbered	Fogged frame, Black Frame/Clock only	c,a
# 089, 090, 091	Single Frame advance, SAL open, 2MM Fog on 091	b,c
# 3 Unnumbered	Fogged frame, Black Frame/Clock only	c,a
# 150, 151, 152	Single Frame advance, SAL open, 2MM Fog on 152	b,c
# 3 Unnumbered	Fogged frame, Black Frame/Clock only	c,a
# 224	.75 MM fog band	c
# 3 Unnumbered	Fogged frame, Black Frame/Clock only	c,a
# 252 & 3 Unnumbered	Fogged frame, Black Frame/Clock only	c,a
# 330, 331, 332	Single frame, SAL open	b
# 3 Unnumbered	Fogged frame, Black Frame/Clock only	c,a
# 399	2.5 MM fog band	c
# 400	Light fog, hand print, tape on film	c,e
Canister CT 13		
Frame # Unnumbered	Black Frame/Clock only	a
# 065, 066, 067	Single frame advance, SAL open	b
# Unnumbered	Fogged frame	c
# 68, 69	Single frame advance, SAL open	a
# 68	2 MM fog band	c
# 142 thru 146	Single frame advance, SAL open	b
# 146	2 MM fog band	c
# 3 Unnumbered	Fogged Frame, 2 Black Frame/Clock only	c,a
# 198, 199, 200	Single frame, SAL open	b
# 200	2 MM fog band	c
# 3 Unnumbered	Fogged frame, 2 Black Frame/Clock only	c,a
# 417	5 MM fog band	c
# 418	Tape on film, light fog frame	e,c

* See page 3-9 for cause legend.

Table 3.5.7-1 SL4 Individual Frame Analysis (Cont)

FILM IDENTIFICATION	ANOMALY OR CONDITION	CAUSE *
Canister BW 03		
Frame # 2 Unnumbered	Black Frame/Clock only	a
# 18" film	No exposures	j
# 48 6 Unnumbered	3 Black Frame/Clock only fogged frame 2 Black Frame/Clock only	b,c,a
# 87, 88, 89, 90	Single Frame advance, SAL open	b
# 4 Unnumbered	Fogged, 3 Black Frame/Clock only	c,a
# 122, 123, 124	Single frame advance, SAL open	b
# 124	Narrow fog band	e
# 3 Unnumbered	Fogged, 2 Black Frame/Clock only	c,a
# 162, 163, 164	Single frame advance, SAL open	b
# 1 Unnumbered	Fogged frame	c
# 165, 166	Single Frame advance, SAL open	b
# 241, 242, 243	Single frame advance, SAL open	b
# Unnumbered	Fogged frame	c
# 244, 245	Single frame, SAL open (Lunar)	a
# 377, 378, 379	Single frame, SAL open	b
# 1 Unnumbered	Fogged frame	c
# 380, 381	Single frame, SAL open	a
# 456	Tape on film	e
Canister IR 03		
Frame # 001	Single frame advance, SAL open	a
# 071, 072, 073	Blue Streak in frame	g
# 114, 115, 116	Single frame advance, SAL open	b
# 3 Unnumbered	1 fogged 2 Black Frame/Clock only	c,a
# 198, 199, 200	Single frame advance, SAL open	b
# 3 Unnumbered	1 fogged, 2 Black Frame/Clock only	c,a
# 236, 237, 238	Single frame advance, SAL open	b
# Unnumbered	Fogged	e
# 239, 240	Single frame advance, SAL open	a
# 300, 301, 302	Single frame advance, SAL open	b
# 3 Unnumbered	1 fogged, 2 Black Frame/Clock only	e,a
# 326, 327	Blue Streak	g
# 406	Tape on film	e

* See page 3-9 for cause legend.

4. EXPOSURE ACCURACY DETERMINATION (SPE-S190-002, JSC/PTD)

An evaluation was made of the exposures used for the S190B Earth Terrain Camera (ETC) during the SL-2, SL-3, and SL-4 missions. This analysis was accomplished by visual examination of the original film, aided by densitometric analyses of all rolls. The resulting data was compared to previously determined optimum exposure density ranges in order to estimate exposure accuracy.

4.1 SL-2 Exposure Accuracy Determination

4.1.1 Data Review - Table 4.1.1-1 summarizes the results of the exposure accuracy evaluation for the SL2 flight film. The geographical locations listed are only approximate reference points and should not be taken as accurate.

In almost all cases, the original exposure recommendations supplied by PTD are still valid.

One exception is the South American jungle areas. The vegetation in those areas is apparently much darker than vegetation found in the United States. Exposures for these areas should be increased 1/2 stop over U.S. vegetation exposures.

The exposures for the black and white films should follow the original PTD recommendations with the exception that no compensation for latent image decay is necessary.

The exposure for the color and color IR films should also follow the original recommendations. Both color films will have lower maximum densities as a result of increased radiation dosage, thereby reducing the latitude for underexposure.

4.1.2 Recommendations - It appears from the SL2 imagery that terrain types can be separated into two classes as a basis for exposure. One class includes all desert and sandy areas, such as most of the Southwest United States. The second class includes all vegetated and mountainous areas, with the possible exception of the South American jungles, as mentioned previously.

Thus, the following exposures should be used for these two classes when sun elevation angles are 45° or higher.

Class I - Deserts and Bright Sandy Soils

SO-242 1/200 sec with filter no. 6
3414 1/140 sec with filter no. 2
3443 1/200 sec with filter no. 4

Class II - Vegetation and Mountainous Terrain

SO-242 1/140 sec with filter no. 5
3414 1/200 sec with filter no. 1
3443 1/140 sec with filter no. 4
See paragraph 9.1.4 for filter information.

4.2 SL3 Exposure Accuracy Determination

4.2.1 Data Review - Table 4.2.1-1 gives a summary of exposure accuracy, with terrain descriptions and sun angles. The geographical locations given are only approximate reference points and should not be taken as accurate.

The overall exposure accuracy for SL3 was generally better than that of SL2. However, several areas could use improvements.

In several instances, the original exposure recommendations supplied before the pass were not followed. Inadvertent errors made in messages transmitted to the crew resulted in different pre-pass pads to the crew, resulting in serious exposure errors in several cases.

The 1/2 stop exposure increase for the South American rain forest areas did not produce any noticeable improvement in the imagery. In fact, setting up passes to accommodate this exposure increase necessitated compromises in other parts of the pass.

Increases made for coastal areas on SL3 only resulted in overexposure, with very little gain in detail.

Very few areas are bright enough to require a full stop exposure decrease from normal vegetation exposures. The areas in this class encountered during SL3 were the Southern California desert areas around the Salton Sea, some areas in Utah and Nevada, and the Sahara Desert.

Several coastal areas were overexposed during passes which approached from the ocean. This was due to the exposure remaining at the increased setting for water detail for too long a period, rather than being changed before the coastline.

Overexposure was evident in all of the solar inertial passes. This was due partly to the obliquity angle, but an additional factor was the increased ground reflectance inherent when looking along the sun line.

The SO-242 film exposed in the ETC exhibits much greater sensitivity to haze conditions than the SO-356 exposed in S190A. This is probably due to the lack of a haze filter on the ETC. The haze filter coated on the SO-242 film itself is apparently not efficient enough and must be supplemented by a camera haze filter.

4.2.2 Recommendations - The sun angle - exposure change recommendations should be altered as follows:

35° - 90°	nominal settings
25° - 35°	+ 1/2 stop
15° - 25°	+ 1 stop
10° - 15°	+ 1 1/2 stops
7° - 10°	+ 2 stops
5° - 7°	+ 2 1/2 stops

The South American rain forest areas should be given normal vegetation exposures.

Exposure increases for water detail should be restricted to clear ocean water only.

With the exception of the very bright areas mentioned in 4.2.1, exposure decrease for bright terrain should be limited to 1/2 stop.

When approaching land from the ocean, water detail exposures should be cut off well before the coast to avoid overexposure of land areas.

Exposure for solar inertial passes should be decreased at least 1/2 stop to account for the angular reflectance increase.

The SO-242 film should be given 1/2 stop less exposure when heavy haze or cloud cover exists.

4.3 SL4 Exposure Accuracy Determination

4.3.1 Data Review - Camera exposures used to expose the seven sets of six rolls of S190B SL4 films were evaluated. To accomplish the exposure analysis, a visual scene identification was made by using the Skylab 4 coverage maps (Appendix A), 'EREP Sensor Data Acquisition Status Report for the Skylab 4 Mission; and frame to frame tabulations. Exposures used were verified by correlation with the same documents to determine sun angle, camera shutter speed and camera aperture. Each scene was analyzed densitometrically and the results correlated with density versus log exposure curves discussed in paragraph 4.3.2 for each of the film types used. The results are tabulated in Table 4.3.1-1. These data consist of film roll numbers, Skylab pass and track numbers, camera 'f' numbers, filter numbers, shutter speeds, subject scene, sun angle, scene start frame number, an evaluation of the exposure accuracy and any appropriate notes. This evaluation of Skylab 4 S190B experiment camera exposures showed the following results:

- The S190B experiment included about 2,159 frames of imagery with 97% exposed within plus or minus one-half f/stop of normal.
- Less than one percent of the S190B frames had exposures exceeding one full stop of normal.
- Cloud cover affected imagery in a significant number of scenes.
- A tendency toward an overexposure of snow scenes 1/2 to 1 f/stop occurred on SL-4 where snow scenes were a new exposure problem.
- A tendency toward underexposure of Brazilian jungle scenes by one f/stop or more was still a problem on SL-4.

- The SL-4 results, compared to SL-3 and SL-2, represented significant improvement. Little exposure difficulty was encountered where cloud cover was minimal resulting in less than one percent of the exposures exceeding a full f/stop, tolerance. Coastal areas, a problem on SL-2 and SL-3, were no problem on SL-4.

- SL-4 results demonstrated the value of experience gained in exposure determination and evaluation on SL-2 and SL-3.

4.3.2 SL4 Density vs. Log Exposure Curves - The density versus log exposure graphs given in Figure 4.3.2-1 are the I-B sensitometric simulations of the S190B film-filter combinations.

Notations are made on each curve to indicate the location of image densities which would be classified as normal exposure, 1/2 f-stop over or under exposed and 1 f-stop over or under exposed.

The density range of each scene; i.e. the difference between the high and low densities were determined and a mid-range density value was determined to locate the scene on the D log E curve to derive exposure accuracy.

Table 4.1.1-1 SL2 Exposure Accuracy Determination (S190B)

EREP Pass	Track	Canister/ Roll No.	Filter-f/Number	SS*	Terrain	Sun Angle	Exp. Accuracy	Notes
5	34	CT07(81)	5 (f/5.6)	200	Nevada - Texas Coast Gulf of Mexico - Yucatan - Caribbean	60 - 80°	Good +1/2 +1/2 +1	Very heavy haze condition
6	19	CT07(81)	5 (f/5.6)	140	Washington State - Georgia - Caribbean - Brazil	27 - 60°	Good -1	
7	33	CT07(81)	5 (f/5.6)	140	Vancouver - S. Carolina - Atlantic Ocean	20 - 68°	Good -1	
8	48	BA01(82)	1 (f/4.0)	140	Washington State - Texas - Gulf of Mexico - S. America	26 - 65°	+1/2(S. America)	Excessive cloud cover over U.S.
10	5	BA01(82)	1 (f/4.0)	140	Montana - Flordia	22 - 45°	Good +1/2	Overexposed at high sun angles
				200	Caribbean - S. America	48-55-44°		
11	20	CT07(81)	5 (f/5.6)	140	Nevada - C. America - S. America	22 - 50°	Underexposed	Difficult to assess due to cloud cover

*Units of SS are in seconds^{-1}; thus the exposure time is $(SS)^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.2.1-1 SL3 Exposure Accuracy Determination (S190B)

EREP Pass	Track	Canister/ Roll No.	Filter-f/Number	SS**	Terrain	Sun Angle	Exp. Accuracy	Notes
13	48	CT03(83)	5(f/5.6)	200	Wash. State - Gulf of Mexico	40 - 74°	Good -1/2	
					(Veg.) Columbia - Brazil - Veg.	83 - 40°	+1/2	
14	61	CT03(83)	5(f/5.6)	100	B.C. - Minnesota (Veg.)	20 - 40°	Good	
				140	Wisconsin - Wash. D.C. (Veg.)	42 - 58°	Good	
15	62	CT03(83)	5(f/5.6)	100	Wash. State - Idaho (Varied)	33 - 41°	Good +1/2	
				140	Idaho - Gulf of Mexico (Varied)	41 - 74°	Good	
				140	Caribbean - Brazil	83 - 44°	+1/2 Good	
16	34	CT03(83)	5(f/5.6)	100	Pacific - Utah (Varied)	24 - 34°	Good +1/2	
				140	Utah - Gulf of Mexico (Varied)	36 - 57°	-1/2 Good	
				100	Brazil (Veg.)	69 - 61°	Good +1/2	
				140	Brazil (Veg.)	60 - 47°	Good	*A
18	6	CT04(84)	5(5/5.6)	100	Pacific - Nevada (Varied)	22 - 27°	-1/2 Good	
				140	Nevada - Central America(Varied)	30 - 54°	Good -1/2	
				100	Peru - Bolivia (Dark Veg.)	61 - 55°	Good	*B
19	13	CT04(84)	5(f/5.6)	140	Thailand, Malaysia (Veg.)	44 - 57°	Good -1/2	
				200	Central Australia - Desert	52 - 39°	Good -1/2	
				100	S.E. Australia - Tasman Sea - Veg. & Water	39 - 37°	Good	
20	20	BW02(85)	1(f/4.0)	140	Nevada - Bolivia (only U.S. clear)	17 - 54°	Good	
				200	Bolivia - Paraguay (Almost Totally Cloud Covered)	54 - 50°	----	
S.I.#1	54	BW02(85)	1(f/4.0)	200	Paraguay (Vegetation)	49 - 50°	+1/2	
S.I.#2	69	CT04(84)	5(f/5.6)	200	East Atlantic Depression - Clouds	42 - 38°	+1	

*A PASS 16 - Shutter speed was changed to SS-140 at 16:21:10. Original instructions called for the change at 16:22:30.

*B PASS 18 - Original instructions called for a change to SS-140 at 15:46:30. This change was never performed, even though the pass ran until 15:47:30.

**Units of SS are in seconds^{-1}; thus the exposure time is $(SS)^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.2.1-1 (Continued)

EREP Pass	Track	Canister/ Roll No.	Filter-f/Number	SS **	Terrain	Sun Angle	Exp. Accuracy	Notes
21	25/26	CT04(84)	5(f/5.6)	100	Chile - Argentina - Sl. Bright	27 - 40°	+1/2	
				140	S. Amer. Coast - Montevideo - Veg.	41 - 52°	Good	
				200	Mali - Algeria - Desert	42 - 39°	Good	
22	39/40	CT04(84)	5(f/5.6)	100	Chile - Argentina - SL.Bright	25 - 35°	Good +1/2	
				200	Mali - Alperia (Veg. - Desert)	58 - 46°	-1/2 +1/2	
				100	Algeria - Tunisian Coast - Desert	37 - 32°	+1	*C
S.I.#3	40/41	BWC2(85)	1(f/4.0)	200	Paraguay (Vegetation)	59 - 64°	+1/2	
23	41/42	CT04(84)	5(f/5.6)	200	Hurricane Christine - Clouds	63 - 49°	+1	
25	68/69	CT04(84)	5(f/5.6)	100	Chile - Brazil - Chile (Br. Veg.)	44 - 72°	+1/2	
				200	Spanish Sahara - Desert	60 - 54°	+1/2	
				100	Corsica - Italy (Veg.)	30 - 27°	Good	
27	30	CT08(86)	5(f/5.6)	200	Baja - Colorado (Bright)	53 - 45°	Good	
				140	Colorado - Iowa (Veg.)	45 - 35°	Good	
				100	Iowa - Canada (Veg.)	35 - 20°	Good -1/2	
28	44	CT08(86)	5(f/5.6)	200	N.E. Mexico - Kansas (Bright-Veg.)	59 - 47°	Good	
				140	Kansas - Wisconsin (Veg.)	47 - 37°	Good	
				100	Wisconsin - Canada (Dark Veg.)	37 - 28°	Good -1/2	
S.I.#4	54	BW02(85)	1(f/4.0)	140	Chile - Argentina - Sl. Bright Terrain (Should have been Paraguay)	28 - 40°	+1	*D
29	1	BW02(85)	1(f/4.0)	200	Mexico - Missouri (Varied)	77 - 54°	Good +1/2	*E
				140	Detroit - Montreal (Vegetation)	43 - 36°	Good	
S.I.#5	11	CT08(86)	5(f/5.6)	140	Atlantic - Africa (V. Hvy Cloud Cover)	60	+1/2	
				200	Africa - Desert	60	+1	

*C PASS 22 - Original instructions called for a change to SS-100 at 14:58:00, which would have been over the Mediterranean Sea. However, the change was made at 14:56:03, in the Algerian desert, badly overexposing this area.

*D SI #4 - The cameras were turned on too early and recorded data from the coast of Chile through Argentina. It is not clear whether any data was actually taken over Paraguay. It is also not apparent why a shutter speed of SS-140 was selected. The exact sun angles are also in doubt.

*E PASS 29 - Original instructions called for SS-140 until 19:12:00 at the beginning of the pass. However, the pass was started at 19:09:15 with SS-200. This change may have been made to get better exposure for clouds.

**Units of SS are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.2.1-1 (Continued)

EREP Pass	Track	Canister/ Roll No.	Filter-f/Number	SS**	Terrain	Sun Angle	Exp. Accuracy	Notes
30	15	BW02(85)	1(f/4.0)	140	Mexico - Arkansas - V.Hvy. Cloud Cover)	67 - 59°	----	*F
				140	Ohio - Vermont - Veg.	51 - 44°	Good +1/2	
31	16	BW02(85)	1(f/4.0)	100	Pacific Ocean - Clouds & Water	68 - 63°	----	
				200	Salton Sea - Colorado River-Bright)	62 - 57°	+1	
				200	Colorado - Minnesota	52 - 43°	+1/2 Good	
				100	Canada - Clouds	30 - 25°	----	
32	26/27	CT08(86)	5(f/5.6)	200	Clouds & Water	62 - 59°	----	*G
				100	Italy - Switzerland - Mts.-Veg.	42 - 40°	Good +1/2	
34	31	CT08(86)	5(f/5.6)	140	Pacific - N. Dakota (Veg.)	53 - 36°	Good	
				100	N. Dakota - Canada (Veg.)	36 - 32°	+1/2 Good	
35	41	CT08(86)	5(f/5.6)	140	Spain - Italy (Veg.)	54 - 42°	Good	
36	43	CT08(86)	5(f/5.6)	140	Mexico City - Gulf of Mexico - Mostly Clouds	64°	----	
				100	Clouds & Water	64 - 63°	----	
				140	Georgia - Cheasapeake Bay - Veg. Water	60 - 56°	Good	
				100	Chess. Bay - Cape Cod - Land - Water	56 - 51°	Water - Good	*H
37	45	CT08(86)	5(f/5.6)	200	N. Calif. - Idaho Falls (Varied)	56 - 49°	Good	
				140	Idaho Falls - N. Dakota (Veg.)	49 - 42°	Good	
S.I.#6	57	CT08(86)	5(f/5.6)	140	Sargasso Sea - Total Cloud Cover	60°	----	
38	58	IR02(87)	4(f/11)	200	El Paso - Kansas (Varied)	60 - 56°	Good -1/2	
				140	Illinois - Lake Huron (Veg.)	53 - 49°	Good	

*F PASS 30 - Original instructions called for exposure at SS-200. However, the entire pass was run at SS-140.

*G PASS 32 - No shutter speed of SS-200 was called for in the original instructions. This may have been done for cloud exposures.

*H PASS 36 - The original instructions called for SS-100 from 17:09:26 to 17:09:45, followed by SS-140. However, once the shutter speed was changed to SS-100 at 17:09:26, it remained there until the end of the pass (17:11:40).

**Units of SS are in seconds^{-1}; thus the exposure time is $(SS)^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.2.1-1 (Continued

EREP Pass	Track	Canister/ Roll No.	Filter-f/Number	SS**	Terrain	Sun Angle	Exp. Accuracy	Notes
39	59	CT09 (88)	5(f/5.6)	200	Calif. Coast - S. Dakota(varied)	58 - 46°	+1/2 Good	*I
				100	Gulf of St. Lawrence - Newfoundland Water - Veg.	27 - 20°	Good -1/2	
42	15	IR02(87)	4(f/11)	140	Mexico - Vegetation	48 - 50°	Good	
				140	San Antonio - Ohio - Mostly Veg.	52 - 48°	Good	
				140	Clouds	49 - 48°	----	
				200	Clouds & Water	41 - 29°	----	
43	16	IR02(87)	4(f/11)	200	San Diege - Colorado River-Bright	52°	Good	
				140	Col. River - Gulf of St. Lawrence - Mostly Clouds	52 - 37°	----	
				100	Newfoundland - Mostly Clouds & Water	37 - 29°	----	
				200	Clouds & Water	29 - 20°	----	
44	29	CT09(88)	5(f/5.6)	140	Central Mexico - Veg. Hvy Cloud Cover	41 - 44°	+1/2	
				140	Louisiana Coast - Newfoundland-Veg	50 - 45°	Good +1/2	
45	30	CT09(88)	5(f/5.6)	200	Baja - Iowa - Varied	47 - 48°	Good	
				140	Iowa - Wisconsin-Veg. H. Cloud Cover	48 - 47°	Good	
46	43/44	CT09(88)	5(f/5.6)	100	Mexico - Varied	36 - 38	+1/2	*J
				140	Alabama Coast - Boston - Veg. V. Hazy	42 - 47°	+1/2	
				100	France - Italy - Veg. - V. Hazy	27 - 16°	Good	
47	49	CT09(88)	5(f/5.6)	140	Japan - V. Hvy Cloud Cover	43 - 45°	----	
48	58	CT09(88)	5(f/5.6)	140	Texas - Michigan - Mostly Veg.	41 - 44°	Good	
49	1	IR02(87)	4(f/11)	140	France - Italy (Veg.) - Heavy Clouds	38 - 34°	Good	
				100	Italy (veg.) - Hvy Clouds	34 - 29°	Good	
				100	Israel - Desert	20 - 18°	Good	

*I PASS 39 - Original instructions called for a change to SS-140 at 19:35:00. However, the camera was left at SS-200 until 19:36:50.

*J PASS 46 - Original instructions called for SS-140 until 15:01:30. However, this area was exposed at SS-100, resulting in overexposure.

**Units of SS are in seconds^{-1}; thus the exposure time is $(SS)^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.2.1-1 (Continued)

EREP Pass	Track	Canister/ Roll No.	Filter-f/Number	SS*	Terrain	Sun Angle	Exp. Accuracy	Notes
50	4	CT09(88)	5(f/5.6)	140	Saskatchewan - Lake Superior -Veg.	38 - 36°	Good	
				100	L. Superior - Long Island - V. Cloudy	36 - 27°	Good	
				100	Clouds & Water	24 - 17°	----	
51	19	CT09(88)	5(f/5.6)	200	N.W. Canada - Veg. - VeryCloudy	40 - 39°	Good	
				200	Montana - V. Cloudy	39 - 38°	Good	
				100	S. Dakota - S. Caroline - Hazy	35 - 24°	+1/2	
52	29/30	1R02(87)	3(f/8)	100	Gulf of Mexico	18 - 21°	Good	
				140	Louisiana Coast - NYC - Veg.	21 - 32°	Good +1/2	
				200	NYC - Newfoundland - Veg.	32 - 37°	Good	
				200	France - Sardinia - Veg.	37 - 35°	Good	
				140	Sicily - Mountains & Veg.	33 - 31°	+1/2	
				100	Ethiopia - Indian Ocean - Varied	15 - 6°	+1/2 1/2	

*Units of SS are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	* SS	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
89 BW03	53/6	6.7/2	200	S.E. Utah, S.W. Colorado, N.W. New Mexico.	20 - 23°	1	good	
				S.E. New Mexico, West Texas, South Texas, Gulf of Mexico	23 - 25°	10	good	
				Bolivia, N.E. Paraguay, Brazil	30 - 40°	21	-1/2	
90 CT10	54/19	4.0/5	100	South Dakota, N.E. Nebraska, S.E. Iowa, N.E. Missouri, S. Illinois, W. Kentucky, Tennessee, Georgia, into Atlantic.	18 - 35°	1	-1/2, +1/2 in snow.	
			140	Puerto Rico	48 - 50°	57	good	
			200	Eastern Brazil	57 - 55°	70	good	
90 CT10	55/34	4.0/5	100	N.E. New Mexico area	27 - 31°	86	good	
			140	N.W. Texas cross state into Gulf of Mexico	31 - 42°	92	good	
			200	Western Brazil	63°	109	-1/2 to -1	

*Units of SS are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Note format change from tables 4.1.1-1 and 4.2.1-1.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP /PASS/ TRACK	'f' NUMBER/ FILTER	* SS	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
90 CT10	55/34	4.0/5	140	Southern Brazil	57 - 54°	133	good	
90 CT10	56/48	4.0/5	100	N.W. Oklahoma, E. Texas	24 - 31°	140	good	
			140	S.E. Texas, into Gulf of Mexico	33 - 41°	155	-1/2	
90 CT10	57/49	4.0/5	100	Off S. California coast to Baja	27 - 33°	174	good	
			140	Mexico at Guadalajara	44 - 49°	194	good	
90 CT10	58/62	4.0/5	100	C. Kansas, N.E. Oklahoma, Arkansas. Mississippi, Gulf of Mexico to Florida Keys.	19 - 41°	210	good	
			200	N. Venezuela	54 - 58°	238	good to -1/2 (interior)	

*Units of SS are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO. CANISTER	EREP /PASS/ TRACK	'f' NUMBER/ FILTER	* SS	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
90 CT10	59/63	4.0/5	140	C. California coast, length of California, length of Mexico	18 - 97°	245	-1 1/2 on coast of Cal., -1 in Mexico, rest good	Cloud cover in some areas
90 C T10	60/6	4.0/5	100	West to Central Nevada	15 - 17°	292	good	Clouds
			100	S. Nevada, cross Arizona, into Mexico	20 - 29°	300	good	
			140	Gulf of Mexico, S. Mexico, Guatemala, into Pacific	43 - 54°	325	-1/2 to good at ocean shore.	
91 B W11	61/20	5.6/5	100	Southern Texas into Gulf of Mexico.	27 - 32°	1	good	
			140	Gulf of Mexico, Yucatan, British Honduras, Caribbean Sea, Honduras, Nicaragua, Costa Rican coast, Panama, Pacific (clouds), Columbia	38 - 68°	13	good	

*Units of SS are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	* SS	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
91 BW11	62/48	5.6/5	100	Louisiana coast, into Gulf of Mexico	17 - 21°	91	-1	
			140	Caribbean Sea, Colombia, Central Brazil	44 - 69°	95	good	
			140	Central to S.E. Brazil	71 - 87°	160	good	
91 BW11	64/70	5.6/5	100	Nepal	12 - 20°	180	good	
			140	South Burma, South Thailand, South China Sea	31 - 42°	198	good	
			140	South China Sea, Borneo	46 - 54°	223	good	
			140	Java Sea	61 - 65°	242	good	
91 BW11	65/13	5.6/5	100	Malaysia, Borneo	17 - 25°	250	-1/2	
				3-ea single frames over Lesser Sundra Islands	35°	274	good	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e, for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
91 BW11	65/13	5.6/5	200	Central Australia	47 - 50°	277	good	
89 BW03	66/20	/1	200	Paraguay	40°	49	N/A	Heavy Cloud Cover
89 BW03	69/54	6.7/2	140	S.W. Paraguay	40°	91	good	Heavy Cloud Cover
89 BW03	70/40	6.7/2	140	North Argentina, Paraguay	40°	125	good	Heavy Cloud Cover
91 BW11	73/29	5.6/5	140	Cross Guadalajara to Central Mexico.	48 - 45°	290	good	
			100	Clouds into Ohio, Pennsylvania, New York. (snow)	26 - 19°	304	good	
91 BW11	74/57	5.6/5	140	South Mexico, Gulf of Mexico, Florida Coast	50 - 38°	337	good	
			100	Atlantic of U.S. coast	29 - 26°	364	N/A	Heavy Cloud Cover

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
91 BW11	74/57	5.6/5	100	North Atlantic	19 - 15°	369	N/A	Heavy Cloud Cover
89 BW03	76/71	4.0/1	100	Pacific off Guatemala	51 - 48°	167	good	
			200	Guatemala	48 - 47°	188	good	
			200	Gulf off Florida, Florida at Tampa to Orlando, Atlantic.	41 - 34°	198	good	
			140	Atlantic off U.S. coast	34 - 20°	207	good	Heavy Cloud Cover
89 BW03	78/ 14/15	4.0/1	100	Pacific off Guatemala, Guatemala	48 - 46°	246	good	Heavy Cloud Cover
			200	Guatemala, Caribbean Sea	46 - 44°	295	good	
			140	Gulf of Mexico, Florida tip	42 - 40°	312	good	
			200	Atlantic off U.S. coast to North Atlantic	35 - 20°	322	good	Heavy Cloud Cover

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
89 BW03	80/49	4.0/1	140	Singapore, cross tip of Malaysia	35 - 36°	382	good	
			140	East China Sea, Cross southern Japan	33 - 31°	391	good	
			100	North Japan coast into Pacific	28 - 27°	405	good	
92 BW12	LC-2/ (N/A)	5.6/5	100	Moon, 3 frames	N/A	1	N/A	
			140	Moon, 3 frames	N/A	4	N/A	
			200	Moon, 6 frames	N/A	7	N/A	
92 BW12	81/58	5.6/5	200	N.W. Mexico to S.E. New Mexico	32 - 30°	13	-1/2 to -1	
			140	New Mexico, N. Texas, Kansas (snow) N. Missouri (snow).	30 - 27°	32	-1/2 to +1/2 (snow)	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
92 BW12	81/58	5.6/5	100	Gulf of St. Lawrence, Anticost Island (snow and ice), Strait of Belle Isle, Newfoundland, (snow), Atlantic (clouds).	18 - 11°	61	good	
92 BW12	82/1	4.0/0	200	Gulf of California, Into Mexico	30 - 29°	92	good	
			140	N.E. Oklahoma, Missouri (snow), Illinois (snow), Tip of Lake Huron.	28 - 24°	103	+1/2 to +1	
			140	Newfoundland (snow), Gulf of St. Lawrence.	20 - 18°	137	good	Heavy Cloud Cover
93 IR03	83/29	4.0/0	140	West Virginia (clouds), Pennsylvania (clouds), New York, Vermont, New Hampshire, Maine, Newfoundland	23 - 21°	2	-1/2 to good	
93 IR03	83/30	4.0/0	200	Baja coast, Baja, Arizona, Colorado (snow), Nebraska (snow), Minnesota (snow)	22°	51	good to +1 in snow	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
92 BW12	85/19	4.0/0	140	Central Montana (clouds), South Dakota, N.W. Nebraska, S.W. Iowa (clouds), N. Missouri (clouds).	21°	153	good	
			140	Georgia coast to Savannah	20°	192	good	
			100	Atlantic Ocean off Georgia	20 - 19°	196	good	
			100	Atlantic, Puerto Rico (50% clouds)	17 - 16°	209	good	
92 BW12	86/47	4.0/0	200	W. British Colombia	16 - 17°	227	good	
			200	North Central U.S.	21 - 25°	234	N/A	Heavy Cloud Cover
92 BW12	87/62	5.6/5	100	Washington	22 - 24°	253	good	Heavy Cloud Cover
			200	N. Idaho, Wyoming, S.E. Wyoming	24 - 27°	260	good	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO. CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
92 BW12	87/62	5.6/5	100	Kansas	28°	281	-1/2	
			100	N.E. Oklahoma, Arkansas, Mississippi, Gulf of Mexico, Florida keys.	29 - 31°	288	good	
			100	Caribbean Sea, N. Venezuela	30 - 29°	315	good	
93 IR03	88/5	5.6/5	140	Montana (clouds), N.E. Wyoming	23 - 27°	117	good	
			100	N.E. Kansas (snow), S.E. Missouri	28 - 31°	138	good	Heavy Cloud Cover
			100	Memphis, Tennessee; N.E. Mississippi, Alabama, S.W. Georgia, Florida	32 - 35°	145	good	
			100	Dominican Republic	35°	172	good	
			140	Atlantic, into N. Venezuela	35°	181	good	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO./ CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
93 IR03	89/33	5.6/5	100	S.W. British Colombia	9 - 14°	201	N/A	Heavy Cloud Cover
			100	W. South Dakota (snow), S.W. Minnesota (snow), N.E. Iowa, (snow), Illinois, Indiana, Kentucky (clouds)	25 - 33°	206	+1 in snow to good	
92 BW12	91/63	5.6/5	140	N. California to S. California	31 - 34°	33_	good	
			200	S. California to N.W. Mexico	35 - 41°	344	good	
			140	3 ea single frames W. Central Mexico	45°	366	good	
			140	Central Mexico, South across Atlantic	49 - 53°	369	good	
93 BW03	92/2/3	5.6/5	100	Gulf of St. Lawrence, Newfoundland	5 - 8°	241	N/A	Heavy Cloud Cover
			100	Atlantic into Moraccan coast	39 - 42°	254	good	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO. CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	* SS	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
93 BW03	92/2/3	5.6/5	200	Mali	45 - 54°	263	good to -1/2	
94 IR13	93/6	5.6/5	140	N. California, Nevada, Arizona	28 - 39°	1	good	
			140	E. Mexico	46°	37	good	
			140	S.E. Mexico	49 - 51°	41	good	
			140	S. Bolivia, Paraguay, N. N. Argentina	49 - 47°	48	good	
93 IR03	94/20	5.6/5	140	New Mexico, West Texas, into Gulf of Mexico	36 - 46°	303	good	
			140	Bolivia, W. Paraguay, S. Brazil, Atlantic	59 - 44°	332	good	
94 IR13	95/34	5.6/5	100	Oregon coast (clouds), Oregon	14 - 21°	70	good	
			140	Utah, NE New Mexico, Texas, Gulf of Mexico	21 - 49°	79	good	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

Table 4.3.1-1 SL4 Exposure Accuracy Determination (S190B) (Continued)

ROLL NO. CANISTER	EREP PASS/ TRACK	'f' NUMBER/ FILTER	SS*	SUBJECT	SUN ANGLE	START FRAME	EXPOSURE ACCURACY	NOTES
94 IR13	96/48	5.6/5	140	Idaho, Colorado, Texas, Gulf of Mexico	15 - 46°	147	good	
			140	British Colombia	60 - 63°	193	+1/2	
94 IR13	98/6	5.6/5	100	Pacific off Oregon, N. California, (50% clouds)	10 - 19°	201	good	
			140	Arizona, Length of Mexico, Pacific, Ecuador, Peru	23 - 80°	224	good	

*Units are in seconds^{-1}; thus the exposure time is (SS)$^{-1}$, i.e., for SS = 200, the exposure time is 1/200 sec.

DATE 1974 CONTROL # U 5 inch TASK Skylab PREPARED BY

FILM 3414 EMULSION # MFG EK EXPIRATION DATE

EXPOSURE DATA	PROCESSING DATA	DENSITOMETRY
SENSITOMETER I-B	PROCESSOR Fultron #1	INSTRUMENT MacBeth
ILLUMINANT 2850 °K	CHEMISTRY MX-819	TYPE TD-217DR
TIME 1/10 SEC.	SPEED Full TANKS 20 FPM	APERTURE SIZE 2 MM
FILTER 5500 °K	TEMP °F 90 TIME	FILTER Visual

SPEED ( )	
D-MAX	
GAMMA	
BASE + FOG	

CHEMICAL ANALYSIS

SP GR

pH

TA

TRP

KB,

21	2.41
20	2.34
19	2.25
18	2.14
17	1.99
16	1.79
15	1.58
14	1.34
13	1.08
12	.84
11	.62
10	.47
9	.38
8	.33
7	.30
6	.29
5	.28
4	.28
3	.27
2	.27
1	.27

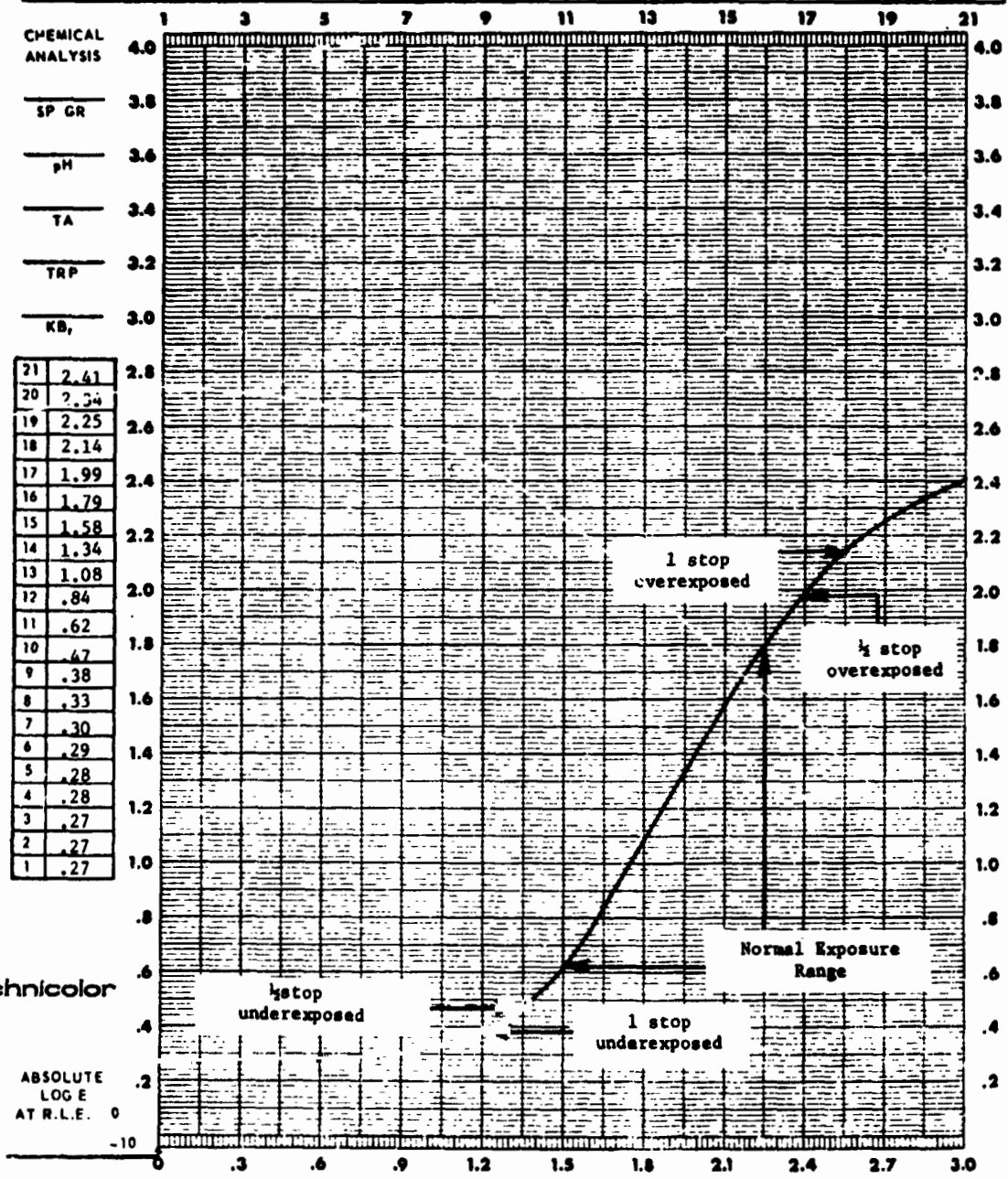


Figure 4.3.2-1 Density vs Log Exposure Curves

Change 1 - October 25, 1974

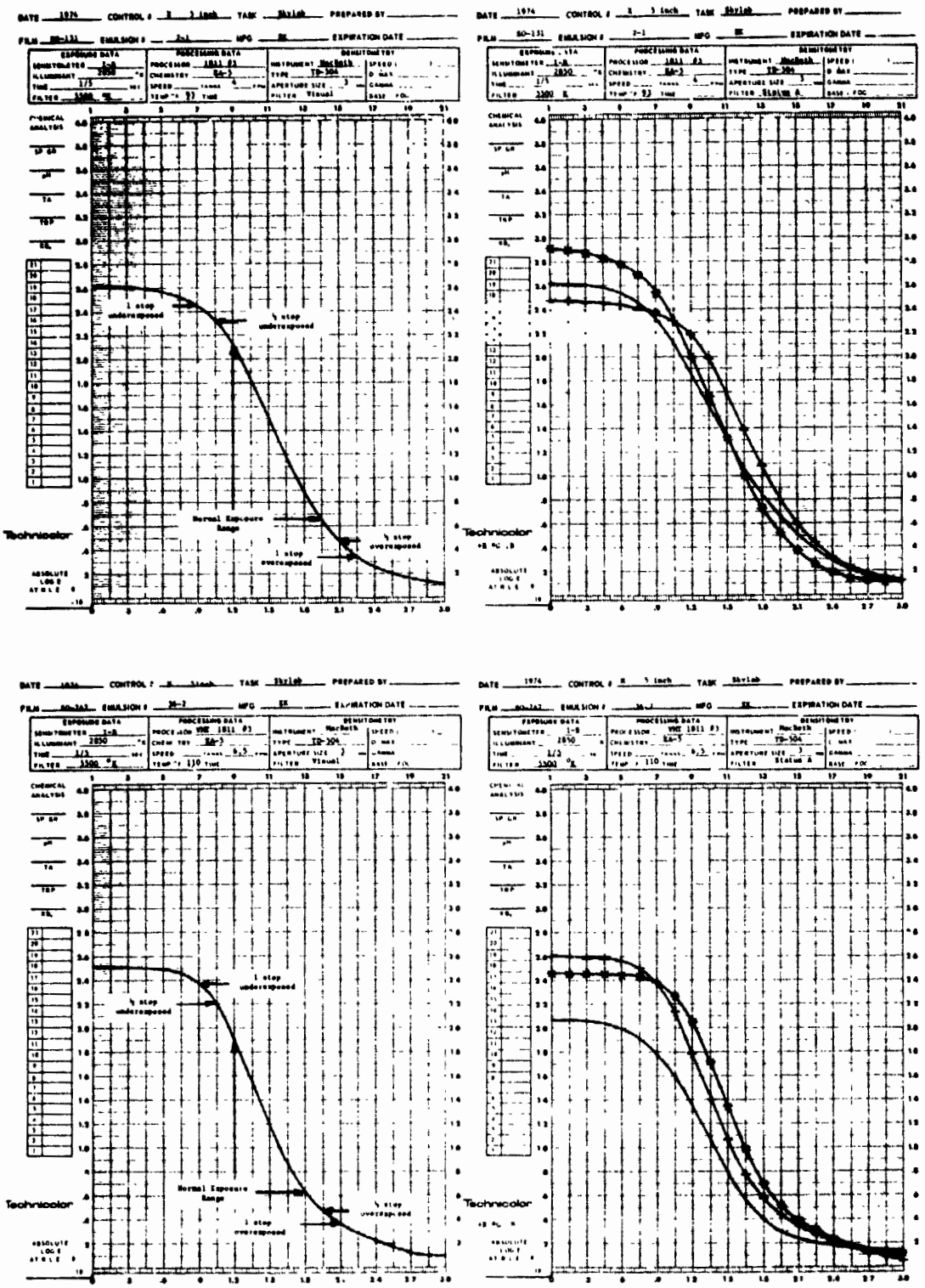


Figure 4.3.2-1 (continued) Density vs Log Exposure Curves

5. SPECTRORADIOMETRIC ACCURACY AND SIGNAL TO NOISE DETERMINATION (SPE-S190B-003, JSC/S&AD)

This section was not available for inclusion in this report.

6. SPATIAL RESOLUTION DETERMINATION (SPE-S190B-004; ITEK)

The Spatial resolution performance evaluation task was performed by the ITEK Corporation, Lexington, Massachusetts.

6.1 SL2 Image Analysis Evaluation - This section contains the results of a partially completed image analysis program which has been designed to produce, upon completion, a description of the S-190B sensor performance primarily in terms of the two dimensional spatial performance of the film.

All analysis has been performed on second generation duplicate positives made directly from the original negatives. These results cannot be used to determine exactly the actual performance of the S-190B camera, however, when the fact that duplicate imagery has been used for the analysis is taken into account, the results can be construed to be indicative of general camera performance. The primary purpose in generating this data at this time is to assist users of the material in evaluating the potential and limitations of the imagery on second generation duplicate positives.

The original film types used in flight by the ETC and the duplicate materials upon which the analysis was performed are:

Original Film	Duplicate Film
3414	2430
SO-242	SO-360

6.1.1 Image Quality Evaluation - During the Skylab 2 mission, the S190B high resolution camera acquired aerial photography over portions of North, Central and South America. This photographic coverage was recorded on both black and white and color film. A partial set of second generation duplicate positive transparencies was submitted to Itek for evaluation of image quality. A high percentage of this coverage was acquired over water and/or cloud covered areas thus limiting the number of frames available for image evaluation analysis.

An initial quality and photographic coverage review was conducted in order to determine if any camera system malfunction had occurred, number of frames available for image quality analysis, amount of water and/or cloud coverage and, assessment of any system anomalies. The initial evaluation identified the

limited quantity of good cloud free cultured photographic frames and also found that the black and white photography was grossly out of focus due to lack of vacuum previously discussed.

The subjective rating or image quality was accomplished by detailed study of images under high magnification in a systematic process. Two approaches were employed during this investigation. The first involved using a transparent one centimeter grid under the frame being studied, with each centimeter area having culture being ranked. This approach is then repeated throughout the photography. From the data extracted by the use of this matrix an overall pattern did evolve showing image quality variations within a frame. The second approach utilized a four-circle zone pattern as shown in Figure 6.1.1-1. This zonal pattern best suited the color photography for image quality evaluation.

The imagery was evaluated by a technique called Visual Image Evaluation (VIE). This technique uses a standard photo-interpreter viewing table with a variable zoom binocular microscope. The photographic image is magnified to the point where the image becomes divorced from instant recognition (the image breaks down due to grain, image resolution, image contrast and other image degrading factors) as judged by the person viewing the photography. This magnification is then converted to an estimated film resolution number based on a calibrated conversion factor that had previously been determined by an analysis of the magnifications required to read 2:1 contrast resolution targets from laboratory and operationally generated aerial photographs. This conversion factor was further verified by cross checks where the resolution was withheld, forcing the interpreter to judge the resolution from the images. This evaluation approach closely matches that of the photointerpreter who is also hampered by image scale, contrast, shadow lengths, spectral response and all other factors that effect the final photograph.

6.1.1.1 Black and White Photography - The black and white panchromatic photography was recorded with a high definition film (3414) having enhanced red senstivity peaking at 680 nanometers with near total loss of sensitivity by 700 nanometers. The original 3414 negative was duplicated on a fine grain duplication film (2430). This transparency (a second generation) was used for the image quality evaluation.

The panchromatic photographic images show both a large variation of image quality within a given frame, and a pattern of image quality change that remains consistent from frame-to-frame. This frame-to-frame consistency suggests that the film was not held flat during its exposure and that each frame conformed to a similar setting with each new frame being transported into the format area.

The image quality of a typical panchromatic duplicate transparency frame can best be described by reviewing the pattern indicated by the VIE resolution numbers shown in Figure 6.1.1-2. Within a given frame the quality of the imagery changes by a factor of three, the best resolution being in this area adjoining the clock and along the titled edge. The highest quality image observed yields approximately 75-foot ground resolved distance (GRD) while the poorest yields approximately 250-foot GRD. Approximately 52 percent of the 3414 photography furnished is cloud covered.

6.1.1.2 Color Photography - The high definition color film (S0242) was duplicated on S0360, an Ektachrome aerographic duplicating film. It is this second generation transparency that was used for evaluation.

The color duplicate transparency imagery shows little quality change throughout the major portion of a frame, with only poor imagery in the four corners of each frame (Figure 6.1.1-3. The best quality color imagery yields 60-foot GRD, with the major portion of the imagery yielding 85-foot GRD. A minor component of motion was detected in edges of roads and farm plots where these edges have higher than average contrast. This smear disturbance is considered very minor at the current resolution level of the SO 242 film. Should either the SO 242 or 3414 films yield higher resolution on future Skylab missions the observed motion may very well be a major factor, by limiting the system performance in one direction. Approximately 31 percent of the color photography is cloud covered.

6.2 Spatial Resolution Determination - This paragraph presents the preliminary results of VEM (Visual Edge Match) analysis performed on the S190B black and white duplicate film for SL2, SL3 and SL4.

6.2.1 Visual Edge Matching - Visual Edge Matching (VEM) is a technique for determining photographic image quality in the absence of special targets. The edge comparison technique involved visually comparing a photographic edge of unknown quality with a calibrated, laboratory-made matrix of edges. Figure 6.2.1-1 illustrates the VEM analysis method.

The matrix consisted of rows and columns of edges. Columns contained edges of constant sharpness but varying contrast, and rows contained edges of varying sharpness but constant contrast. Sharpness steps were determined that gave equal psychological steps, and also an unambiguous visual sharpness scale. Each edge was one millimeter long. Included in each edge column was a resolution target which allowed ranking the visual sharpness steps in terms of 2:1 contrast resolution. Actually, any type of target could have been included for reference. It was possible to make matrices on any photographic material. However, it was imperative that they were made on the same material as the film under analysis, so that the graininess for both the matrix and the unknown photography would be equivalent.

The edge matrix was placed on one side of a split field, double microscope comparator, and an edge of the unknown photograph selected and matched in contrast to a matrix contrast. The observer then moved the matrix in the sharpness row until a sharpness match was obtained.

Since the matrix was calibrated in terms of resolution, the resolution of the film under analysis was readily determined. Not only did the matrix edges have to be made of the same material as the film under analysis, but processing conditions had to be duplicated in order to obtain consistent and accurate matching results. Preflight resolution targets exposed through the S190 camera also had to be produced for the matrix calibration to determine the resolution/contrast functional relationship.

VEM analysis was performed on the black and white duplicate film of the S190B camera. Resolution estimations of the color film was produced through VIE analysis, and is found in section 6.1.1.2.

6.2.2 Procedures - Matrix Production and Calibration - An important capability of VEM analysis was that system performance and original negative quality could be determined from the evaluation of duplicate material. A duplicate VEM matrix was constructed and calibrated using duplicate test imagery. Calibration was performed by matching matrix edges to edges in the duplicate calibration 3-bar targets.

The resolution of the target was read at the same time as the matching. Upon averaging, fitting and plotting the resolution data versus edge number, a resolution value was assigned to each matrix column of edges. The contrast of the original 3-bar targets determined the contrast for which the calibration was valid. The same 3-bar targets used on the duplicate material were then read on the original negative (O.N.) material. Upon averaging, fitting and plotting of this data versus edge number, a second set of resolution values which define original negative quality was assigned to the matrix (one value for each column). Thus, VEM analysis of duplicate imagery produced a set of two values: the resolution of the duplicate, and the resolution of the original film. Proper processing and duplication of the matrix edges and test bar targets was necessary for this technique to work.

A 2430 duplicate matrix has been assembled for evaluation of the S190B imagery. At the time of this report the matrix calibration had not been completed. Thus, no values are given here for O.N. resolution, and duplicate resolution values are considered preliminary.

The contrast of the calibration test targets was 2:1. Thus, all resolution values shown here are for 2:1 ground target contrast.

6.2.3 Results - These results are preliminary. VEM calibration and all data reduction have not been completed at this time. Table 6.2.3-1 gives resolution values for all Skylab missions, 2430, duplicate quality only. The SL2 results show an average resolution over the full format. The SL3 and SL4 results are given for an area of $\pm$ 8 degrees over the S190B format. This area includes all of the format except small areas near the corners.

The reason for the drop in resolution on SL2 is known to be a malfunction in the camera's vacuum platen system. The reason(s) for the resolution losses on the Solar Inertial Passes is not fully understood at this time. Post Pass Summary Data indicates

that this loss could be due to an improper FMC setting. This data also shows that the Skylab crews had some problems with the camera's vacuum system during some of these (Solar Inertial) passes. Less Post Pass data is available on the SI passes than on the EREP Passes. Consequently, investigation into the cause(s) of these resolution losses is incomplete at this time.

A rather large loss in resolution between the O.N. and duplicate test targets was observed. This loss averaged about 25%. Thus, O.N. resolution as predicted from the VEM analysis will be about 25% higher than those values shown in Table 6.2.3-1. All results shown here must be considered preliminary since matrix calibration has not been completed at this time.

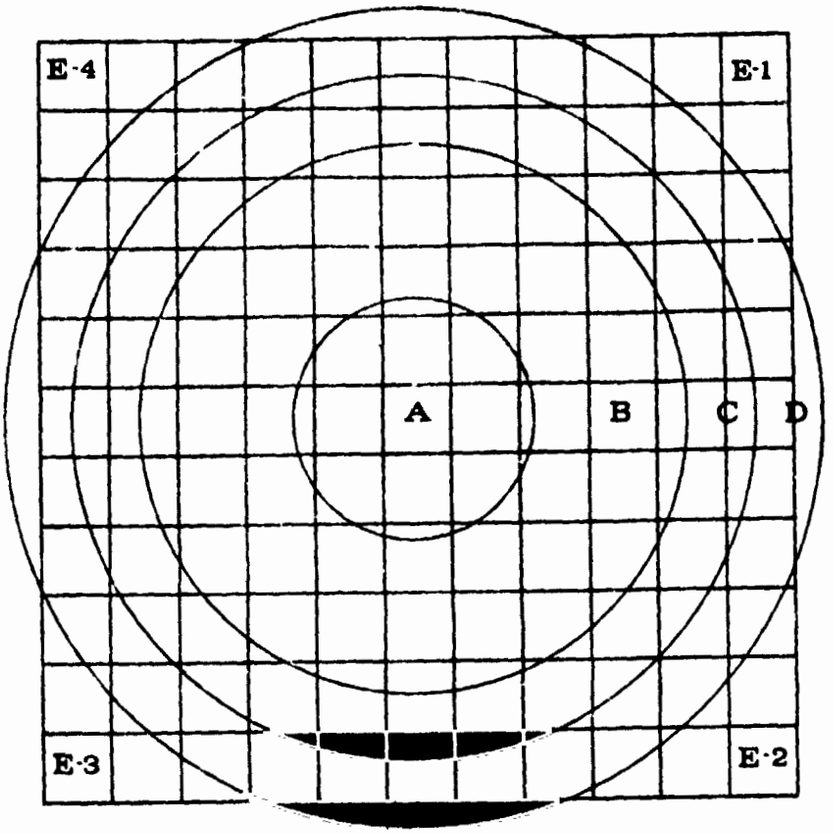
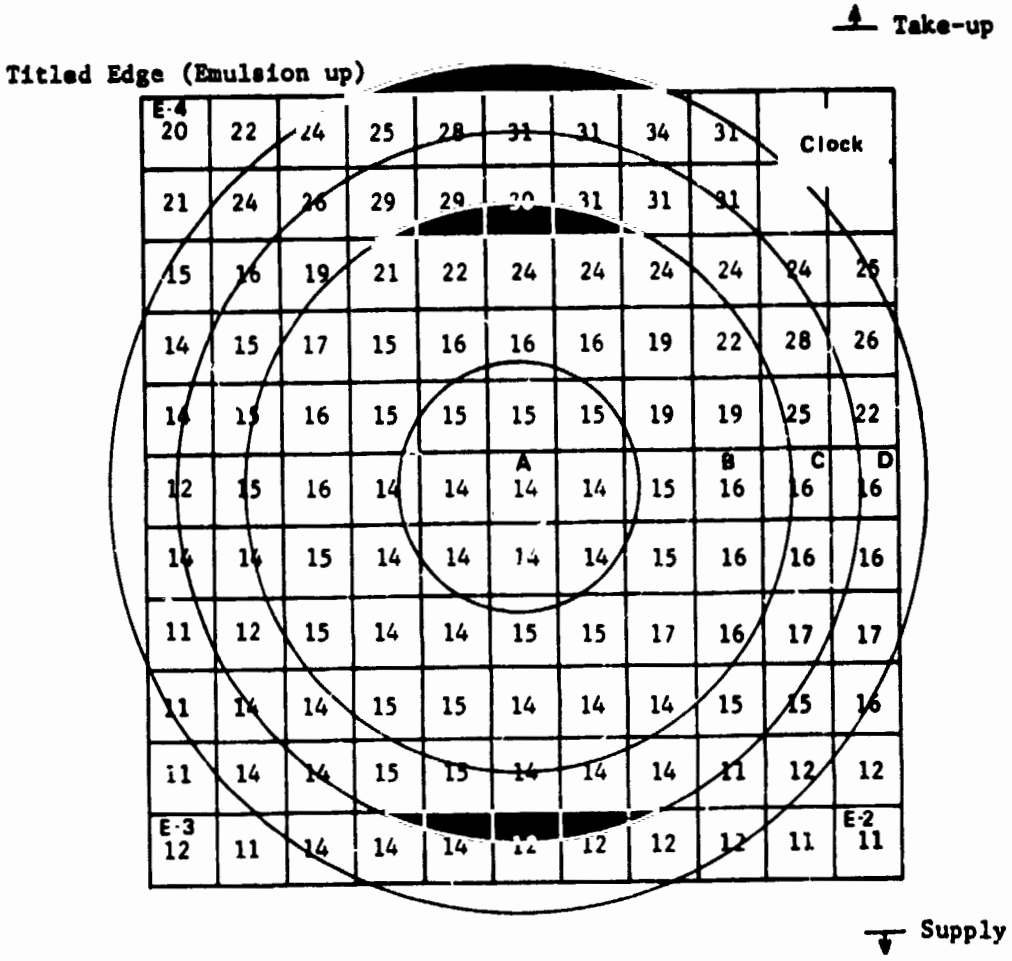


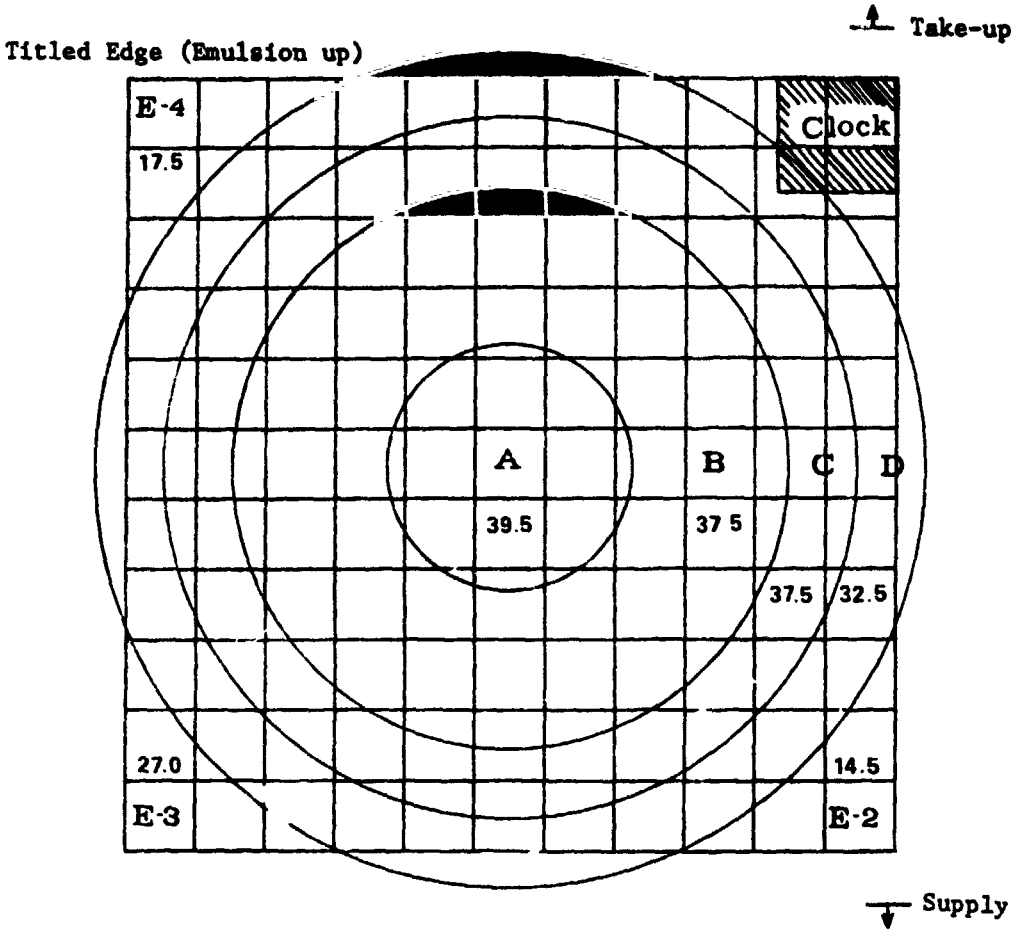
Figure 6.1.1-1 - Overlay Grid and Zone Array



Resolution — Average of two or more readings per centimeter area.

Zone	Resolution (lp/mm)
A	14.3
B	16.8
C	19.3
D	18.5
E-1	Clock
E-2	11.3
E-3	11.3
E-4	21.0

Figure 6.1.1-2 - VIE Resolution - 3414 Film



Resolution — Average of 10 or more readings per zone.

Zone	Resolution (lp/mm)
A	39.5
B	37.5
C	37.5
D	32.5
E-1	Clock
E-2	14.5
E-3	27.0
E-4	17.5

Figure 6.1.1 - 3 - VIE Resolution - SO242 Film

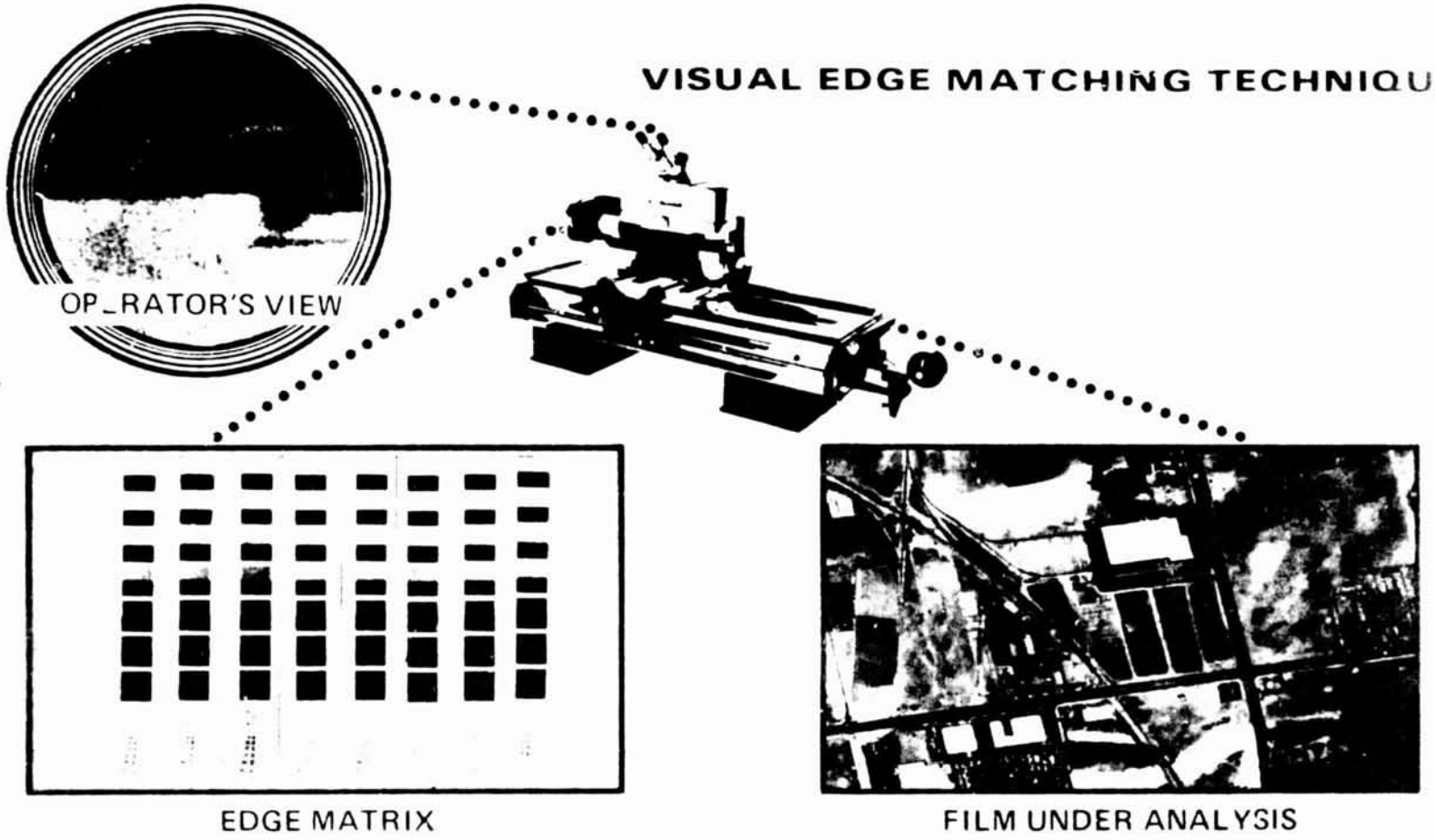


Figure 6.2.1-1 Visual Edge Matching Technique

Table 6.2.3-1 S190B Resolution* @ 2:1 Contrast on Second Generation Duplicate (2430) Film

EREP Pass	Resolution, lp/mm
Skylab 2 (all passes)	13
Skylab 3	
20	60
Solar Inertial 1	45
Solar Inertial 2	43
Solar Inertial 3	47
29	63
30	57
31	53
Skylab 4	
EREP 3 (Solar Inertial)	65
Solar Inertial 2	45
76	62
78	60
80	58

* Preliminary Results

7. GEOMETRIC DISTORTION DETERMINATION (SPE-S190B-005, JSC/S&AD)

The geometric distortion task was performed as an integral part of task SPE-S190B-006 reported in section 8. Several strips of photography as noted in section 8 were analyzed by performing a simultaneous analytical phototriangulation using a modified version of LOSAT. This was performed with no film deformation corrections, lens distortion corrections or atmospheric refractive corrections. The residual errors in transferring from image coordinates to ground control were 8.2 μm rms for SL2 imagery and 8.5 μm rms for SL3 imagery. SL4 results were similar to SL3 results. Since the laboratory mensuration methods have a residual rms error of about 5 μm, it has been determined that the lens distortion contribution to the residuals of about 8.2 μm rms is small and well within the specification requirements for the lens.

8. POINTING ACCURACY, FIELD OF VIEW AND TIMING CORRELATION DETERMINATION (SPE-S190B-006, JSC/S&AD)

8.1 SL2 Pointing Accuracy Evaluation - This section presents a comparison of ground point positioning errors between SKYBET photo-support data and actual ground positions, and an analysis of the pointing angle difference between the S190A and S190B cameras. Contact positives made from the original flight film were used in this analysis.

8.1.1 Ground Positioning Errors - Ground positioning errors were determined for one portion of the SL2 mission by performing a simultaneous analytical phototriangulation of a strip of S190A and a strip of S190B imagery over a common area. Using a modified version of the LOSAT (Lunar Orbiter Strip Analytical Triangulation) computational program, a statistically-rigorous simultaneous photogrammetric adjustment to a dense network of ground control was accomplished. The results of this fit were then compared with published SKYBET photo support data to evaluate the positioning errors in the S190A and S190B imagery.

The photography used for this evaluation consisted of five frames of S190A data from camera station 5 (frames 11-240 through 11-244) acquired in the vicinity of Terre Haute, Indiana during EREP Pass 7, track 33; and frames 81-336 through 81-344 of companion S190B data. A well-distributed pattern of 25 of more ground control points was carefully selected on each frame of imagery. Conjugate images were steroscopically located and transferred between overlapping frames using conventional photogrammetric techniques. These control point images were measured on a Mann Model 1210-3 precision monocomparator to obtain coordinates necessary for the analytical adjustment. Object space (geographic) coordinates of the control were derived by digital interpolation of measurements of the points on 1:250,000 scale USGS maps. Initial approximations for the location, attitude and time of exposure parameters for the various photographs were obtained directly or derived from SKYBET data. These parameters were subsequently allowed to adjust, subject to the a priori knowledge of their values, in the LOSAT adjustment.

In processing these data through the LOSAT adjustment, photo image measurements were weighted at 8 micrometers, ground control was considered known to an accuracy of 50 meters and the times of exposure of the five S190A frames were treated as if known to .001 second. The manufacturers focal length value of 152.429 mm was used for the S190A station 5 exposures; and a

value of 457.411 mm, as derived from the stellar calibration performed by JSC, was employed for the S190B frames used in the phototriangulation. It should be noted that no film deformation corrections, lens distortion corrections or atmospheric refraction corrections were applied to the photo image measurements. Correction for principal point offset was, however, applied. In the LOSAT reduction photo positions and orientation (attitudes) and the times of the S190B exposures were provided complete freedom to adjust such as to "best fit" the network of ground control. It should also be noted that the mathematical model employed in LOSAT confines all of the exposure stations to lie somewhat on an orbital arc which is physically defined by dynamical equations of motion.

Ultimately, the LOSAT adjustment converged to a stable result with 8.2 micrometer root mean square error on the photo images of the ground control points. The results of this adjustment, as it pertains to ground positioning errors, i.e., differences between SKYBET and actual ground positions, is depicted in Figure 8.1.1-1 for one typical frame of photography in the triangulated strip.

The most significant finding of this portion of the evaluation is that the SKYBET data for the S190A and this EREP pass is apparently one frame off, i.e., the SKYBET data for frame 240 most nearly coincided with the triangulation results for frame 241*. If this discrepancy is taken into account, then the rms differences in the principal point (center of photo) location between the SKYBET and photogrammetrically derived values are 6808 meters for S190A and 5822 meters for S190B. Converted to intrack and crosstrack components, these differences are:

S190A: 4166 Meters intrack; 5423 Meters crosstrack

S190B: 5776 Meters intrack; 730 Meters crosstrack

The above-described analytical phototriangulation was subsequently reperformed, this time using control point coordinates derived from 1:24,000 scale USGS maps. The control point pattern was identical to that originally selected on the 1:250,000 scale maps. The results of this triangulation were virtually identical with those of the triangulation using the 1:250,000 source control. The root mean square error of the photo coordinates for the 1:24,000 source triangulation was 8.0 micrometers, as compared with 8.2 micrometers for the 1:250,000 source triangulation.

*The S190A tabulation S022-1 as described in PHO TR 524 is being corrected.

Tests performed on differences in the passpoint coordinates and photo parameters for the two triangulations indicate that no statistically significant differences exist between the two reductions.

This indicates that, with proper procedures, 1:250,000 scale maps meeting National Map Accuracy Standards can be utilized to support metric exploitation of both the S190A and S190B SKYLAB photography.

8.1.2 S190A and S190B Pointing Angle Differences - The LOSAT analytical triangulation, previously described in Section 8.1.1, yielded, as a byproduct, photo orientation parameters which enable the angular pointing differences to be established between the S190A and S190B cameras. Since the photo triangulation is based on coordinates of readily photo-identifiable points on the ground, it provides a means of determining camera position and orientation information that is completely independent of spacecraft attitude data, external tracking, etc.

The LOSAT-derived attitude data and pointing angle differences are presented in this section in terms of pitch, roll and heading referenced to a "local vertical" coordinate frame. This local vertical system is originated at the exposure station with the +Z axis directed away from the earth along the normal to the spheroid which passes through the origin. The X-Y plane is tangent to the normal at the origin, with the +X axis directed toward north and +Y 90° to the east so as to form a right-handed rectangular system.

In order to define the photo pitch, roll and heading orientation angles in terms of this system it is first necessary to define a photo-based coordinate system for each system. Since the S190A and S190B cameras do not possess classical photogrammetric fiducial systems, the photo system must be defined differently for each system.

S190A - The internal reseau system is utilized to define the S190A photo coordinate system, as depicted in Figure 8.1.2-1 for a first generation positive (diapositive). With the photo positioned emulsion up and the imagery in the direction of flight situated toward the right, the system is originated at the center reseau with the +X axis aligned with the two outside reseau marks in the middle row. The +X axis is to the right, in the direction of the flight, and +Y is toward the top, normal to the X-axis at

the center reseau. The Z axis is normal to the plane of the photo at the center reseau, plus directed away from the emulsion side.

S190B - The S190B photo-coordinate system is shown in Figure 8.1.2-2. It is originated at the principla point of the photo, as defined by analytical stellar calibration. With the diapositive photo positioned emulsion up and the imagery in the direction of flight situated to the right, the +X photo axis passes through the middle dot fiducial on the leading and the trailing edge. The +X axis is to the right, in the direction of flight, and +Y is toward the top, normal to X at the origin. The photo Z axis is normal to the plane of the photo at the origin, plus directed away from the emulsion.

In terms of these systems, the "local vertical" orientation angles are defined as follows:

Pitch - A component rotation about the Y photo coordinate system which defines the attitude of the +X photo axis relative to the horizontal X-Y plane. A positive pitch corresponds to +X above the local horizontal, i.e., nose up.

Roll - A component rotation about the X photo coordinate system which defines tha attitude of the +Y photo axis relative to the plane of the horizontal X-Y plane. A positive pitch corresponds to +Y above the local horizontal, i.e., left wing up.

Heading - The azimuth of the +X photo axis measured positive clockwise from true north.

Figure 8.1.2-3 graphically depicts the local vertical pitch, roll and heading angles for the five S190A and the nine S190B exposures triangulated in the LOSAT reduction.

The somewhat erratic behavior of the S190B pitch angle is explained by the nature of the operation of this camera's image motion compensation mechanism. The camera is pitched about an axis which is nominally normal to the direction of the flight in order to accomplish the image motion compensation. The tolerance (or variation) on the pulse to actuate the focal plane shutter is sufficient to account for the variations experienced in the S190B pitch angles relative to those of the fixed-mounted S190A.

A difference for each of the component "interlock" angles was determined by linearly interpolating the S190B orientation angles to the five times of S190A, differencing the values for each angle and averaging. This resulted in the following differences (S190B relative to S190A):

Pitch	-6' 48" $\pm$ 2' (1σ)
Roll	-23'53" $\pm$ 2' (1σ)
Heading	+14'31" $\pm$ 45' (1σ)

This translates to a distance of 3176 $\pm$ 363m (1σ) meters at an aximuth of 123^{o} on the surface of the earth, between the intercepts of the S190B and the S190A principla points. The S190B principal point falling to the right and ahead of the S190A principal point.

8.2 SL3 Pointing Accuracy Evaluation - This section basically presents a duplication of the various comparisons described in Section 8.1, this time utilizing photographic imagery and SKYBET data from the SL3 mission.

8.2.1 Ground Positioning Errors - Ground positioning errors for one short portion of the SL3 mission were determined in a manner similar to that presented in Section 8.1.1. A statistically rigorous simultaneous photogrammetric adjustment was performed on a strip of S190A and a strip of S190B photography acquired over a common area during the same orbital pass.

These photographs consisted of five frames of S190A data (47-277 through 47-281) from camera station 5, and seven frames of S190B data (87-263 through 87-269) acquired during orbit 52 over southern Louisiana.

Unless otherwise noted, procedures employed to reduce these data were as described in Sections 8.1.1. Ground control was from 1:250,000 scale USGS maps.

The results of this photo triangulation were completely consistent with those obtained from the SL2 triangulation . The rms mean error of the photo residuals was 8.5 micrometers (vs 8.2 for SL2). In all other respects, the results were comparable to those of the SL2 adjustment.

8.2.2 S190A and S190B Pointing Angle Differences - Again, a procedure similar to that employed for SL2 data was utilized for this portion of the evaluation. The "local vertical" orientation angles for the five S190A and the seven S190B frames are plotted in Figure 8.2.2-1. Reduced to individual "average differences", via the procedure detailed in Section 8.1.2, the orientation of S190B relative to S190A was:

Pitch	- 1' 48" $\pm$ 2' (1 σ)
Roll	-22' 21" $\pm$ 2' (1 σ)
Heading	+18' 14" $\pm$ 45' (1 σ)

This translates to a distance of 2821 meters $\pm$ 385m (1 σ) as compared with 3176 meters $\pm$ 363 meters (1 σ) for the SL2 triangulation. The 355 meter difference falls within the statistical uncertainty in the two values.

It should also be noted that a significant, but undeterminable, portion of this difference can be attributable to variations in the principal point location from film magazine to film magazine (see Actron Industries report entitled "Engineering Report, Earth Terrain Camera, Metric Capabilities Study" dated 19 July 1972 for a detailed discussion of this variation). The anticipated variations in principal point can range up to about .150 mm. For relatively narrow cone angles, however, such a shift in the principal point can be perfectly absorbed or metrically compensated for by a translation in the exposure station and/or small angular changes in the pitch and roll components of camera orientation. Since LOSAT confines the exposure stations to lie on an orbital arc, any error in the principal point will likely be compensated by orientation changes rather than by positional displacement in the crosstrack (roll) direction. The intrack component (pitch) however will be compensated by a movement of the exposure station along the orbital arc rather than by a pitch change.

8.3 SL4 Pointing Accuracy Evaluation - This section, except where noted, presents a duplication of the various comparisons described in Section 8.1.

8.3.1 Ground Positioning Errors - No comparison was made of the SL4 results of phototriangulation analysis of S190A frames with the corresponding SKYBET photo support data. Due to gyro drift during the mission the SKYBET data was deemed sufficiently biased and erratic to negate any meaningful ground positioning accuracy evaluation.

8.3.2 S-190A and S-190B Pointing Angle Differences - Strips of S-190B photography from the same orbital revolution, and covering approximately the same ground scene as the 5-photo strips of S-190A photography, were employed to determine the angular pointing differences ("interlock angles") between the station 5 camera of the S-190A configuration and the S190B camera. A strip in the vicinity of southern Mississippi, as depicted in Figure 8.3.1-1, was used for the SL-4 mission.

LOSAT analytical triangulations were performed with the S-190A and S-190B photographs over a common area being held to a common orbital arc. The mensuration procedures, control sources, observational weights, etc, were the same as those described in section 8.1.2.

All three of the LOSAT triangulations converged to consistently similar results with rms errors of the photo residuals on the control and pass points ranging between 8 and 9 micrometers. Figure 8.3.2-1 depicts the local vertical pitch, roll and heading angles for the triangulated S-190A and S-190B exposures.

A difference for each of the component "interlock" angles was determined for each mission by linearly interpolating the S-190B orientation angles to the times of S-190A, differencing the values for each angle and averaging. The resultant averaged differences produced an orientation of S190B relative to S190A of:

Pitch	11' 24"
Roll	-17' 24"
Heading	17' 34"

The corresponding ground distance between principal points was 2637 meters. These differences are contaminated by the erratic fluctuations in the S190B pitch.

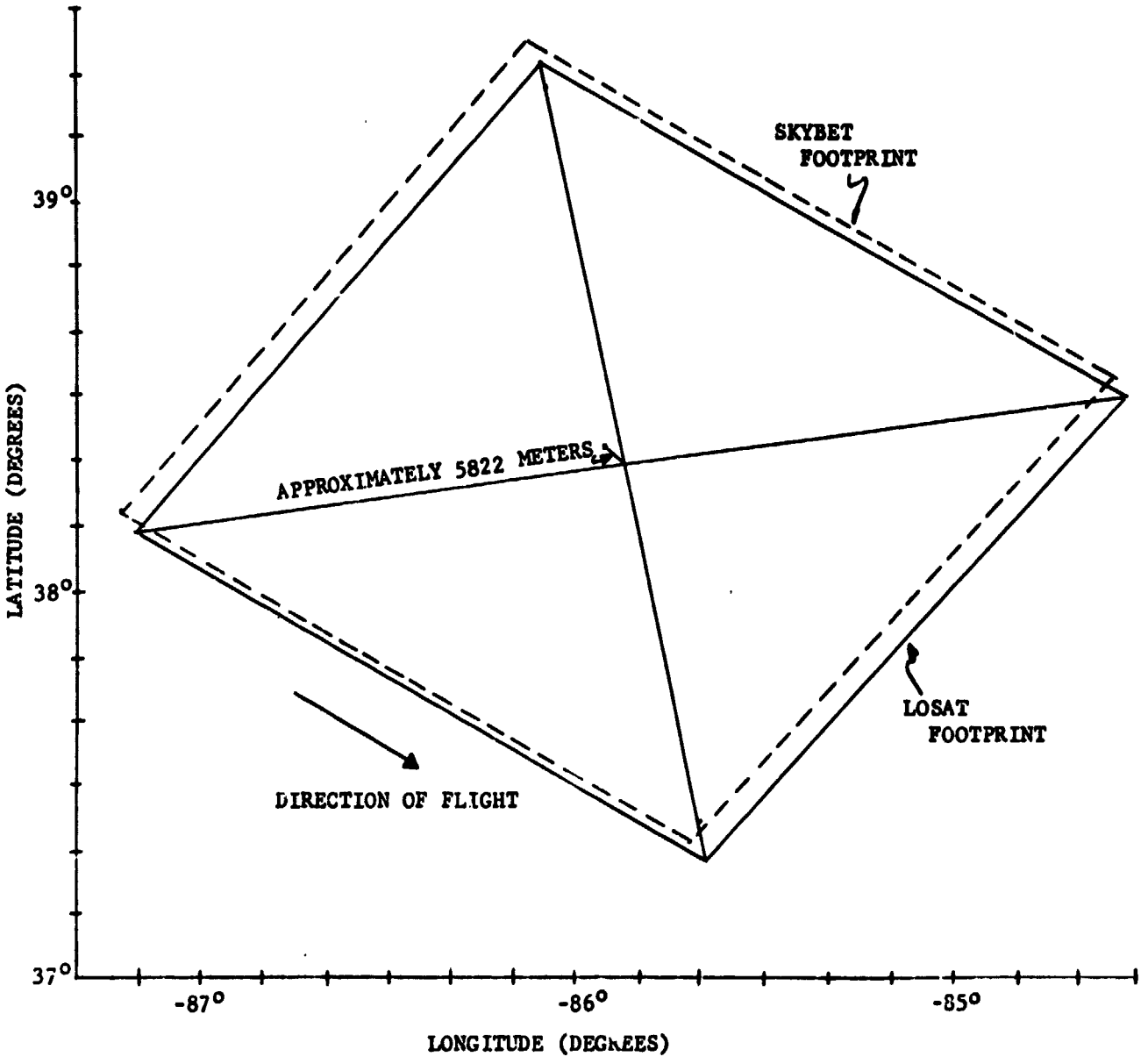


Figure 8.1.1-1 Comparison of SKYBLT S190B Photographic Footprint and Footprint Derived from Photogrammetric Fit to Ground Control (SL2)

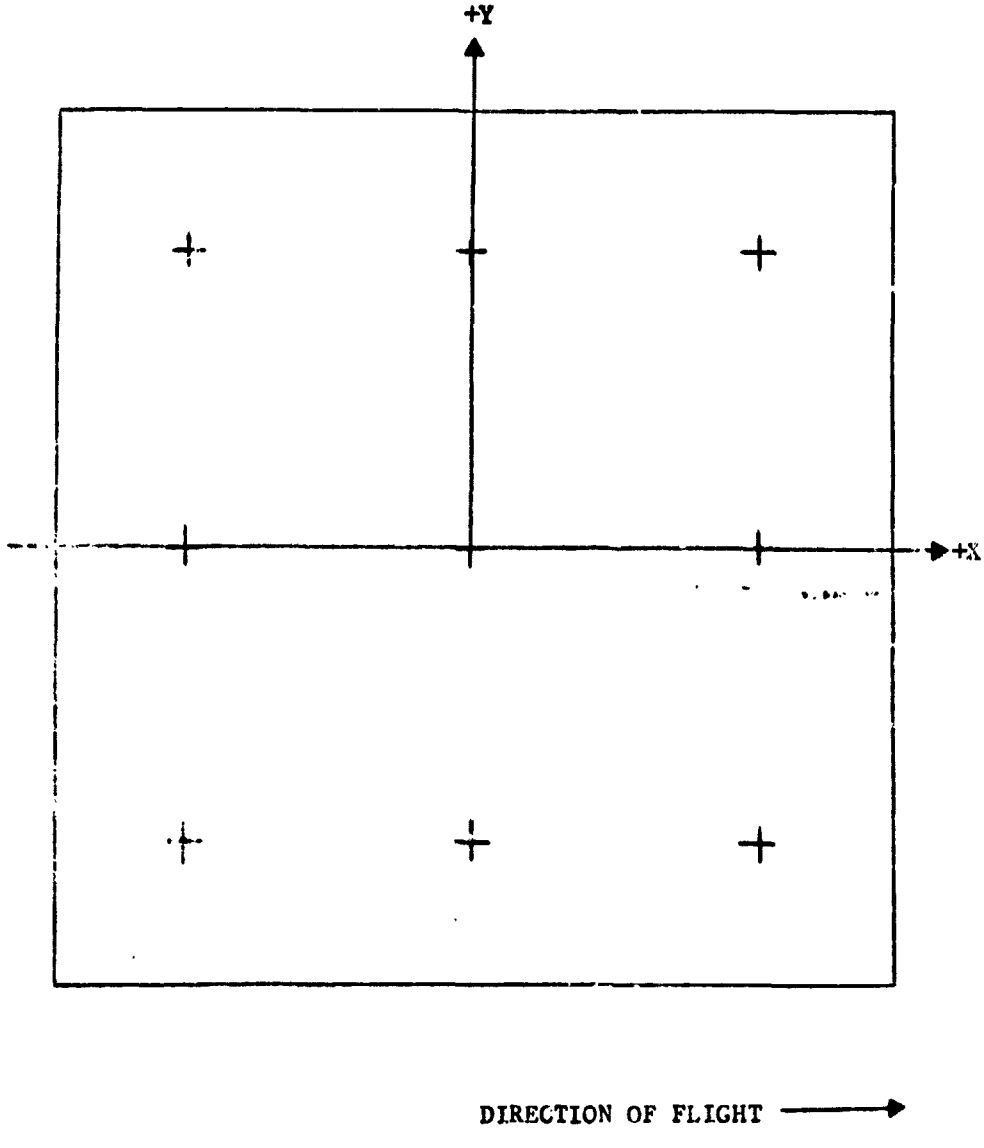


Figure 8.1.2-1 S190A Photo Coordinate System (Station 5, dispositive, emulsion up)

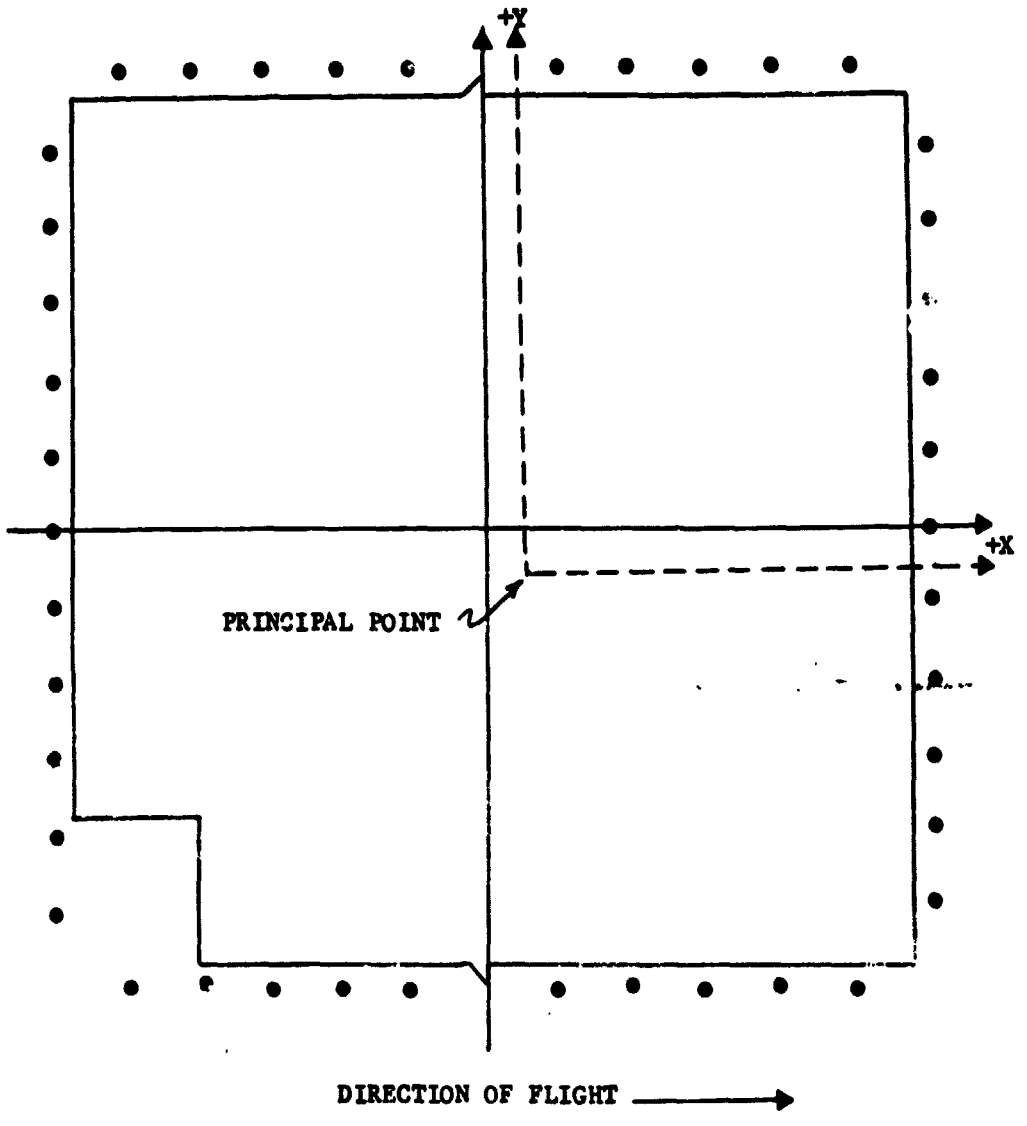


Figure 8.1.2-2 S190B Photo Coordinate System (dispositive, emulsion up)

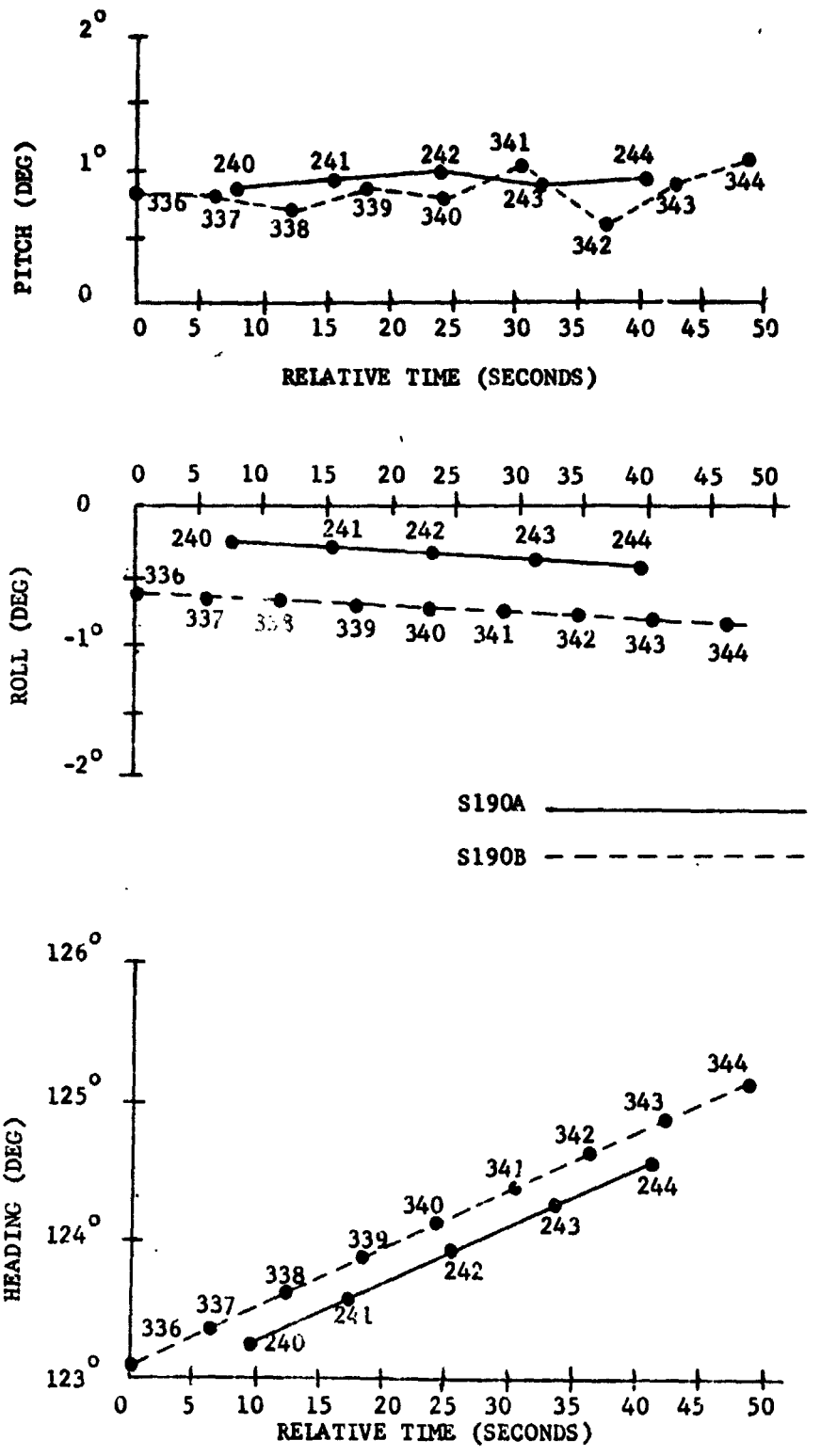


Figure 8.1.2-3 S190A (Station 5) and S190B Camera Orientation Angles as Determined Photogrammetrically by Rigorous Simultaneous Fit to Ground Control (Skylab 2, EREP Pass 7, Track 33)

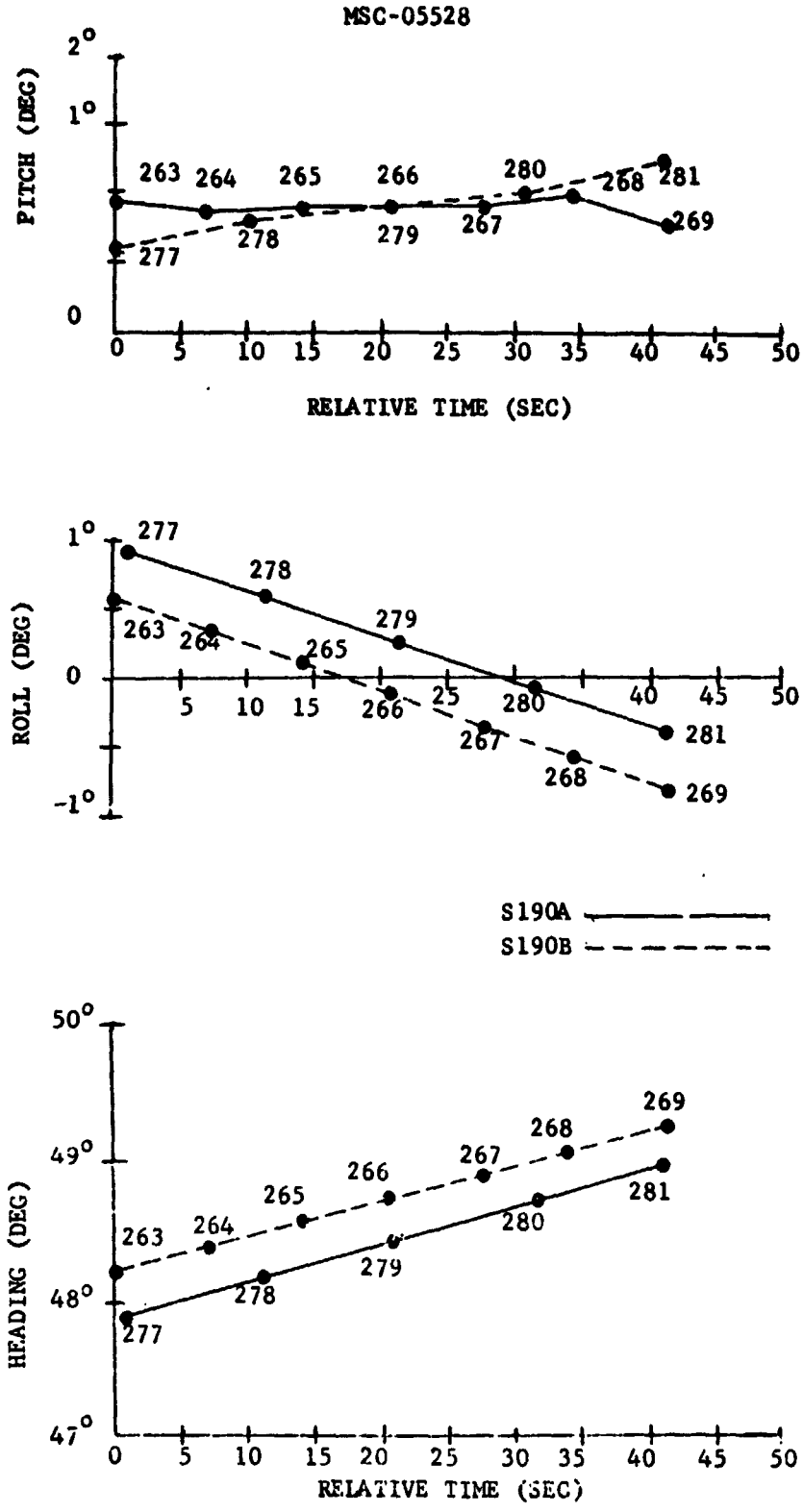


Figure 8.2.2-1 S190A (Station 5) and S190B Camera Orientation Angles as Determined Photogrammetrically by Rigorous Simultaneous Fit to Ground Control (Skylab 3, Pass 52)

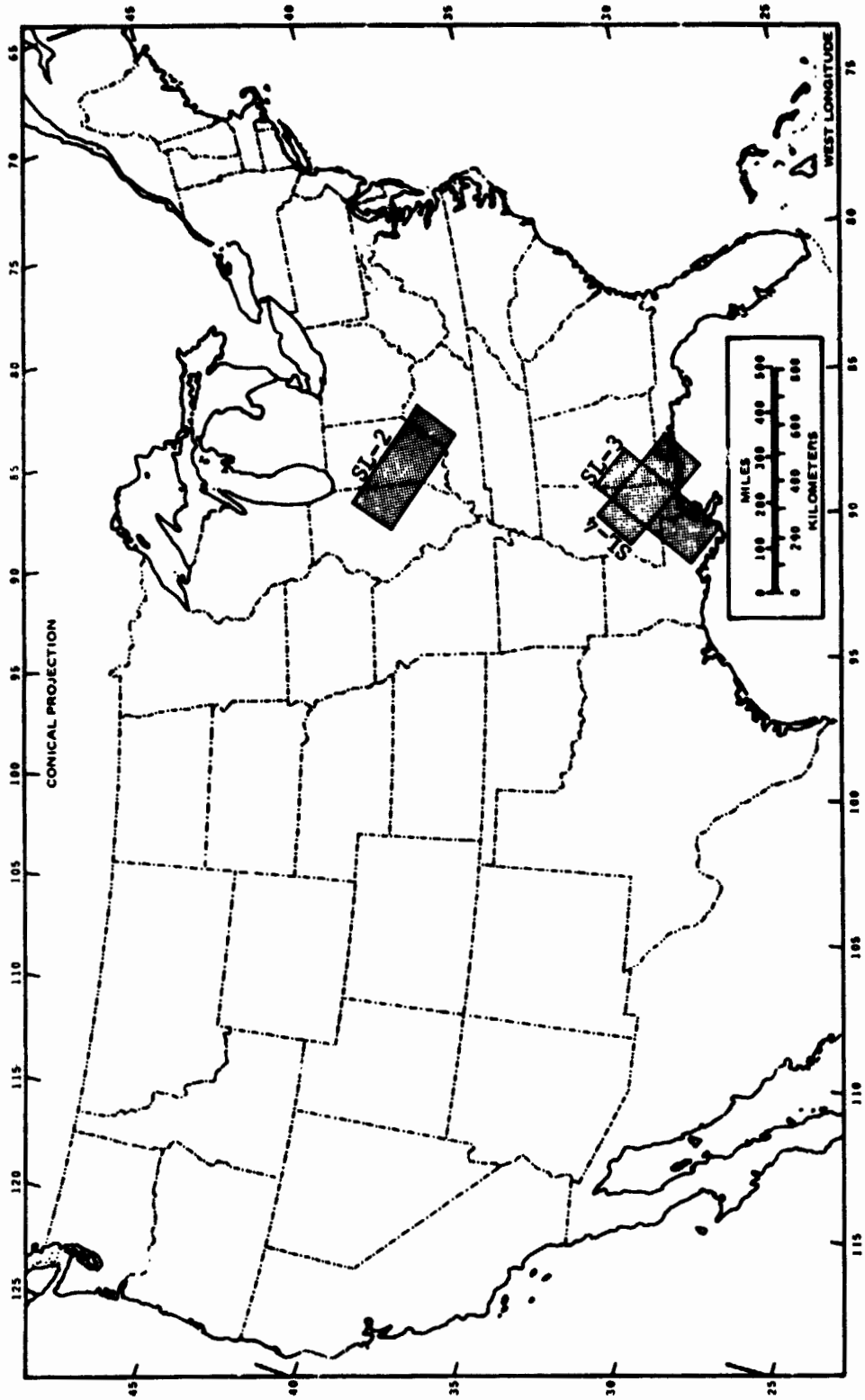


Figure 8.3.1-1 Approximate Areas of Imagery Used for Pointing Accuracy Evaluation and Interlock Angle Determination

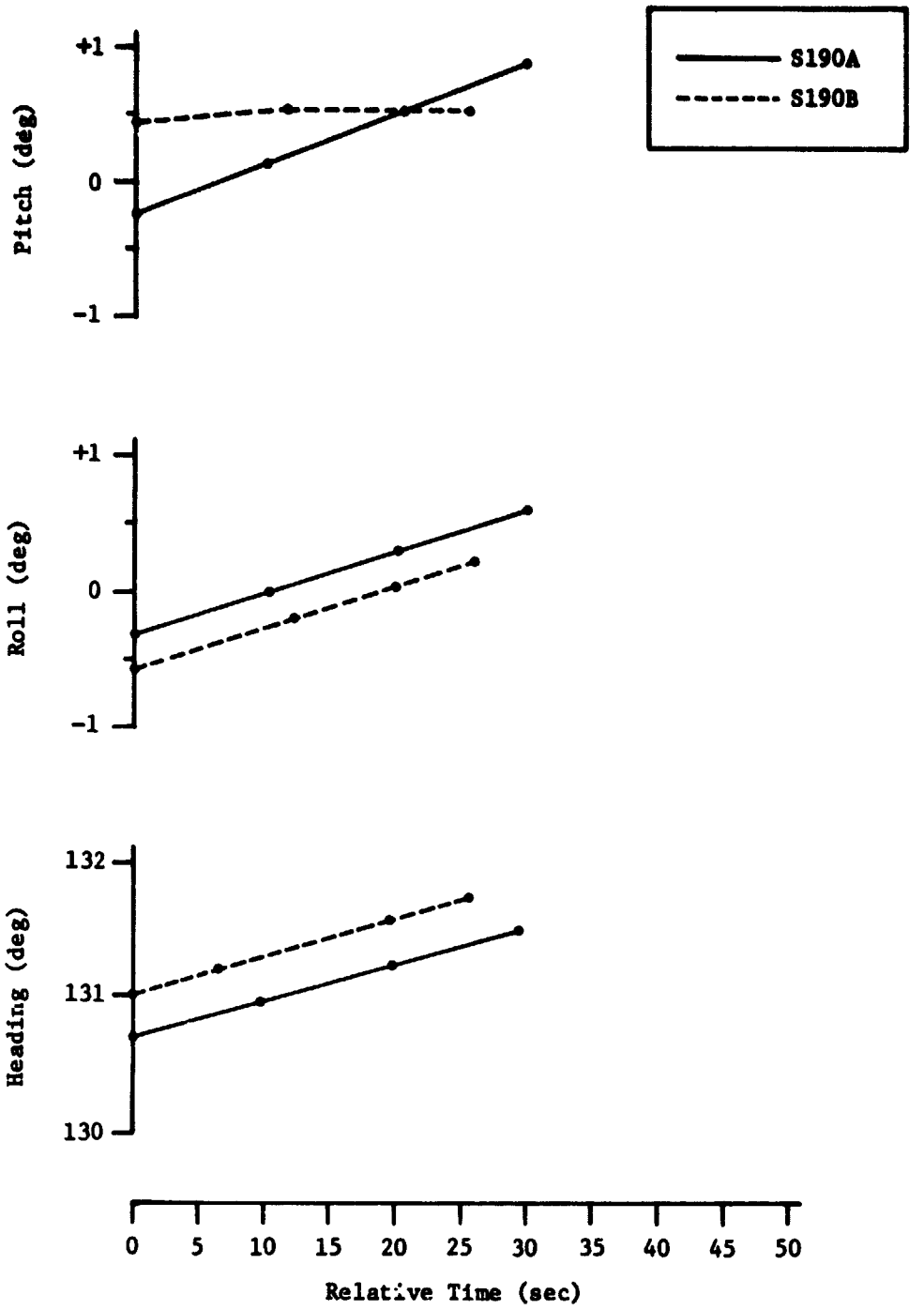


Figure 8.3.2-1 S190A (Station 5) and S190B Camera Orientation Angles as Determined Photogrammetrically by Rigorous Simultaneous Fit to Ground Control (Skylab 4)

9. FILM SENSITIVITY CALIBRATION (SPE-S190B-007, JSC/PTD)

This section describes and presents the photographic calibration data generated by the Johnson Space Center/Photographic Technology Division (PTD) in support of the S190B Sensor Performance Evaluation.

9.1 S190B Film Description - The following defines the film/filter combinations to be used in the S190B camera system.

9.1.1 Kodak Aerial Color (High Definition) SO242 - A daylight-balanced color reversal film with high contrast and good color saturation characteristics. It has extremely fine grain which allows for high resolving power and definition.

9.1.2 Kodak Aerochrome Infrared Film 3443 - This film has a "false color" reversal emulsion and is designed for aerial photography and remote sensing applications where infrared discrimination is required. False color films differ from ordinary color film in that the three layers are sensitized to green, red, and infrared radiation instead of the usual blue, green and red, normally used for rendition of the visible spectrum.

9.1.3 Kodak High Definition Aerial Film 3414 - An extremely fine-grain, slow-speed, panchromatic, negative aerial camera film. This film has high definition and extended red sensitivity for the reduction of atmospheric-haze effects.

9.1.4 Filters - There are six neutral density and/or spectral-shaping filters used with the S190B Earth Terrain Camera. The filters are required to control exposure of films SO242, 3443, and 3414 which cannot be correctly exposed by use of the fixed f/4 lens aperture and shutter speeds alone. The characteristics of each filter are listed below:

Filter	Type	Effective "f" Number
1	Wratten 12	4.0
2	Wratten 12	6.7
3	Wratten 12	8.0
4	Wratten 12	11.0
5	Neutral Density	5.6
6	Neutral Density	6.7

The spectral transmittance for each filter in the 4000 to 9000 Å region is presented in Table 9.1-1.*

* Reference: MSC-01549(Vol. 1) Rev. A, S190 Operational Data Book

9.2 Frame Identification Procedures - Each frame of S190B film is identified outside the usable frame area adjacent to the individual frames as shown in Figure 9.2-1. Roll numbers by mission are as follows:

Mission	Roll Number	Film Type	Canister Number
SL2	81	S0242(Hi Res Color)	CT07
	82	3414 (B&W IR)	BW01
SL3	83	S0242	CT03
	84	S0242	CT04
	85	3414	BW02
	86	S0242	CT08
	87	3443 (Color IR)	IR02
	88	S0242	CT09
SL4	89	3414	BW03
	90	S0242	CT10
	91	S0242	CT11
	92	S0242	CT12
	93	S0131	IR03
	94	S0242	CT13

The frame number is a three-digit number, beginning on each roll with 001 and running consecutively through the roll.

9.2.1 Color Reversal Film - To identify the frames of original color reversal film, it was necessary to perforate the identification information outside the frame. Actual perforating was accomplished by manually aligning the individual frames in a preset perforating machine. Because of the design characteristics of perforators and the limited space available outside the frame area on the S190B films, it was necessary to apply the information in two stages.

a. In the first stage, the film was perforated with the word "NASA" and the appropriate mission number.

b. In the second stage, the film was perforated with the roll number and frame number.

9.2.2 Black and White Film - The B&W films afford a clear border that lends itself to identification by hot press techniques by use of Brownsville tape.

9.3 S190B Photographic Processing Controls - Each primary processing solution was analyzed chemically. The analyses were then compared against the standards set forth by the PTL Quality Control Department.

For each of the flight films processed, a series of five sensitometric control strips of the flight emulsion were processed. At the completion of the processing, the strips were read on the MacBeth TD217DR densitometer, the points averaged (step by step), and the resultant average plotted. At this point, the resultant plot was compared to a preestablished process control curve.

Appropriate procedures were followed for mechanical certification of each processor. Final approval on film and chemistry certification was made by the NASA and contractor personnel of the SPO.

9.3.1 S190B Flight Film Processing - The processing configuration and tolerances for the S190B flight films are listed in Table 9.3-1.

9.4 Sensitometry - Sensitometry is the measurement of the response of photographic materials to radiant energy. In order to use photographic sensors as radiometers, it is necessary to have an adequate understanding of the input and output variables used to specify the response of photographic films.

9.4.1 Input Variables - The energy received by a photographic material can be specified in two types of units - radiometric and photometric. Radiometric units specify the absolute amount of energy received, independent of the response of the detector. These units are preferable when photographing subjects in narrow spectral bands or in the nonvisible regions. Thus, radiometric units must be used for any multispectral photography. Typical units are ergs/cm^2 or watts/cm^2.

Photometric units specify the visual sensation of intensity, i.e. the visual brightness of a scene. These units are sometimes used when the spectral band of the sensor is comparable to the spectral band of human vision, i.e. 400nm to 700nm, or the subject being photographed is close to a spectral neutral. Photometric units are still employed in the calculation of film speeds, since they are relatively easy to measure and correlate well with the film's response to broadband daylight illumination. Typical units are meter-candle-seconds or lumens/m^2.

9.4.2 Output Variables - The most common unit for specifying the response of photographic materials is density. This is defined as the negative logarithm of transmittance:

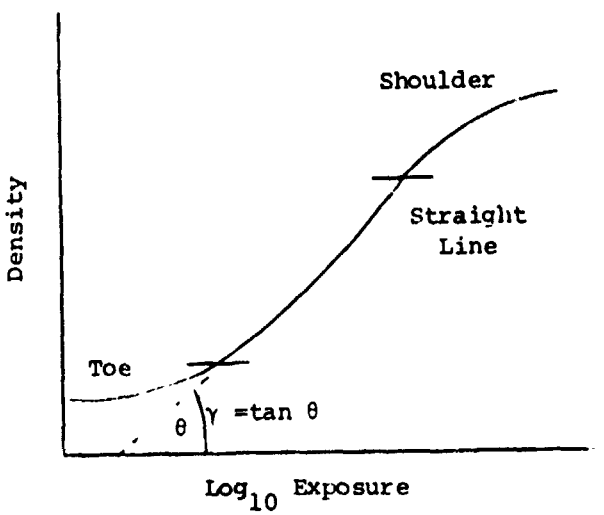
$$D = -\log_{10} T = -\log_{10} \frac{\text{energy transmitted by film}}{\text{energy indicent on film}}$$

This unit best represents the manner in which film responds to brightness ratios - equal brightness ratios produce equal density differences (within the linear response range of the film).

When using a camera as a radiometer, density itself is of little interest. It is the relationship of density to exposure that is important. This relationship is specified by the film's characteristic curve.

9.4.3 Characteristic Curve - Variously known as the D-log E curve or H&D curve (after its originators, Hurter and Driffield), the characteristic curve is the most common way of presenting a film's sensitometric response.

The curve is constructed by plotting density as a function of the logarithm of the exposure necessary to prcduce that density.



The figure shown previously illustrates the three sections of the characteristic curve.

Toe - this is the region from threshold film response to the beginning of the straight line portion. The relationship of density to log exposure is non-linear with an increasing gradient.

Straight Line - this is the region of linear film response. Equal brightness ratios produce equal density differences.

Shoulder - in this region the response again becomes non-linear as the film reaches maximum density. The gradient decreases with increasing exposure.

Gamma - Gamma is the slope of the straight line portion of D-log E curve. Higher gammas produce greater visual contrast and better discrimination of small reflectance differences.

In practice most good exposures fall on the straight line and the upper portion of the toe. Only severe overexposure produces densities in the shoulder.

9.4.4 Sensitometer - A sensitometer is used to apply an accurately known calibration exposure to film. It basically consists of three parts.

a. An accurately controlled light source of known spectral energy distribution, usually a high intensity incandescent lamp.

b. A device for controlling the time of exposure. One of the most accurate, and the one used in PTD's I-B sensitometer, is a rotating drum with a series of slits. The drum is driven by a synchronous motor, and a timing circuit opens a capping shutter when the proper slit passes across the exposure plane.

c. An intensity modulator. In the I-B sensitometer a 21-step carbon tablet is used. The nominal density varies from 0.15 to 3.15 in 0.15 density increments, producing 21 levels of exposure at 0.15 log exposure intervals.

The I-B sensitometer is calibrated in both radiometric and photometric units. Incident exposure is known or can be calculated for various filter combinations.

9.5 S190B Sensitometry - Sensitometric calibration exposures are placed on all original film for two purposes. One is to provide a check on processing and sensitometric effects such as sensitivity loss and latent image failure. A second purpose is to allow conversion of image density to image exposure.

9.5.1 Sensitometry and Spectral Sensitivity - Two types of calibrated sensitometric exposures are applied to all S-190B film. One is an intensity modulated exposure to a simulated 5500°K source filtered by a broadband Wratten filter simulating the flight filter. The second is a spectral sensitometric exposure to a calibrated source to determine the film response as a function of wavelength. The parameters of these exposures are listed in Table 9.3-1.

Following the preflight sensitometric application for the flight rolls, a piece of flight film of sufficient length to accept two sensitometric exposures was exposed and retained as a Houston control film. The strips were placed in light-tight cans, identified, sealed with black vinyl tape, and stored at room temperature.

9.5.2 Arrangement of Pre- and Postmission Sensitometry - The pre- and postmission sensitometry was applied to the S-190B film as follows:

Prior to the application of the premission sensitometry, 25 feet of film was cut off the head end of each roll of film types 3443 and SO-242.

The sensitometric exposures were made on each roll of film prior to flight and upon receipt of the film after mission according to the illustration of Figure 9.5-1.

9.5.3 "Houston Control" Pre- and Postmission Sensitometry - Following the sensitometric application procedures for the flight rolls, a piece of flight film of sufficient length to accept two sensitometric exposures, was exposed and retained as a "Houston Control". The strips were placed in light-tight cans, identified, sealed with black vinyl tape, and stored at room temperature. The exposures were presented on these strips in the manner shown in Figure 9.5-2.

9.6 SL2 S190B Sensitometric Data - The sensitometric data for SL2 is not contained in this document due to the volume of the data. This data can be found in the following reports:

SL2 Sensitometric Data Package, Report Number JL12-502, 26 July 1973.

Skylab I (1/2) Sensitometric Summary, Report Number TR73-3, September 1973.

The Sensitometric Data Package itself contains a brief explanation of sensitometry, the Skylab S-190B sensitometric data, the procedures for calculation of exposure using S190B sensitometric data, spectral sensitometry data, calculation of target radiance and absolute log exposure values. The Appendices to the package includes: (A) Process Certification, (B) Original Pre- and Post-Sensitometry, (C) Houston Control Pre- and Post-Sensitometry, (D) S190B Duplicate Densities and (E) Spectral Sensitometry Report. The Skylab I (1/2) Sensitometric Summary presents the sensitometric data obtained from all rolls of Skylab I original film containing the sensitometric exposures applied by PTD and identifies by appropriate supply and take-up magazine numbers, the amount of radiation and the change in Dmax or Base + Fog due to heat and radiation for each roll of original film.

9.7 SL3 S190B Sensitometric Data - Due to the excessive volume of the SL3 S190B sensitometric data, it could not be included in this document. It can however, be found in the following documents:

SL3 Sensitometric Data Package, Report Number JL12-503, 23 November 1973.

Skylab II (3) Sensitometric Summary, Report Number TR73-4, November 1973.

9.8 SL4 S190B Sensitometric Data - As was the case for the previous Skylab missions, the volume of sensitometric data for SL4 precludes its inclusion into this document. This data has, however, been provided to each S190 Principal Investigator under separate covers:

(1) SL4 Sensitometric Data Package, Report Number JL 12-505, June 1974.

(2) Skylab III (4) Sensitometric Summary, Report Number TR 74-2, June 1974.

To save paper usage and document handling, the SL4 Sensitometric Data Package was distributed on microfiche. The package contained 900 pages and distribution was made to 200 people associated with Skylab.

Table 9.1-1 Spectral Transmittance for S190(B) Components

Wavelength (Å)	ETC SAL Window	Filter T_1 (SN 002)	Filter T_2 (SN 002)	Filter T_3 (SN 002)	Filter T_4 (SN 002)	Filter T_5 (SN 002)	Filter T_6 (SN 002)	S190(B) Lens (SN 002)
4000	0.929	0.000	0.000	0.000	0.000	0.515	0.350	0.400
4200	0.929	0.000	0.000	0.000	0.000	0.510	0.350	0.500
4400	0.930	0.000	0.000	0.000	0.000	0.505	0.350	0.580
4600	0.930	0.000	0.000	0.000	0.000	0.500	0.340	0.650
4800	0.930	0.000	0.000	0.000	0.000		0.340	0.670
5000	0.931	0.010	0.004	0.002	0.001		0.340	0.730
5200	0.931	0.150	0.053	0.013	0.018		0.340	0.760
5400	0.931	0.930	0.326	0.080	0.112		0.340	0.800
5600	0.931	0.950	0.333	0.233	0.114		0.340	0.830
5800	0.932	0.960	0.336	0.235	0.115		0.340	0.850
6000	0.932	0.970	0.400	0.238	0.116		0.340	0.870
6200	0.932	0.960	0.336	0.235	0.115		0.340	0.860
6400	0.932	0.965	0.338	0.236	0.116		0.340	0.880
6600	0.932	0.920	0.322	0.225	0.110		0.340	0.880
6800	0.932	0.940	0.329	0.230	0.113		0.340	0.880
7000	0.932	0.970	0.400	0.238	0.116		0.340	0.880
7200	0.933	0.950	0.333	0.233	0.114		0.345	0.875
7400	0.933	0.950	0.333	0.233	0.114		0.345	0.875
7600	0.933	0.955	0.334	0.234	0.115		0.345	0.875
7800	0.933	0.950	0.333	0.233	0.114		0.345	0.870
8000	0.933	0.920	0.322	0.225	0.110		0.345	0.870
8200	0.933	0.920	0.322	0.225	0.110		0.345	0.870
8400	0.933	0.925	0.324	0.227	0.111		0.345	0.870
8600	0.933	0.930	0.326	0.228	0.112		0.350	0.870
8800	0.933	0.930	0.326	0.228	0.112		0.350	0.870
9000	0.933	0.925	0.324	0.227	0.111		0.350	0.870

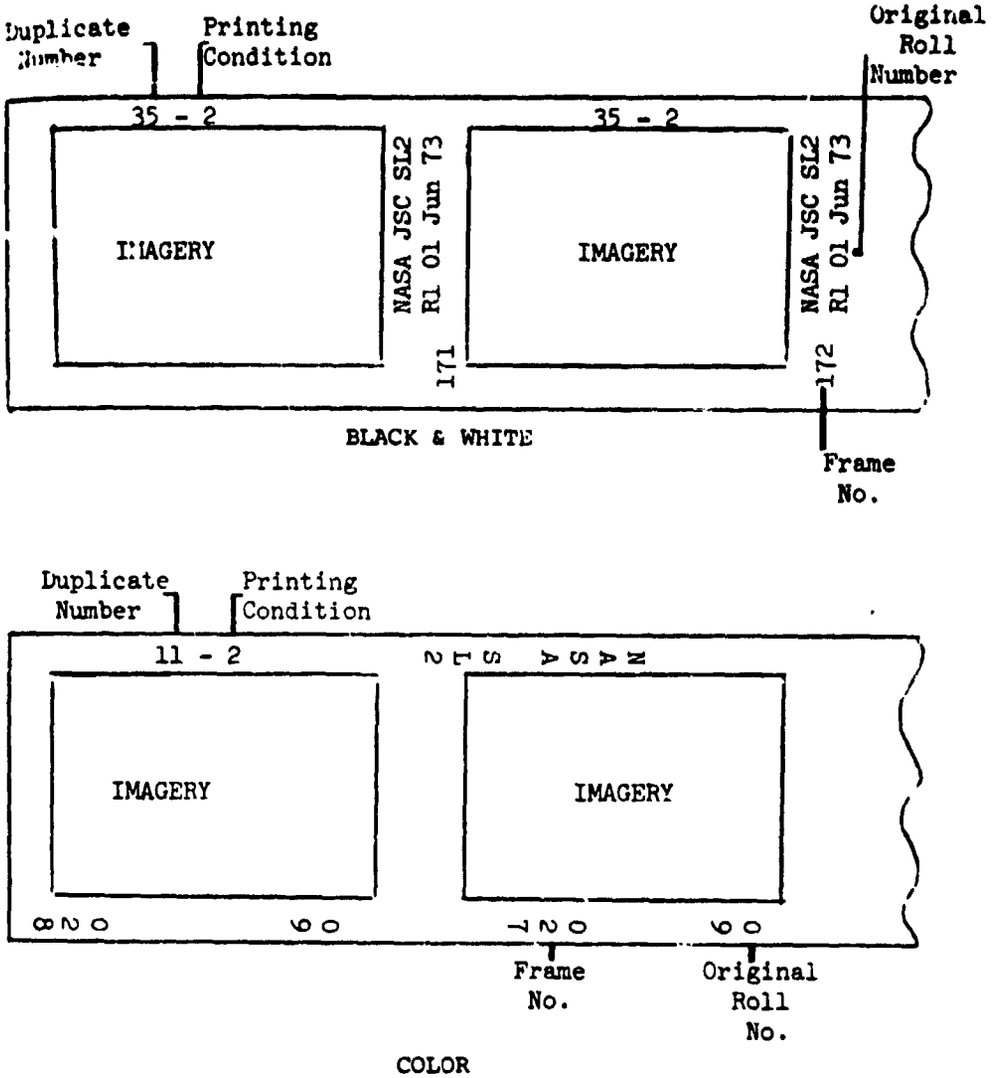
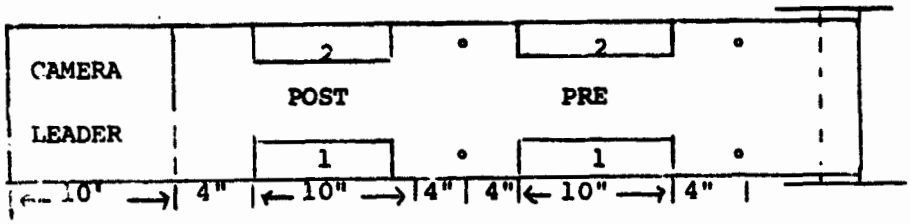


Figure 9.2-1 Location of Roll and Frame Information

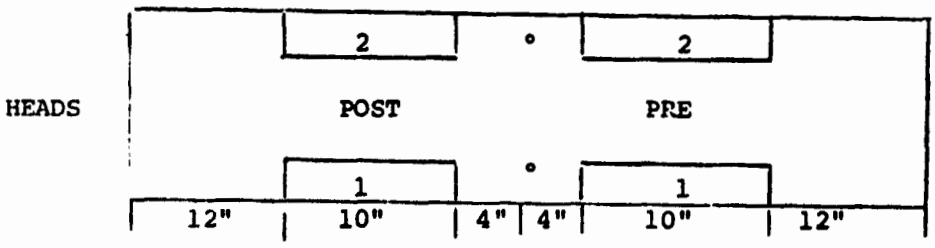
Table 9.3-1 Film/Process/Sensitometry Configuration

				Sensitometry			Sensitivity
Film Type	Emulsion Number	Processor	Chemistry	Illuminant Color Temp.	Filtration	Exposure Time (Seconds)	Exposure Time
SO242	36-2	Versamat 1811	EA-5	2850°K	5500°K + Broadband	1/5	1/30 No Filters
3443	11-2	Versamat 1811	EA-5	2850°K	5500°K + Broadband	1/50	1/100 No Filters
3414	21-8/2	Fultron	MX-819	2850°K	5500°K + Broadband	1/10	1/10 No Filters



° punched for I.D.
No. 1. - Pre- and postmission sensitometry incorporating one of the broad band filters to be used on the mission.
No.2. - Pre- and postmission spectral sensitivity exposures.

Figure 9.5-1 S190B Pre- and Postmission Sensitometry



° punched for I.D.

No. 1. - Pre- and Postmission sensitometry incorporating one of the broad band filters to be used on the mission.

No. 2. - Pre- and postmission spectral sensitivity exposures.

Figure 9.5-2 'Houston Control' Pre- and Postmission Sensitometry

APPENDIX A

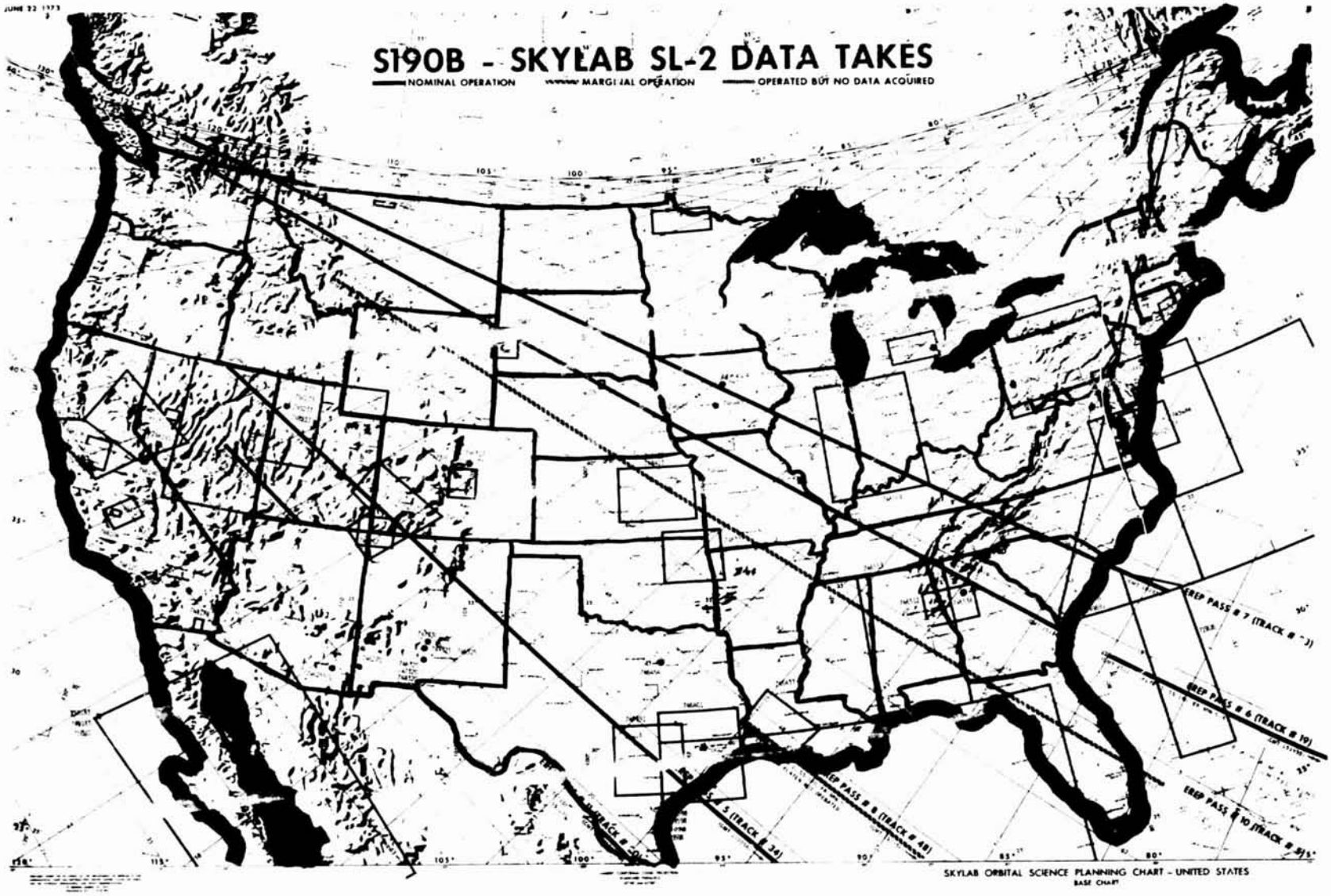
S190B U.S. and World-wide Data Take Maps

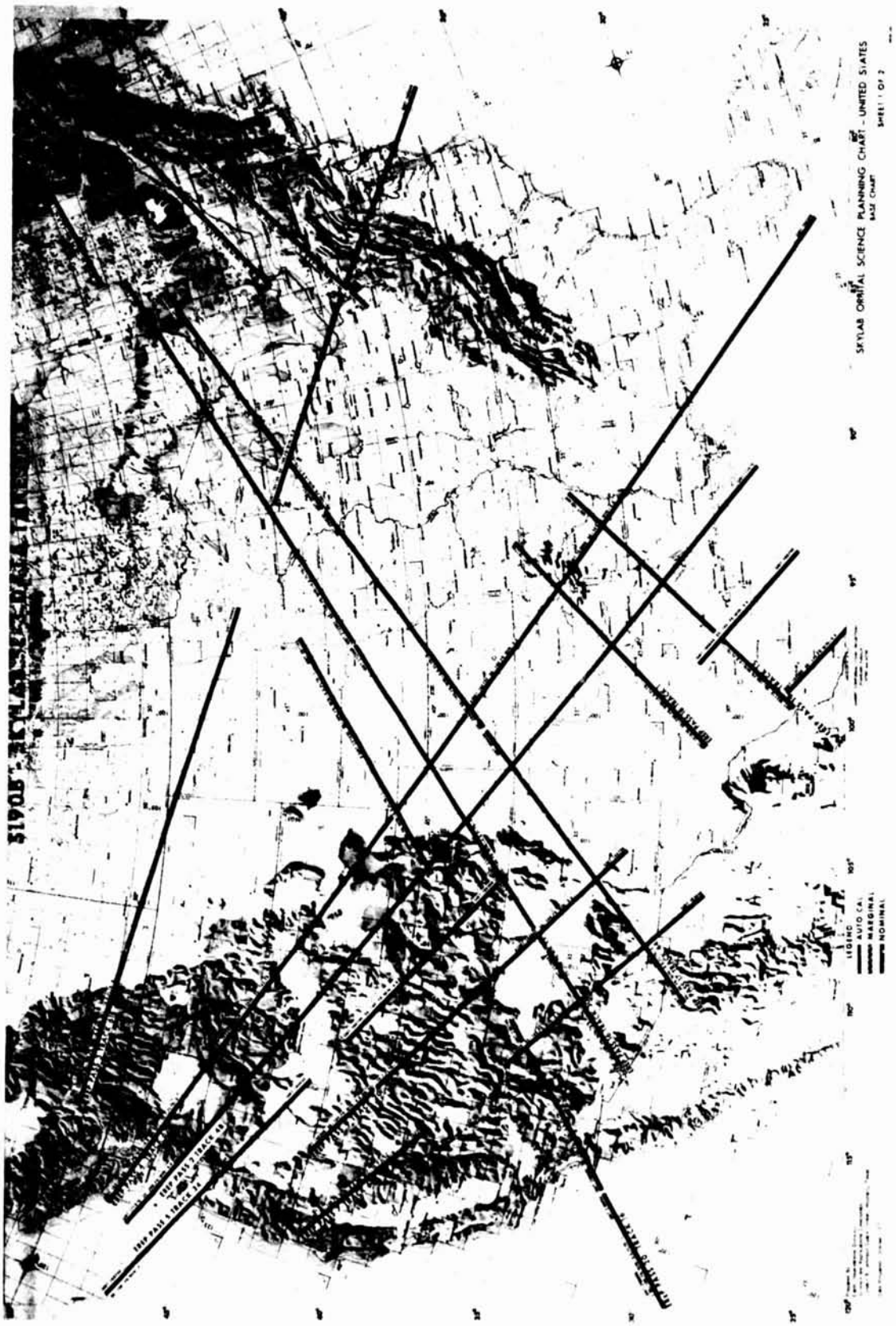
CONTENTS

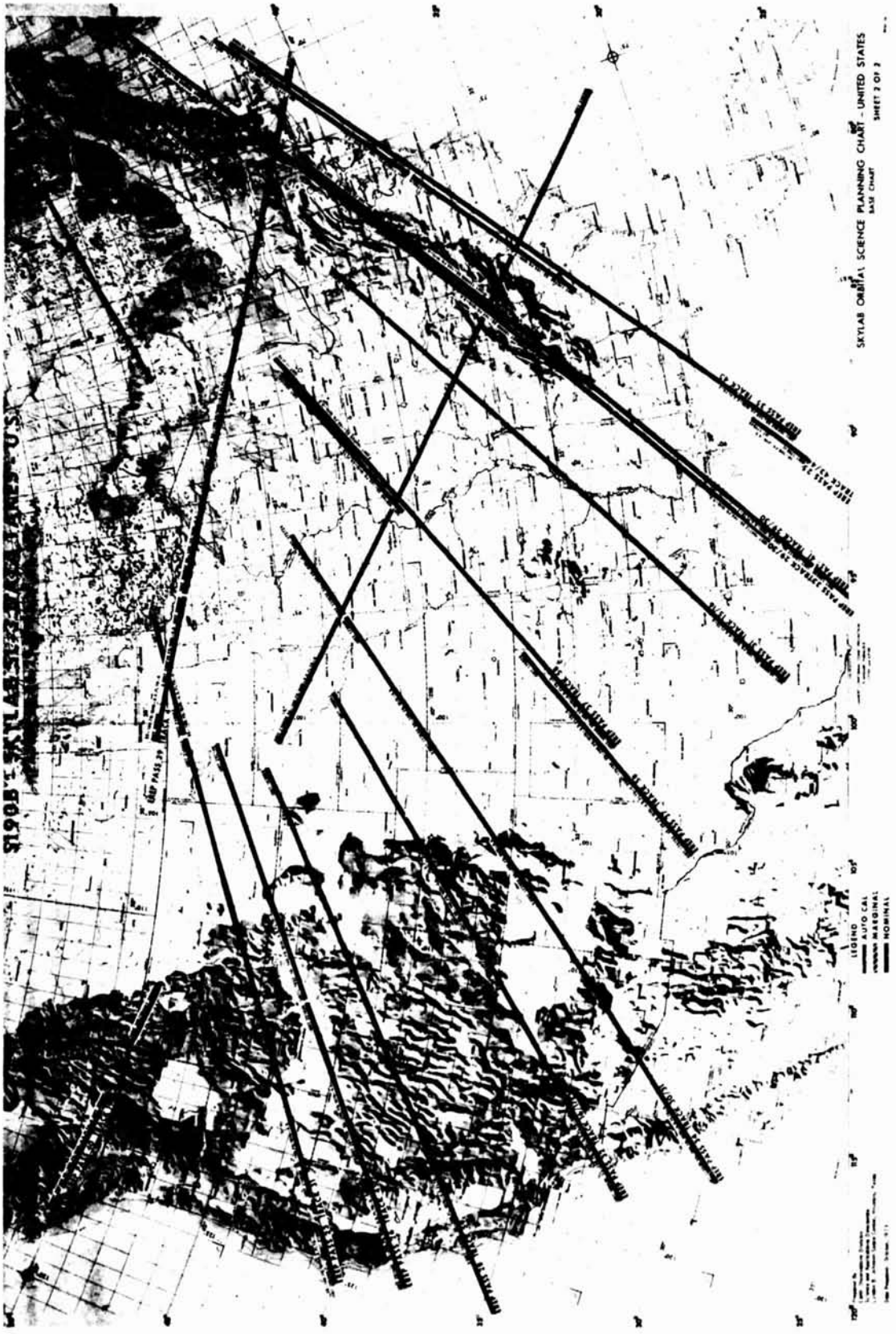
S190B Skylab Data Take Maps

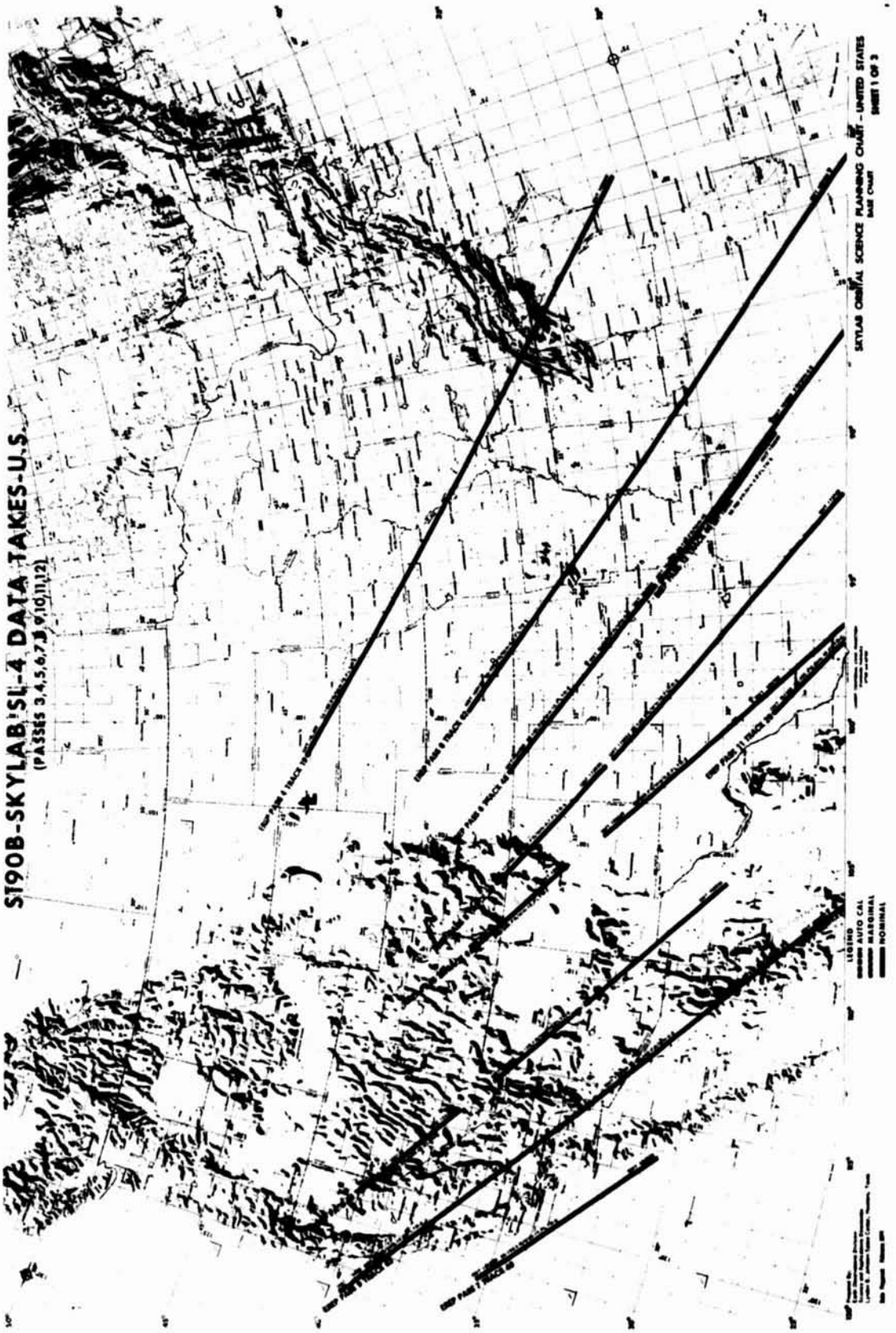
It should be noted that the EREP pass numbers used in the present report are sequential throughout all of the Skylab missions. However, the EREP pass numbers shown on the data take maps in this Appendix start at one for each Skylab mission. To alleviate confusion, a cross index between the two designations is given in Appendix B.

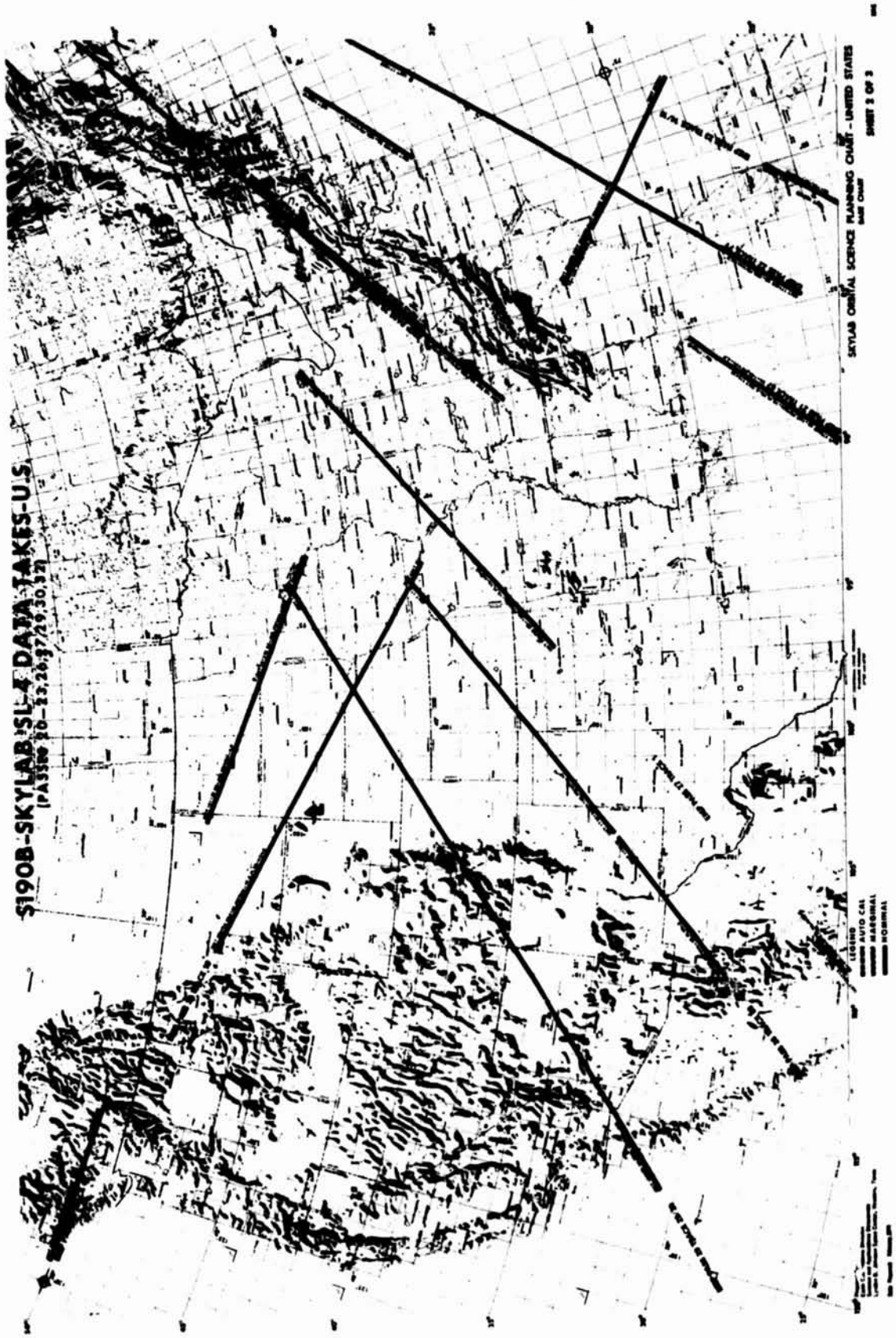
SENSOR PERFORMANCE EVALUATION TEST SITES UNITED STATES

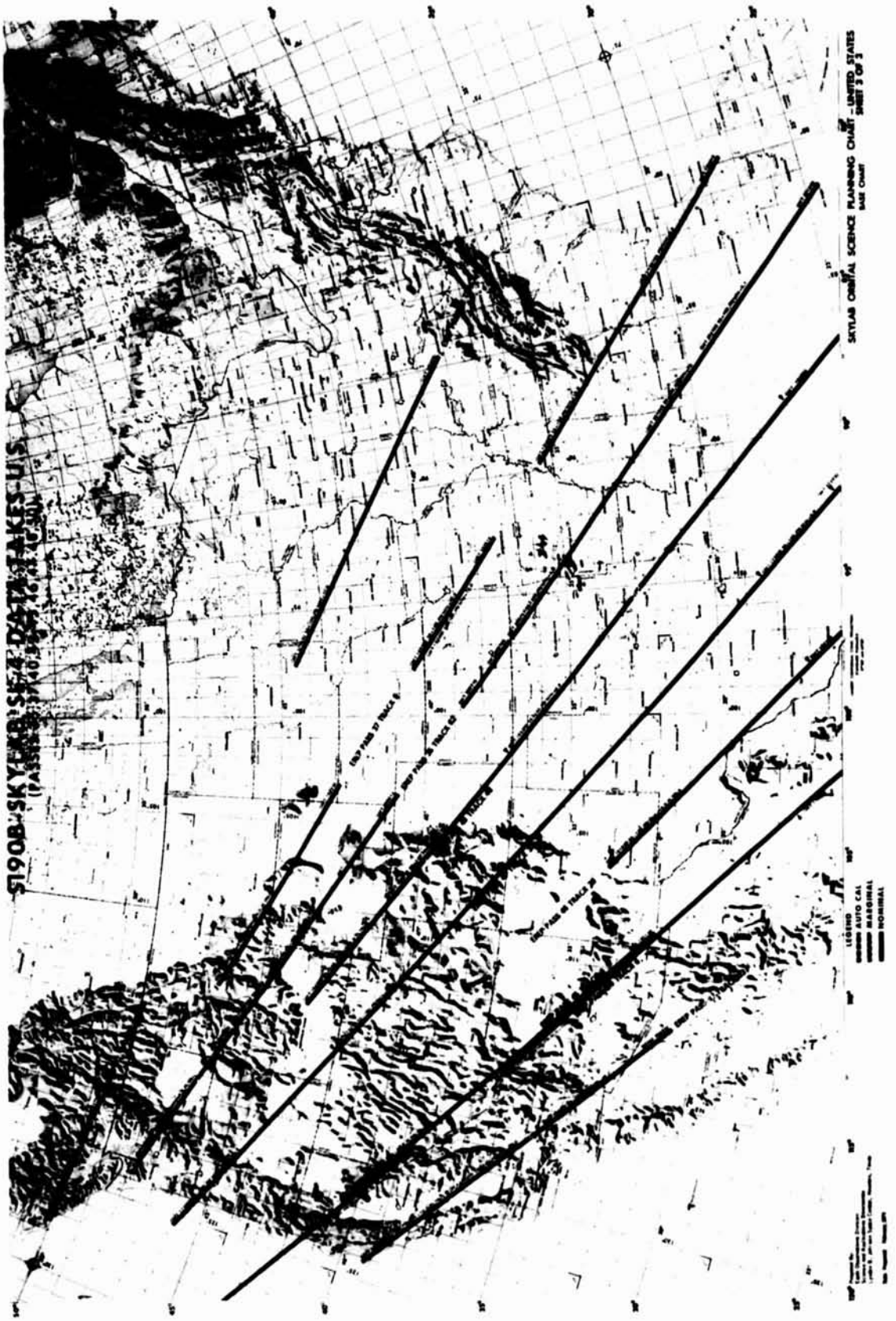



SKYLAB ORBITAL SCIENCE PLANNING CHART - UNITED STATES
LEGEND
NOMINAL

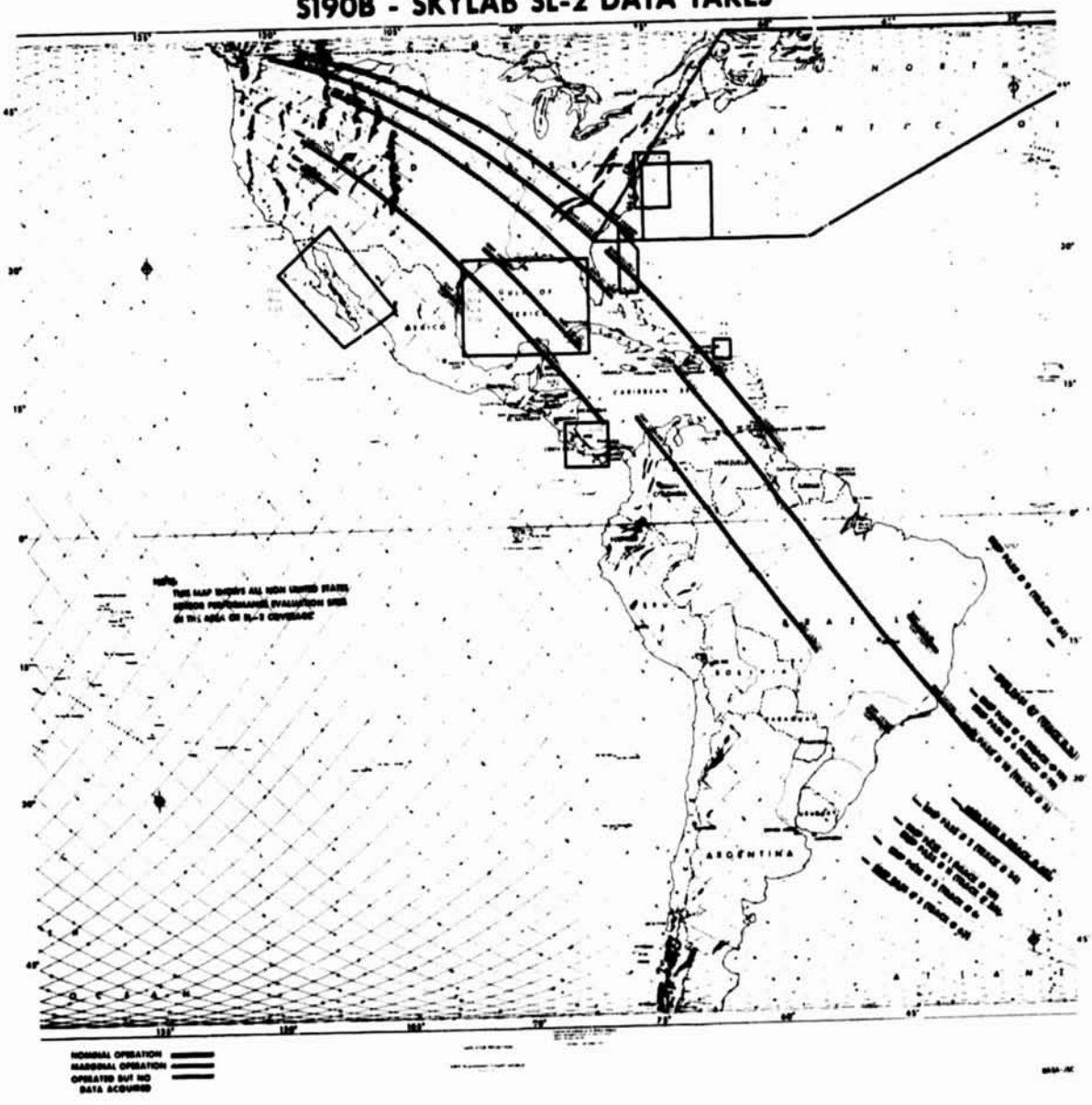




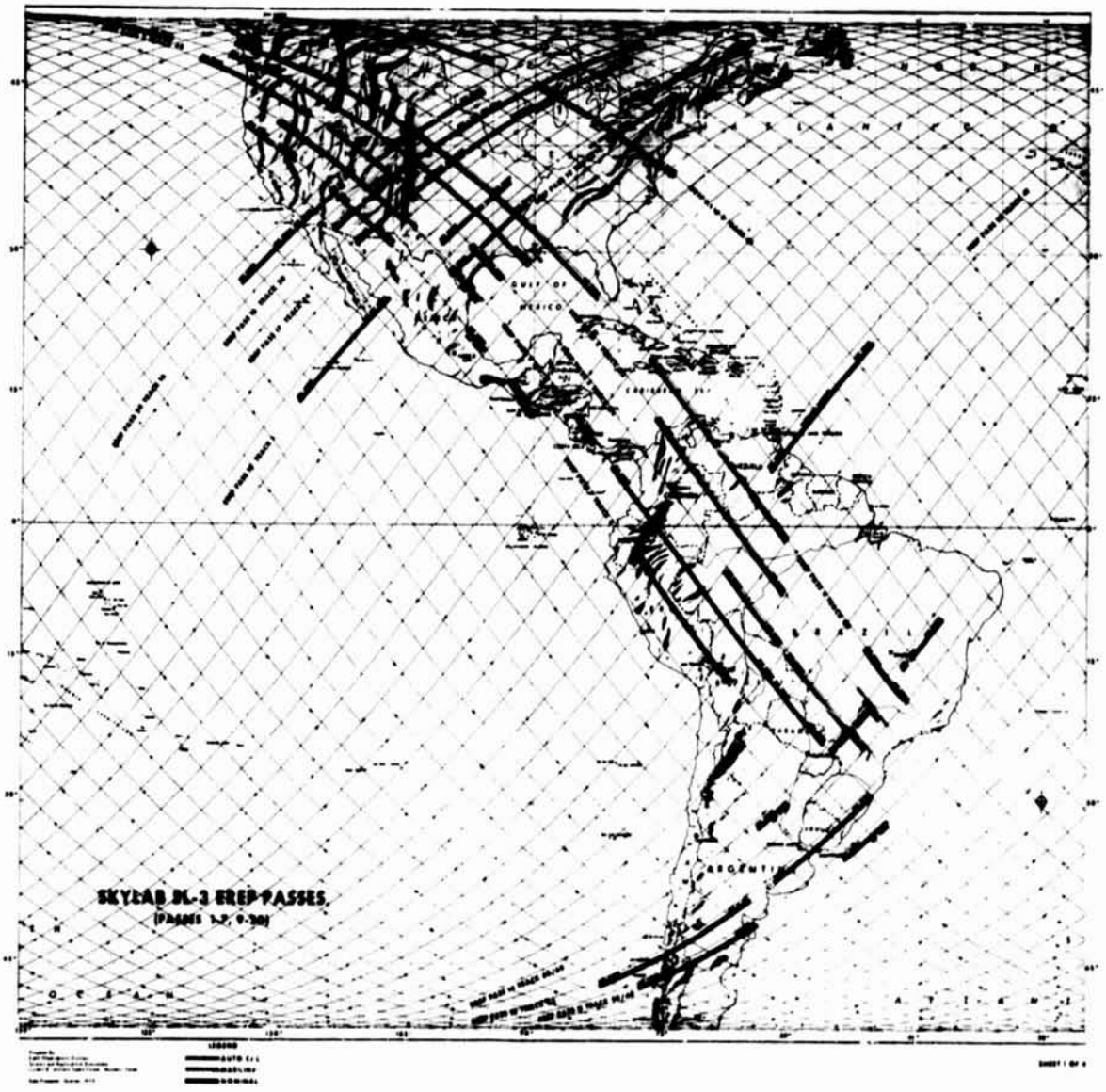




S190B - SKYLAB SL-2 DATA TAKES



S190B SKYLAB SL-3 DATA TAKES-WORL WIDE



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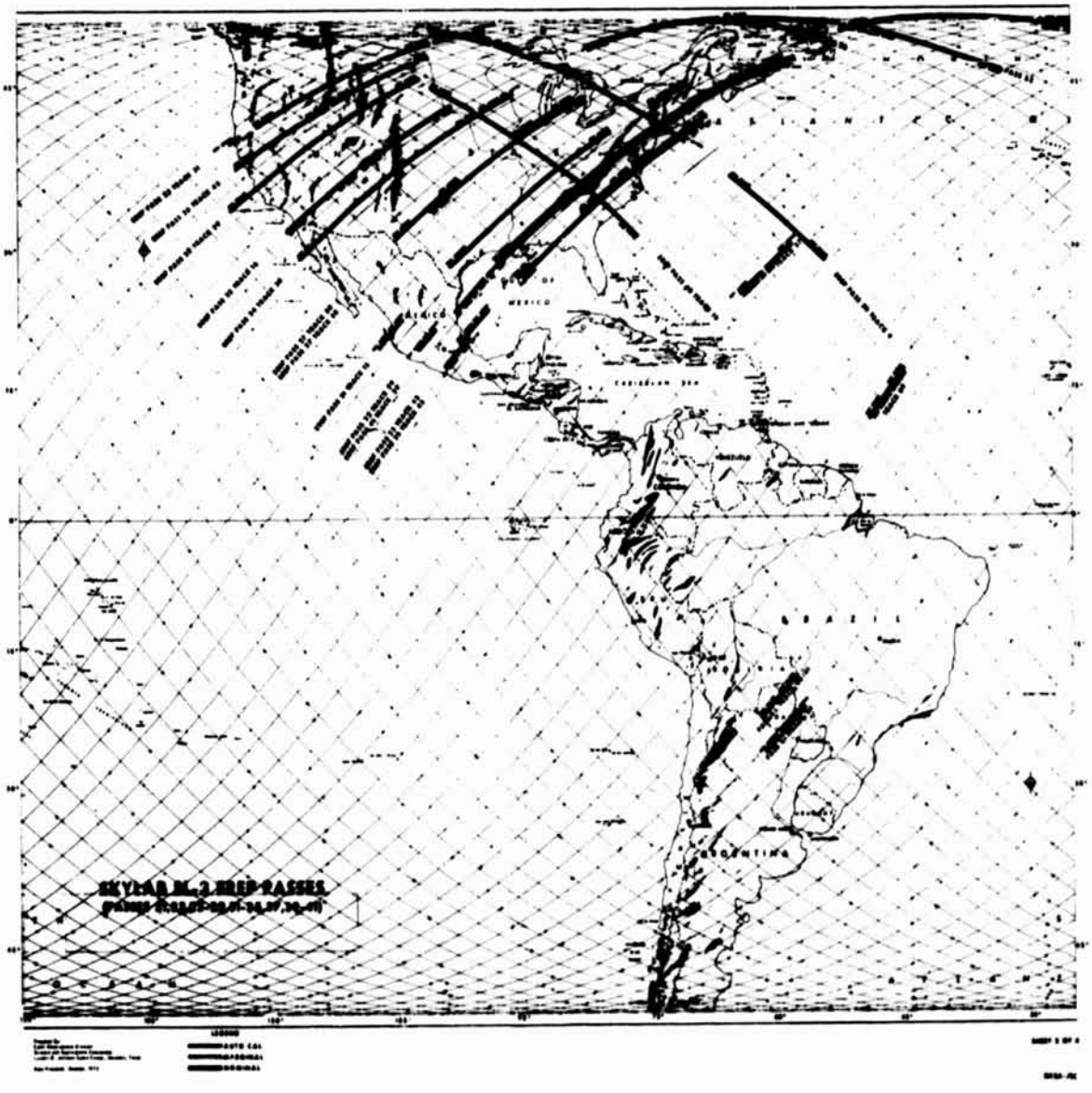
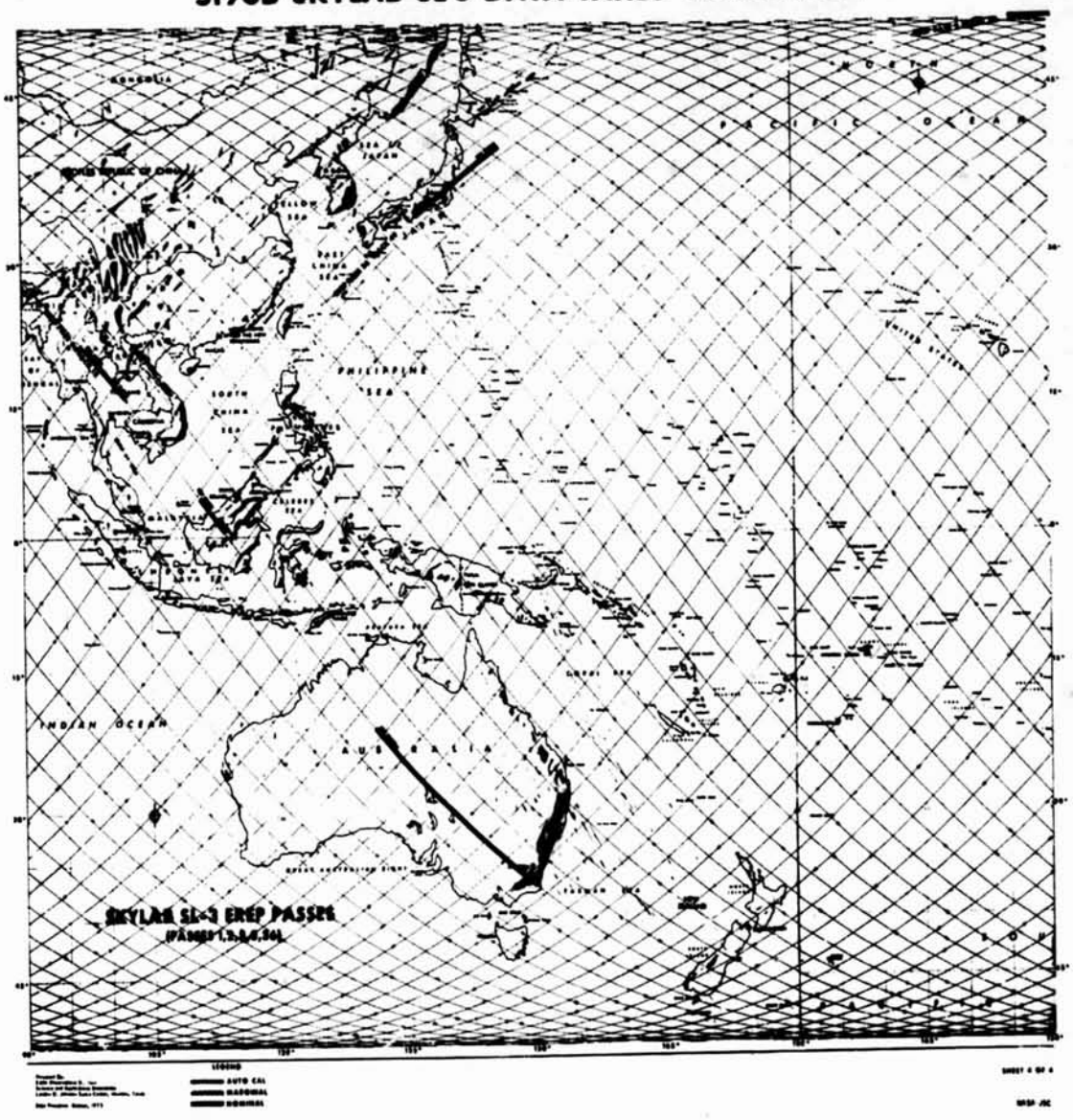
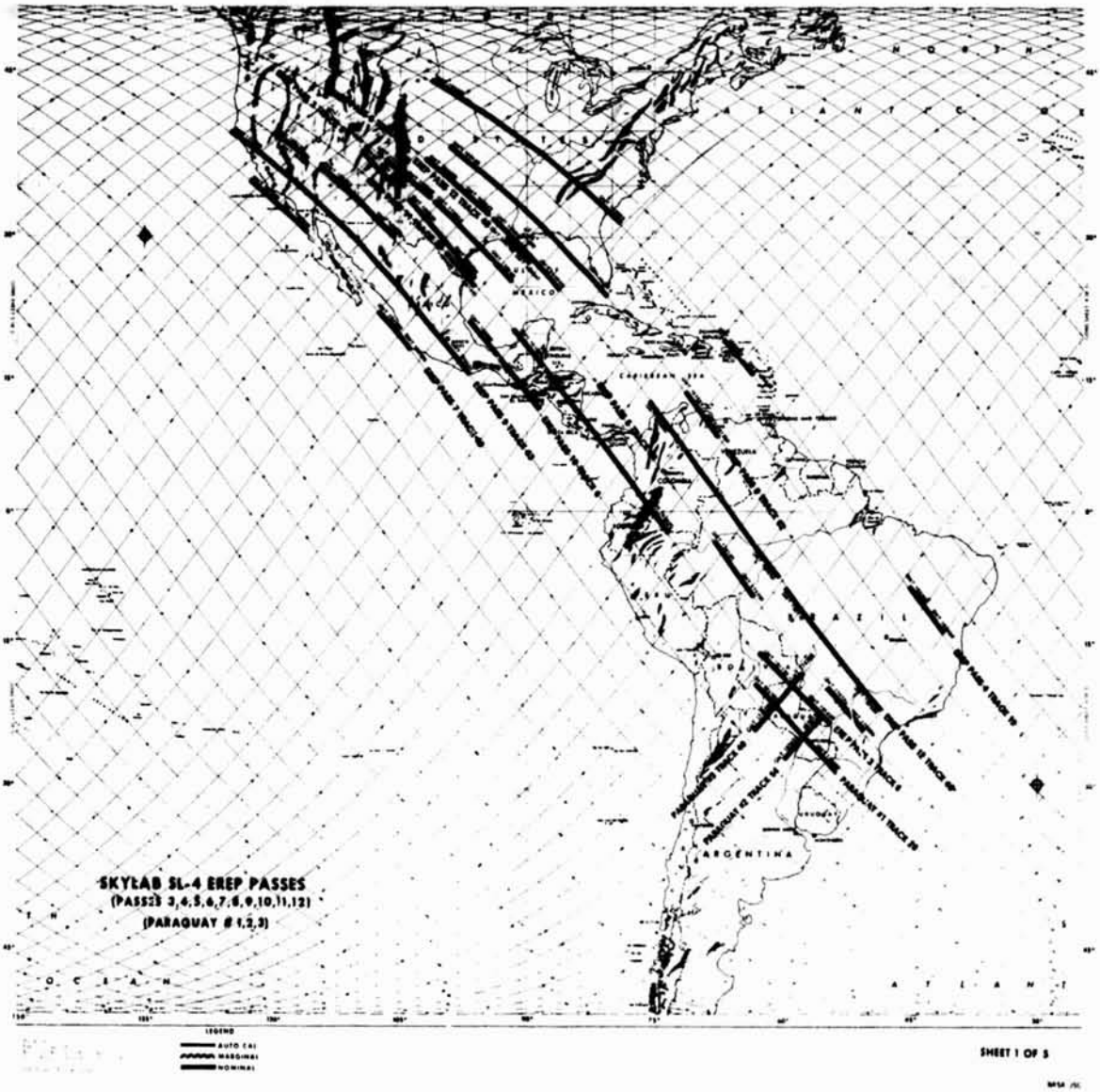


S190B SKYLAB SL-3 DATA TAKES-WORLD WIDE

S190B SKYLAB SL-3 DATA TAKES-WORLD WIDE

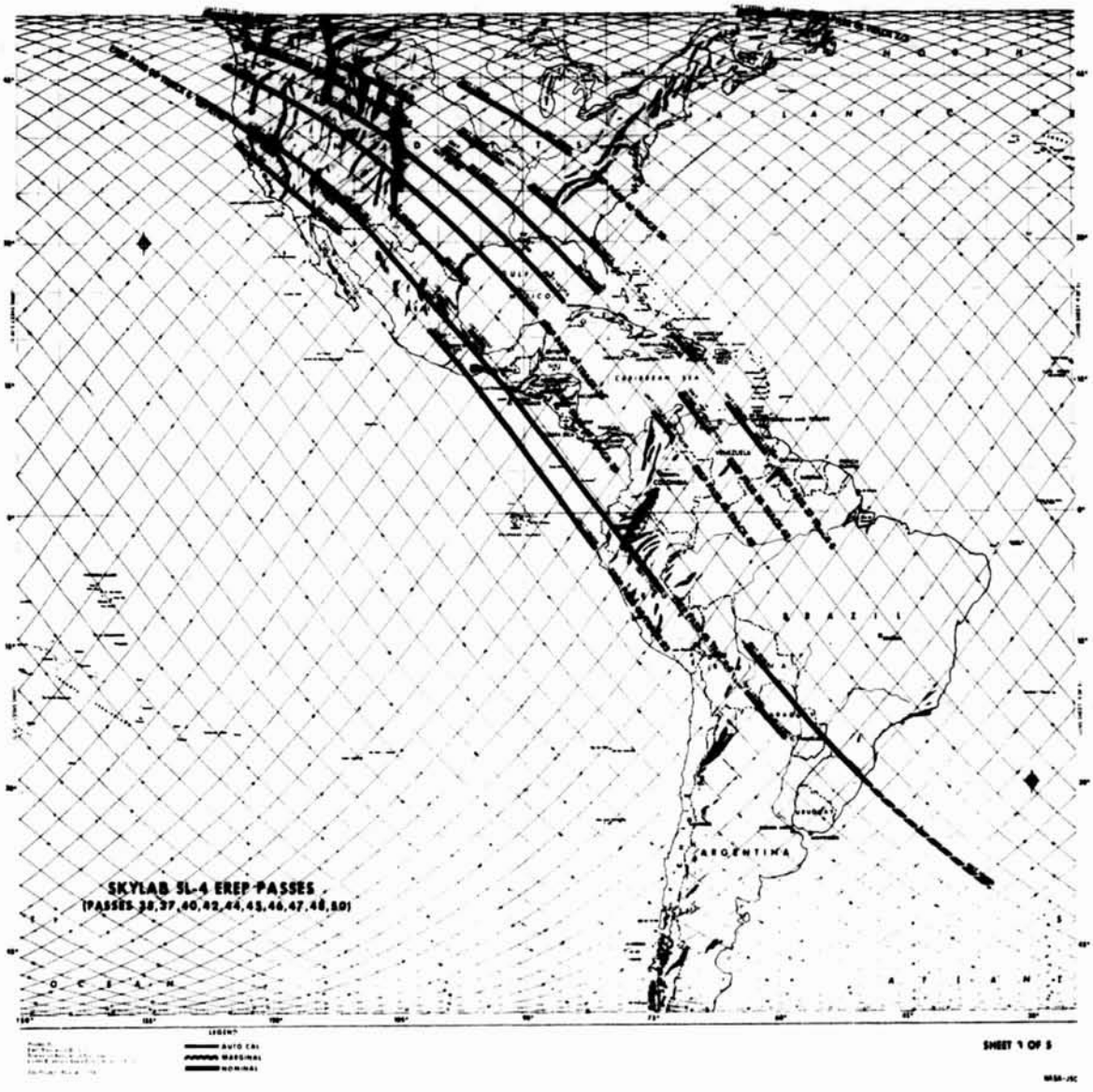


S190B SKYLAB SL-4 DATA TAKES-WORLD WIDE

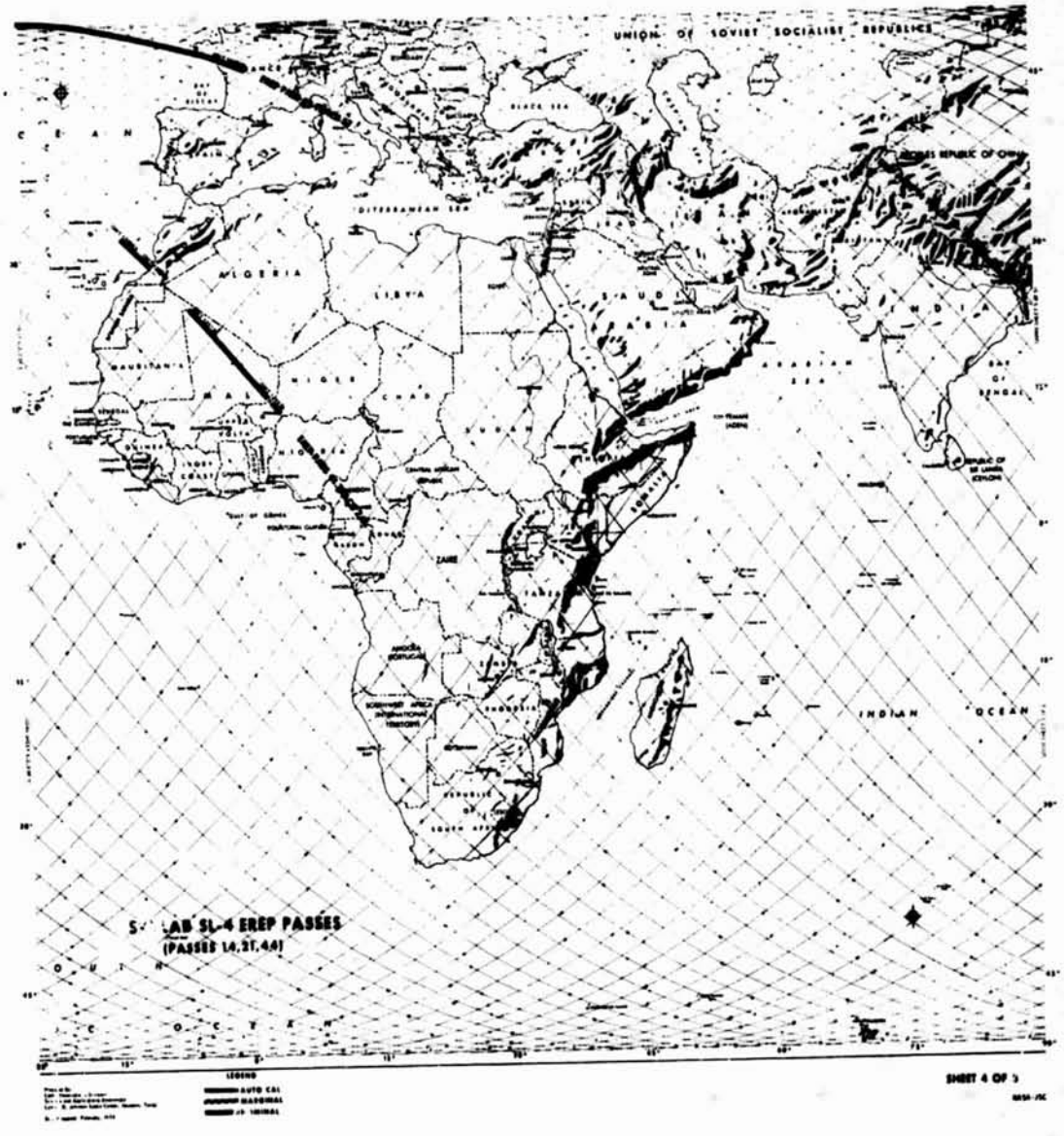


S190B-SKYLAB SL-4 DATA TAKES-WORLD WIDE

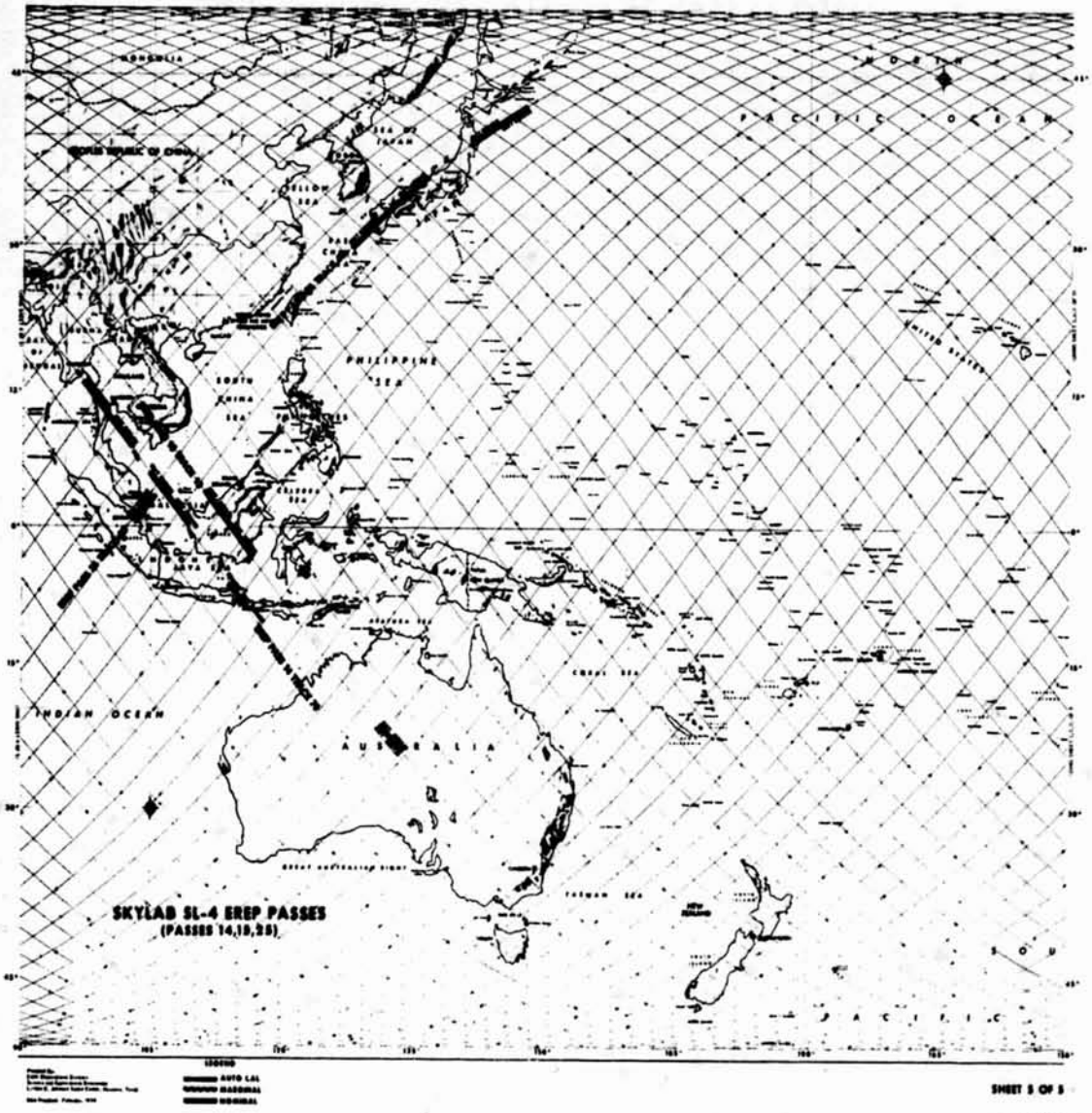
S190B SKYLAB SL-4 DATA TAKES-WORLD WIDE



S190B SKYLAB SL-4 DATA TAKES-WORLD WIDE



S190B SKYLAB SL-4 DATA TAKES-WORLD WIDE



APPENDIX B

Skylab Pass Index Correlation

The following cross index has been compiled to alleviate the confusion between the passes designated as EREP passes in this document and those designated as EREP passes on the data take maps shown in Appendix A. The first column contains the EREP pass number used in the present document. The second column, designated SL-X PASS contains the number used for the EREP passes on the Data Take maps. For reference purposes the third column contains the day of the year the pass was made, and the fourth column contains the track number which is also shown on the maps in Appendix A.

EREP PASS	SL-2 PASS	DOY	TRACK NO.
1	1	150	20
2	2	153	63
3	3	154	6
4	4	155	19
5	5	156	34
AVA	AVA	157	49
6	6	160	19
7	7	161	33
8	8	162	48
9	9	163	61
10	10	164	5
11	11	165	20
LC1	LC1	165	--

EREP PASS	SL-3 PASS	DOY	TRACK NO.
12	1	215	34
13	2	216	48
14	3	217	61
15	4	217	62
16	5	220	34
17	6	221	47
18	7	223	6
19	8	223	13
20	9	224	20
21	10	244	25/6
22	11	245	39/40
23	12	245	41
24	13	246	54/55
25	14	247	68/69
26	15	247	70
27	16	249	30
28	17	250	44
29	18	252	1
30	19	253	15
31	20	253	16
32	21	254	26/27
33	22	254	30
34	23	254	31
35	24	255	41

EREP PASS	SL-3 PASS	DOY	TRACK NO.
36	25	255	43
37	26	255	45
38	27	256	58
39	28	256	59
40	29	257	1
41	30	257	2
42	31	258	15
43	32	258	16
44	33	259	29
45	34	259	30
46	35	260	43
47	36	260	49
48	37	261	58
49	38	262	1
50	39	262	4
51	40	263	19
52	41	264	29/30

EREP PASS	SL-4 PASS	DOY	TRACK NO.(1)
53	3 SI	333	6
54	4	334	19
55	5	335	34
56	6	336	48
57	7	336	49
58	8	337	62
59	9	337	63
60	10	338	6
61	11	339	20
62	12	341	48
63	LC-1	342	69
64	14	242	70
65	15	348/9	13
66	PAG 1	349	20
67	16	351/2	58
68	17	352	63
69	PAG 2 SI	356	54A
70	PAG 3 SI	360	40A
71	18	1	53A
72	19	3	10
73	20	4	29A
74	21	6	57A
75	LC-2	7	69
76	22	7	71A

(1) An A after the track number indicates an ascending pass.
(2) PAG - Paraguay

EREP PASS	SL-4 PASS	DOY	TRACK(1) NO.
77	191 CAL 1	7	5
78	23	8	14A
79	24	9	28A
80	25	11	49A
81	26	11	58A
82	27	12	01A
83	29	14	29/30A
84	SI	16	60
85	30	18	19
86	32	20	47
87	35	21	62
88	37	22	5
89	40	24	33
90	41	25	45
91	42	26	63
92	44	27	2/3
93	45	27	6
94	46	28	20
95	47	29	34
96	48	30	48
97	49	31	61/62
98	50 LC-3	32	6

(1) An A after the track number indicates an ascending pass.