# SKYLAB DISTRIBUTION A (Revised October 3, 1972)

AB/Deputy Director Delco Electronics Dept. 40 ATTN: James Becker Galeta, California 93017 AP3/Public Information Office (50) CA/Director CB/Chief (5) CB/Crews (18) CE/Chief CE2/Chief (2) CG/Chief CG3/Chief (2) CG4/Chief (7) CG5/Chief (4) DD63/Radiological Health Section DD/Chief EA/Director EB/Chief EE/Chief EE3/Chief (2) EA22/Technical Assistant for Skylab EP2/Chief EP4/Chief EP5/Chief ES12/Chief FA/Director of Flight Operations FA/Deputy Director of Flight Operations FC/Chief FC3/Chief (5) FC4/Chief (5) FC5/Chief (10) FC6/Chief FC7/Chief (4) FC8/Chief (4) FC9/Chief (4) FM/Chief FM/Deputy Chief FM/Assistant Chief, Mission Design FM/Assistant Chief, Systems Analysis FM13/Chief (3) FM13/Skylab Mission Design Manager FMJ 3/Skylab Mission Engineer FM14/Raport Control File (25) FM2/Chief (4) FM3/Chief (4) FM4/Chief (4) FM5/Chief (2) FM13/Data Management Office (2)







## SKYLAB DISTRIBUTION A - Continued Page 2

FM7/Chief (4) FM8/Chief (5) FM9/Chief (3) FS/Chief (16) FS5/Chief (7) FS6/Chief (4) HA58/(TBC)/E. Gremillion JM2/Center Data Management (3) KA/Manager KA/Deputy Manager KM/Manager (5) KS/Manager KW/Manager NA/Manager PA23/Skylab Data Manager (5) PF/Chief PT/Chief PT3/Test Division Library (2) SA/Assistant Manager for Systems Safety TA/Director TF/Chief(5)TF6/T. R. Kloves (3) NASA/Marshall Space Flight Center ATTN: R. E. Beaman/PM-SAT-E ATTN: J. Lindberg/S&E-AERO-M ATTN: R. Benson/S&E-AERO-MM ATTN: O. Hardage/S&E-AERO-M (4) ATTN: H. N. Scofield/S&E-ASTR-SD ATTN: A. McNair/PM-MO-I ATTN: L. F. Belew/PM-SL-MGR ATTN: B. T. Recio/PM-MO-P (3) ATTN: G. Worley/S&E-AERO-D ATTN: W. CHubb/S&E-ASTR-SG ATTN: C. Hagood/S&E-CSE-A NASA Headquarters ATTN: W. C. Schneider/ML ATTN: R. V. Aller/MLO DDMS-TAG(2)Bldg. 425 MU805 32925 Patrick Air Force Base, Florida ETOOP-2 (11) Air Force Eastern Test Range Patrick Air Force Base, Florida 32925 Bellcomm, Inc. 955 L'Enfant Plaza North S. W. Washington, D. C. 20024 ATTN: D. A. DeGraaf ATTN: D. A. Corey McDonnell Douglas Astronautics Co. P. O. Box 516 St. Louis, Missouri 63130 ATTN: A. Story/MEZZ

# SKYLAB DISTRIBUTION A - Continued Page 3

McDonnell Douglas Astronautics Co. 5301 Bolsa Avenue Huntington Beach, California 92647 ATTN: C. Guenther/A3-253-MS2 McDonnell Douglas Astronautics Co. 16915 El Camino Real Houston, Texas 77058 ATTN: D. Boling (6) IBM Houston/G. W. Ebker (6) IBM Houston/Library IBM Houston/52/E. W. Poole RCA Aerospace Systems Division P. O. Box 588 Burlington, Mass. 01801 ATTN: H. W. Pownell/M.S. 34 Link Group General Precision P. O. Box 57668 Webster, Texas 77598 ATTN: Director (2) MIT Draper Laboratory Cambridge, Mass. 02142 ATTN: P. Felleman (5) North American Rockwell Corp. Space Division Downey. California 90241 ATTN: RASPO ATTN: Flight Plans and Procedures/FC48 (25) ATTN: Mission Evaluation/DA37 ATTN: Guidance and Control/FC-4 (3) ATTN: CSM Propulsion Analysis/FB66 TRW Houston/Dave Austgen (5) TRW Houston/Library (4) Commander Manned Spacecraft Recovery Force Atl. (CTF-140) Bldg. SP-71 U.S. Naval Air Station Norfolk, Virginia 23511 NASA/Goddard Spaceflight Center ATTN: D. J. Graham/822 (3) ATTN: J. Donegan/830 W. Adams/333 (4) ATTN: ATTN: J. Shaughnessy/834 ATTN: T. Roberts/810 (2) ATTIN: R. Capo/821.2 (14) ATTN: Dr. F. O. VonBun/550 (2) NASA/John F. Kennedy Space Center : MTTA Dr. A. H. Knothe/RS ATTN: Chief, Tech. Document Control Center/LS-TMP-3A (13) ATTN: H. Smith/FSK

#### SKYLAB DISTRIBUTION A - Continued Page 4

NASA/John F. Kennedy Space Center ATTN: A. R. Raffaelli/AA-SVO ATTN: R. C. Shirley/IN-TEL-2 ATTN: L. E. Thompson/CEK (10) Flight Crew Training Bldg. No. M7-409 ATTN: F. Bryan/LV-ENG-A Martin Marietta/Houston ATTN: W. D. Carmean (2) ATTN: Joe Radcliff Delco Electronics Div., GMC 2B11, Dept. 32-60 Milwaukee, Wisconsin 53201 ATTN: Dean E. Zenther Dr. J. Weinberg Dudley Observatory 104 S. Lake Avenue Albany, New York 12206 Dr. D. Packer Naval Research Laboratory Mail No. 7141P Washington, D. C. 20390 M. Shapiro Naval Research Laboratory Mail No. 7020 Washington, D. C. 20390 Dr. A. Bonner University of Wisconsin Department of Physics Sterling Hall Madison, Wisconsin 53706 Dr. Carl Henize Manned Spacecraft Center Astronaut Office (CB) Houston, Texas 77058 Capt. A. D. Grimm Air Force Weapons Lab. (Systems) Kirkland AFB, New Mexico 87117 R. Randle Ames Research Center Moffett Field, Calif. 94035 Monsieur M. Magnan Laboratorie d'Astronomic Spatiale Traverse du Siphon - Les Toris Lucs Marseille 12e, France J. Milligan Marshall Space Flight Center S&E-SSL-T Huntsville, Alabama 35812

# SKYLAB DISTRIBUTION A - Concluded Page 5

Martin Zombeck American Science & Engineering Systems 11 Carleton Street Cambridge, Mass. 02142 Dr. R. M. MacQueen High Altitude Ubservatory HAO-ASTRO-Geophysics Bldg. University of Colorado Boulder, Colorado 80302 Dr. E. M. Reeves Harvard College Observatory Solar Satellite Project 767C Concord Avenue Cambridge, Mass. 02138 Dr. R. Tousey Naval Research Laboratory Washington, D. C. 20390 Dr. J. A. Muscari Martin Marietta Aerospace P. O. Box 179 Denver, Colorado 80201 Norm Baker Martin Marietta-Denver/MC8847 CG54/B. Killian TRW/J. R. Scott

ADDITION: FM2/C. Osgood (25)









NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# MSC INTERNAL NOTE NO. 73-FM-7

February 6, 1973

# OPERATIONAL TRAJECTORY FOR THE FIRST SKYLAB MISSION (SL-1/SL-2)

Mission Integration Branch,

Flight Performance Branch,

and Guidance and Dynamics Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER HOUSTON, TEXAS

MSC-07691

MSC INTERNAL NOTE NO. 73-FM-7

# SKYLAB PROGRAM

OPERATIONAL TRAJECTORY FOR THE FIRST SKYLAB MISSION (SL-1/SL-2)

By Mission Integration Branch, Flight Performance Branch, and Guidance and Dynamics Branch

February 6, 1973

MISSION PLANNING AND ANALYSIS DIVISION NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MANNED SPACECRAFT CENTER HOUSTON, TEXAS Approved Approved: V. Bennett, Chief Floyd Morris V. Jenkins, Chief **Mission Integration Branch** Flight Performance Branch Approved: Approved: /lanto Marlowe D. Cassetti, Chief Marlowe D. Cassetti Guidance and Dynamics Branch Skylab Project Manager Approved: For John P. Mayer, Chief Mission Planning and Analysis Division

#### ATTENTION

The following two changes to the First Skylab Mission were made shortly before publication and are not incorporated in this document.

1. Launch date: This document was based on an SL-1 launch on April 30, 1973, and an SL-2 launch on the following day. Officially, the Skylab lift-off has been delayed, and no firm launch date has yet been announced.

2. Entry targeting: The target point for entry has been changed such that, for the nominal end of mission, the target is 60 n. mi. north of the groundtrack (out of plane) at 27.65°N latitude and 129.35°W longitude. This change will simplify onboard monitoring procedures for nominal and contingency cases.

In addition, the deorbit sequence is being re-evaluated and small changes may be approved.

Please direct any questions or comments on this document to Skylab Mission Engineer, FM13.

#### FOREWORD

The spacecraft preliminary reference trajectory (PRT) for Skylab was published in three documents. The initial document, MSC IN 70-FM-151, was published October 13, 1970, and contained the detailed mission profile for the first Skylab mission based on an SL-1 launch in July 1972. Revision 1 to the PRT, MSC IN 71-FM-46, published March 2, 1971, presented the detailed mission profiles for the first and second Skylab mission (SL-1/SL-2 and SL-1/SL-3), with a summary profile for the third Skylab mission (SL-1/SL-4). It was based on an SL-1 launch in November 1972. Revision 2 to the PRT incorporated an April 1973 launch date for SL-1 as well as the requirement for the two-burn deorbit sequence. The reference trajectory (RT), MSC IN 72-FM-143, published June 1972, differs from the PRT in that it introduced the controlled orbit, which affords a repeating orbit for all the missions. Trim maneuvers are performed to maintain the reference groundtrack pattern. This document, the operational trajectory (OT), differs from the RT in that recovery will now occur in the Pacific off the west coast of the United States.

The detailed trajectory printout of the Skylab missions will not be published. However, anyone desiring detailed trajectory data can obtain through the Mission Planning and Analysis Division a magnetic tape containing pertinent trajectory data for each of the published documents. Reference 1 describes the tape in detail and defines the procedure for obtaining copies.

Please direct any comments concerning the contents or format of this document to the Skylab Mission Engineer, FM13, by March 1, 1973.

# CONTENTS

Section	Pa	ge
1.0	SUMMARY AND INTRODUCTION	1
	1.1 Summary	1
	1.2 Introduction	1
2.0	SYMBOLS AND NOMENCLATURE	7
3.0	MISSION PLANNING GUIDELINES AND INITIALIZATION DATA 1 C. T. Osgood/FM2 and G. L. Hunt/FML3	.3
	3.1 General Mission Ground Rules	.3
	3.2 Mission Planning Constraints	<u>4</u>
	3.2.1       Mandatory       1         3.2.2       Highly desirable       1         3.2.3       Desirable       1	_4 _6 _6
	3.3 Initialization Data	16
4.0	WORKSHOP LAUNCH (SL-1)	L9
	4.1 Launch and Initial Activation	19
	4.2 Mission Sequence	19
	4.3 Skylab Controlled Orbit	21
	4.4 TACS Propellant Analysis	22
5.0	FIRST MANNED VISIT	40
	5.1 Mission Summary	40
,	5.2 SL-2 Prelaunch Phase	40
	5.3 Launch	41 ,
	5.4 Rendezvous Phase	42

Section

5.5 Orbital Assembly Activation	44
5.6 Controlled-Orbit Trim Maneuvers	45
5.7 Experiments Phase	45
5.7.1 Selection of SL-1 groundtrack pattern	46 47
5.8 Separation and Deorbit	49
5.9 SL-2 Entry Following SPS Deorbit D. W. Heath/FM4, and D. Gardner, TRW	50
APPENDIX - TRAJECTORY PLANNING CONSIDERATIONS	115
A-1.0 SELECTION OF SKYLAB LIFT-OFF TIMES	117
A-2.0 CONTROLLED-ORBIT ANALYSIS	120
A-3.0 CONTINGENCY SM-RCS DEORBIT AND ENTRY FOR SL-2 A. H. Benney/FM2, D. W. Heath/FM4, and D. Gardner, TRW	121
REFERENCES	131

Page

#### TABLES

Table		Page
3 <b>-</b> I	SL-1/SL-2 INITIALIZATION DATA	17
)4-I	SL-1 LAUNCH VEHICLE SEQUENCE OF EVENTS	24
4-II	TACS BUDGET SUMMARY	25
5 <b>-</b> I	SL-2 LAUNCH VEHICLE SEQUENCE OF EVENTS	52
5-II	LAUNCH REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES	
	<ul> <li>(a) Applicable maneuver</li> <li>(b) Definition of REFSMMAT</li> <li>(c) REFSMMAT components</li> <li>(d) Target load for SEP maneuver</li> <li>(e) Gimbal angles at t<sub>IG</sub></li> </ul>	53 53 53 53 53
5-III	RENDEZVOUS REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES	
	<ul> <li>(a) Applicable maneuvers</li></ul>	54 54 54 54 54
	(f) Target load for NC2 maneuver	54 55
	<ul> <li>(h) Target load for NCC maneuver</li></ul>	55 55
	(j) Target load for NSR maneuver	55 55
	(1) Target load for TPI maneuver	55 56
5-IV	MAJOR MANEUVER AND TRAJECTORY EVENTS SUMMARY FOR SL-2	57
5 <b>-</b> V	SL-2 SPS PROPELLANT USAGE SUMMARY	58
5-VI	SM RCS PROPELLANT USAGE SUMMARY FOR SL-2	59
5-VII	CM RCS PROPELLANT USAGE SUMMARY FOR SL-2	60
5-VIII	STDN STATIONS AND EQUPIMENT	61
5-IX	STDN COVERAGE FOR SL-2 DURING RENDEZVOUS (0° ELEVATION ANGLE AT ACQUISITION AND LOSS OF SIGNAL)	62
5 V	MANFINER TABLE FOR TYPICAL FLYAROIND SECTENCE	64

# Table

•

5-XI DEORBIT REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES

	(a) Applicable maneuvers65(b) Definition of REFSMMAT65(c) REFSMMAT components65(d) Target load for SPS-1 maneuver65(e) Gimbal angles at t65(f) Target load for SPS-2 maneuver65(g) Gimbal angles at t65(a) Gimbal angles at t65(b) Gimbal angles at t65(c) Gimbal angles at t65	55555555
5-XII	SL-2 (400 000 FT) ENTRY STATE VECTOR AND TARGET LOCATION FOR	
	SPS DEORBIT MANEUVER	5
5-XIII	COMMAND MODULE AERODYNAMIC COEFFICIENTS FOR SL-2 67	7
5-XIV	SL-2 SEQUENCE OF EVENTS FROM UNDOCKING TO LANDING	3
A-3-I	DEORBIT REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES	
	<ul> <li>(a) Applicable maneuvers</li></ul>	3 3 3 3 3 3 3 3 3 3
A-3-II	SL-2 ENTRY (400 000 FT) STATE VECTOR AND TARGET LOCATION FROM A SM-RCS DEORBIT MANEUVER	4

# FIGURES

Figure		Page
1-1	Saturn V workshop launch vehicle configuration (ref. 3)	3
1-2	Saturn IB launch vehicle configuration (ref. 3)	4
1-3	Skylab CSM configuration (ref. 3)	5
1-4	Skylab orbital assembly configuration (ref. 3)	6
4-1	SL-1/SL-2 time line from SL-1 lift-off through 7 1/2 hours	
	<ul> <li>(a) Lift-off through 1 hour and 15 minutes</li></ul>	26 27 28 29
4-2	SL-1/SL-2 time line from 7 1/2 hours through time of SL-2 launch	
	<ul><li>(a) 7 hours and 30 minutes through 12 hours and 30 minutes</li><li>(b) 12 hours and 30 minutes through 17 hours and</li></ul>	30
	30 minutes	31
	30 minutes	32 33
4-3	Relationship between ground lighting and launch and recovery opportunities for Skylab program (SWS launch at 12:30 p.m. e.s.t., April 30, 1973)	34
4-4	Launch and recovery data for SWS launch 12:30 p.m. e.s.t., April 30, 1973	35
4-5	Time history of beta angle and percent of orbital sunlight for SWS launch at 12:30 p.m. and 2:00 p.m. e.s.t., April 30, 1973	36
4-6	Ground traces for SWS in circular orbit of 233.8 nautical miles and 50° inclination for 71 revolutions	37
4-7	Orbital decay and mean semimajor axis for SL-1/SL-2	39
5-1	Phase-plane launch window for northerly SL-2 launch (early rendezvous case, M=5 through 8 only)	69
5-2	Relative motion of SL-1/SL-2 in S-IVB curvilinear coordinate system from separation through first phasing maneuver	70

х

Figure

5-3	SL-1/SL-2 time line from lift-off through rendezvous
	<ul> <li>(a) Lift-off through 5 hours</li></ul>
5-4	SL-1/SL-2 ground traces from lift-off through rendezvous 73
5-5	SL-1/SL-2 rendezvous orbital geometry
5-6	Relative motion of CSM in SWS curvilinear coordinate system from insertion to rendezvous
5-7	CSM range and range rate to SWS from 300 n. mi. to rendezvous
5-8	Skylab orbital assembly ground traces for SL-1/SL-2 (CSM revolutions 6 through 77, SWS revolutions 20 through 91)
	(a) CSM revolutions 6 through 12
5-9	SL-1/SL-2 docked trim sequence for groundtrack control 87
5-10	SL-1/SL-2 U.S. EREP lighting conditions
5-11	SL-1/SL-2 EREP pass information
5-12	SL-1/SL-2 operational trajectory EREP passes showing S190 swath
	(a) Pass 1       90         (b) Pass 2       91         (c) Pass 3       92         (d) Pass 4       93         (e) Pass 5       94         (f) Pass 6       95         (g) Pass 7       96         (h) Pass 8       97         (i) Pass 9       98         (j) Pass 10       99         (k) Pass 12       101         (m) Pass 14       103



Figure

5-13	End of mission sequence for SL-1/SL-2 SPS deorbit	
	<ul> <li>(a) 12 hours to 17 hours</li></ul>	104 105
5-14	Relative motion of the CSM for a typical flyaround sequence	106
5-15	SL-1/SL-2 entry ground trace for an SPS deorbit maneuver $\ldots$	107
5-16	CM maneuver envelope from an SPS deorbit for SL-1/SL-2 $\ldots$	108
5-17	Low-speed entry corridor for SL-1/SL-2	109
5-18	Altitude and range profile for SL-1/SL-2 entry $\ldots$ .	110
5-19	Program 67 DSKY displayed CMC commanded bank angle, cross- range error, and down-range error time histories for SPS deorbit	111
5-20	Program 67 DSKY displayed CMC commanded bank angle, inertial velocity, and load factor time histories for SPS deorbit	112
5-21	SL-1/SL-2 SPS EMS parameters	
	<ul> <li>(a) Load factor versus inertial velocity</li></ul>	113 113
A-1-1	Launch opportunities and available recovery opportunities for 5:15 a.m. e.s.t. and 12:30 p.m. e.s.t. SL-1 lift-off times on April 30, 1973	119
A-3-1	Hybrid deorbit sequence	125
A-3-2	End of mission sequence for SL-1/SL-2 SM RCS deorbit	
	<ul> <li>(a) 12 hours to 17 hours</li></ul>	126 127
A-3-3	SL-1/SL-2 entry ground trace for SM RCS deorbit maneuver	128
A-3-4	CM maneuver envelope from a SM RCS deorbit for SL-1/SL-2 $\ldots$	129
A-3-5	SL-1/SL-2 RCS EMS parameters	
	<ul> <li>(a) Load factor versus inertial velocity</li></ul>	130
	inertial velocity	TOO

#### OPERATIONAL TRAJECTORY FOR

#### THE FIRST SKYLAB MISSION (SL-1/SL-2)

#### By Mission Integration Branch, Flight Performance Branch, and Guidance and Dynamics Branch

#### 1.0 SUMMARY AND INTRODUCTION

#### 1.1 Summary

This document gives the detailed trajectory profile for the first Skylab mission. This mission entails two launches: the workshop launch (SL-1, launched by the Saturn V) and, almost 24 hours later, the first manned visit (SL-2, launched by the Saturn IB). The workshop launch will insert an unmanned Saturn workshop (SWS) into a 50°-inclination, 233.8-n. mi. circular orbit. For the first manned visit, a command and service module (CSM) will rendezvous and dock with the SWS, forming the orbital assembly (OA). This configuration will be maintained for the 28 days of the mission. At the end of this period, the command module will deorbit into the Pacific Ocean off the western coast of the United States.

The description of the Skylab trajectory includes a complete discussion of the earth resources experiment package (EREP) passes, including pass selection criteria and a table of pertinent pass data. In addition, some of the limitations and constraints on mission planning and trajectory design are listed not only for this mission but for all three Skylab missions. An appendix amplifies the rationale used for selection of lift-off times, controlled orbit techniques, and contingency service module/reaction control system (SM/RCS) deorbit and entry.

#### 1.2 Introduction

Planning the first Skylab mission requires, in many cases, a foreknowledge of the spacecraft trajectory - both its shape and its schedule of events. This document is the most complete prelaunch estimate of that trajectory. The trajectory event schedule presented will be followed as closely as possible during actual flight. This information, therefore, can be used as input data for preflight simulations.

The trajectory profile and design are based on published input data, which include the mission requirements, the known spacecraft and launch vehicle constraints, the spacecraft mass properties, aerodynamics and performance characteristics, the ground support network and facilities, and the spacecraft guidance equations, programs, and logic.

The first Skylab mission will use the payload capabilities of the Saturn V and Saturn IB launch vehicles. These are shown and described in figures 1-1 and 1-2. The CSM, also an Apollo vehicle that has been modified for Skylab use,

is shown in figure 1-3. Last, figure 1-4 shows the complete configuration, the OA, which comprises the SWS and the CSM. The major elements of the OA are

a. Command and service module (CSM)

b. Multiple docking adapter (MDA)

c. Airlock module (AM)

d. Apollo telescope mount (ATM)

e. Modified S-IVB orbital workshop (OWS)

f. Instrument unit (IU)

The SWS is the OA without the CSM.



.

.

.

3

Figure 1-1.- Saturn V workshop launch vehicle configuration (ref. 3).

w



Figure 1-2.- Saturn IB launch vehicle configuration (ref. 3).



3

2

Figure 1-3.- Skylab CSM configuration (ref. 3).

J



Figure 1-4.- Skylab orbital assembly configuration (ref. 3).

# 2.0 SYMBOLS AND NOMENCLATURE

ACN	Ascension Island tracking station
ACQ	acquisition
AM	airlock module (includes DA, FAS, and STS)
AOS	acquisition of signal
APCS	attitude and pointing control system (includes CMGS, EPCS, and TACS)
ATM	Apollo telescope mount
ATMDC	ATM digital computer
BDA	Bermuda tracking station
C-band	microwave band, 4200 to 6200 mHz
C <sub>D</sub>	drag coefficient
c.g.	center of gravity
$C_{L}$	lift coefficient
СМ	command module
CMC	command module computer
CMD	command
CMGS	control moment gyro subsystem; also CMG
CM RCS	command module reaction control system
COAS	crew optical alinement sight
CPD	Crew Procedures Division (MSC)
CRO	Carnarvon tracking station
CSM	command and service module
CYI	Grand Canary Island tracking station
DBP	descent battery pack
DRT	deorbit reference time. Time of SPS2 arbitrarily set to $20^{h}00^{m}00^{s}$ .
DSKY	display and keyboard
ECI	earth-centered inertial

ECS	environmental control system
EMS	entry monitor system
EPCS	experiment pointing control system
EPS	electrical power system
EREP	earth resources experiment package
e.s.t.	eastern standard time
EVA	extravehicular activity
FCD	Flight Control Division (MSC)
g	gravity
GCS	guidance cutoff signal
GDS	Goldstone tracking station
g.e.t.	ground elapsed time
G.m.t.	Greenwich mean time
GWM	Guam tracking station
G&N	guidance and navigation
GN2	gaseous nitrogen
HAW	Hawaii tracking station
HSK	Honeysuckle Creek tracking station
IECO	inboard engine cutoff
IMU	inertial measurement unit
INS	insertion
Isp	specific impulse
IU	instrument unit
KSC	John F. Kennedy Space Center
LC	launch complex
L/D	lift-to-drag
LES	launch escape system

LOS	loss	of	signal
-----	------	----	--------

LV launch vehicle

LVDC launch vehicle digital computer

M number of CSM orbits required for rendezvous

MAD Madrid tracking station

MCC-H Mission Control Center - Houston

MDA multiple docking adapter

mev million electron volts

mHz megahertz

MIL Merritt Island tracking station

MPAD Mission Planning and Analysis Division (MSC)

MRD mission requirements document

MSC Manned Spacecraft Center

MSFC George C. Marshall Space Flight Center

NA not applicable

NCC corrective combination maneuver (rendezvous)

NCl phasing 1 maneuver (rendezvous)

NC2 phasing 2 maneuver (rendezvous)

NFL Newfoundland ground station

NPC plane change maneuver (rendezvous)

OA orbital assembly (CSM plus SWS)

ODB operational data book

OECO outboard engine cutoff

OT operational trajectory

OWS orbital workshop

PFA powered flight angle

PGNCS primary guidance and navigation control system

PM posigrade maneuver, midnight

PRT	preliminary reference trajectory
PVT	pressure, volume, temperature
P51	IMU orientation CMC program (coarse alinement)
P52	IMU alinement check CMC program (fine alinement)
Р67	entry - final phase CMC program
R	radius
R <sub>eq</sub>	equatorial radius
RCS	reaction control system
REFSMMAT	reference stable member matrix
RFP	reference flight plan
RN	retrograde maneuver, noon
RT	reference trajectory
RTCC	Real-Time Computer Complex
SA	South Atlantic
SAA	South Atlantic anomaly
S-band	microwave band, 1550 to 5200 mHz
SEP	separation
SI	solar inertial (principal OA X-axis in orbit plane, +Z-axis points directly toward sun. At orbital noon the +X-axis is in the direction of the velocity vector)
SLA	spacecraft-lunar module adapter
SL	Skylab
SL-1	Skylab workshop launch
SL-2	first manned visit
SL-3	second manned visit
SL-4	third manned visit
SM	service module
SM RCS	service module reaction control system

SPS	service propulsion system
SPS-1	deorbit shaping maneuver
SPS-2	deorbit maneuver
STDN	Spaceflight Tracking and Data Network
STS	structural transition section
S-IB	Saturn IB vehicle
S-IC	Saturn V first stage
S-II	Saturn V second stage
S-IVB	Saturn IB second stage
S-V	Saturn V launch vehicle
SWS	Saturn workshop (includes AM, ATM, IU, MDA, and OWS)
TACS	thruster attitude control subsystem
TBD	to be determined
TB1, 2, 3, 4	time base 1, 2, 3, 4
TEX	Corpus Christi, Texas, tracking station
T <sub>GRR</sub>	time of guidance reference release (17 sec prior to lift-off)
$\mathtt{t}_{\mathtt{IG}}$	time of ignition
TLM, TM	telemetry
$T_{L}$	lift-off time
TPF	time of powered flight or terminal phase finalization maneuver (rendezvous)
TPI	terminal phase initiation maneuver (rendezvous)
TRK	tracking
TTY	teletype
UHF	ultra high frequency
U.S.	United States
USB	unified S-band
V	velocity or vehicle

.

VAN SA Vanguard tracking ship located in South Atlantic

VHF very high frequency

 $X_V, Y_V,$  vehicle dynamic body coordinate system with  $X_V$  positive  $Z_V$  through port 5,  $Z_V$  positive through ATM, and  $Y_V$  completes a right-handed system

- Z-LV(E) Z-local vertical earth pointing attitude (+X<sub>V</sub>-axis in orbit plane in direction of velocity vector, -Z<sub>V</sub>-axis along the geodetic local vertical)
- Z-LV(R) Z-local vertical rendezvous pointing attitude [same as Z-LV(E) except -X<sub>y</sub>-axis in direction of velocity vector]
- β angle between earth-sun line and the vehicle orbital plane
- γ flight-path angle

θ

- ΔV incremental velocity
- ΔVP remaining propellant ΔV equivalent
- $\theta$  angular displacement between the launch pad meridian at  ${\rm T}_{\rm GRR}$  and the descending node meridian at spacecraft insertion

regression rate of earth-fixed descending node

#### 3.0 MISSION PLANNING GUIDELINES AND INITIALIZATION DATA

The various systems handbooks and supporting documentation define the limits, guidelines, and procedures that are used for the basic Skylab mission profile. Some limitations and guidelines are restrictive and constrain the mission planning to within certain boundaries. This section will present the selected restrictions that formulate the OT mission planning and trajectory guidelines.

3.1 General Mission Ground Rules

a. The SWS will be launched unmanned from Kennedy Space Center (KSC) launch complex 39A by a two-stage Saturn V launch vehicle and will be inserted into a 233.8-n. mi.<sup>a</sup>, 50° inclination circular orbit.

b. The manned SL-2 CSM will be launched from KSC launch complex 39B by a Saturn IB launch vehicle at the first launch opportunity, which is approximately 23.5 hours after the SWS launch. The CSM will be inserted into an 81- by 120-n. mi.<sup>a</sup> orbit and subsequently maneuvered to rendezvous with the SWS.

c. The SL-1 launch will occur on April 30, 1973.

d. A northerly launch azimuth will be used for all Skylab missions.

e. The SL-2 mission is planned for up to 28 days duration, and the SL-3 and SL-4 missions are planned for up to 56 days duration, all three referenced to CSM launch.

f. The CSM RCS will be used to maintain an OA orbit which results in a nearly fixed groundtrack.

g. Sixty-five opportunities will be provided for performing earth resources experiments during the three Skylab missions. Sixty of these passes will be performed while the OA is in Z-LV(E) attitude, and five passes will be made while the OA is in either solar inertial (SI) or is oriented such that the -Z axis is alined with the moon for an EREP calibration pass.

h. The SM SPS will provide the primary deorbit capability from any orbital position during the mission.

i. The SM RCS will provide backup deorbit capability from at least one point in the orbit.  $\hfill \cdot$ 

j. Normal recovery operations are planned for water impact since the CM is designed for safe landing only on water.

<sup>a</sup>Referenced to equatorial radius of 3443.9335 n. mi.

#### 3.2 Mission Planning Constraints

#### 3.2.1 Mandatory .-

a. An early rendezvous (M=5 through M=8) for SL-2 must be provided to allow crew access to the SWS urine freezer within 24 hours of CSM launch (refs. 4 and 5).

b. An SL-1 launch window of at least 1.5 hours must be provided. Any shorter launch window will not allow enough time to resolve problems which may occur during the count.

c. The interval between CSM launches will be  $90 \pm 6$  days. The 84-day minimum is a launch pad turnaround limit. The 96-day maximum is to constrain the total length of the mission requiring the workshop.

d. The OA will not be maneuvered by the service propulsion system (SPS). The OA structure will not be tested for acceleration of this nature. The OA translational maneuver may be performed by the SM-RCS by firing the +X thrusters.

e. The SM-RCS +X jets must not be fired prior to deorbit more than 53 seconds continuously. Exceeding this limitation may damage the service module (SM) thermal paint. A cooldown period of 83 seconds is required between burns of 53 seconds.

f. For the backup deorbit, the SM RCS +X jets must not be fired more than 2400 seconds continuously. Exceeding this limitation may damage the SM shell.

g. The SM RCS -X jets must not be fired more than 53 seconds continuously. Exceeding this limitation may damage the SM aluminized Mylar insulation blankets.

h. ATM telemetry and command will be required within one revolution after CSM docking and one revolution before undocking. Attitude and pointing control system (APCS) control gains must be changed in the ATM digital computer (ATMDC).

i. For crew safety, SPS and one other deorbit method must be maintained. The mission will terminate if either the SPS or the backup deorbit capability is lost.

j. Except for deorbit, no maneuver will be planned that results in trajectories of perigees less than 80 n. mi. This 80-n. mi. perigee will be the minimum acceptable resultant perigee for maneuver planning purposes because of aerodynamic heating effects.

k. The nominal insertion orbit must have a perigee greater than 70 n. mi. This orbit will be the minimum acceptable orbit to guarantee no adverse spacecraft heating.

1. The minimum time between rendezvous maneuvers will be 30 minutes. For mission planning purposes, 30 minutes will be the minimum time required for crew preparation and/or navigation between burns.

m. Contact with at least one ground station having tracking capability will be required at a time greater than 55 minutes before the deorbit maneuver. Tracking is required between the deorbit shaping burn and the deorbit burn. n. Tracking and update requirements before each maneuver of the deorbit sequence are

Track: 3-minute pass with LOS  $\geq$  25 minutes prior to update

Update: 5-minute pass with AOS  $\geq$  15 minutes prior to burn

o. The maximum time the CSM can be on internal power will be 18 hours because of descent battery pack (DBP) electrical power limitations.

p. The time of free fall from the start of the deorbit burn to entry interface will be equal to or greater than 9 minutes. This time will be needed by the crew to prepare for separation and entry.

q. The predicted SM impact point, including 3σ dispersions, should avoid land masses. The impact point will be based on reducing the probability of death or injury resulting from entry debris.

r. All planned landings will be targeted between 40°N latitude and 40°S latitude. Adverse environmental conditions will exist outside these boundaries.

s. For earth-pointing experiment operations, the SWS shall provide the capability to perform Z-LV(E) maneuvers. The following guidelines assume nominal systems performance:

- (1) The Z-LV(E) attitude for the data-take period may be maintained for up to 160 orbital degrees.
- (2) The Z-LV(E) attitude maneuvers may be planned for beta ( $\beta$ ) angles up to +65°.
- (3) The maximum number of consecutive Z-LV(E) passes shall be two.
- (4) No more than two Z-LV(E) passes per crew day for any two consecutive days shall be planned.
- (5) Availability of electrical power, even under nominal conditions, may be limited for some Z-LV(E) maneuver profiles. Therefore, planning shall include exercising power management as required to stay within EPS capabilities and battery discharge constraints.

Real-time mission planning of Z-LV(E) maneuvers shall be based on actual systems performance, which may dictate changes in these guidelines.

t. For rendezvous, the SWS shall initiate acquisition of Z-LV(R) mode as early in a given revolution as approximately orbital midnight and return to the solar inertial mode at approximately orbital midnight after a maximum of two revolutions.

#### 3.2.2 Highly desirable .-

a. Launch time should be planned to provide daylight for recovery in the north Atlantic abort areas. Acceptable time for landing is defined as no earlier than civil sunrise in any abort area, nor later than 3 hours before civil sunset at the end of the mode II abort area.

b. The nominal recovery area must be in daylight. The required landing time in the selected recovery area is between civil sunrise and 2 hours prior to civil sunset.

c. The deorbit and entry should be planned such that the resulting time line minimizes change to the crew work-rest cycle (circadian rhythm) both before and after landing.

d. The SL-2, SL-3, SL-4 CSM missions will all use the same rendezvous maneuver sequence and time line for the nominal M=5 through M=8 flight plan.

e. If possible, the last half of the SL-2 and SL-3 missions should have daylight in the primary recovery area. For early mission termination the primary recovery area is more likely to be in daylight.

f. Planned recovery support posture for the Skylab missions will provide a landing opportunity in a planned landing area at least once every 13 hours.

g. The deorbit shaping (SPS-1) and deorbit (SPS-2) maneuvers will be heads down at an attitude of approximately -15° with the deorbit shaping occurring two revolutions prior to the deorbit maneuver.

3.2.3 Desirable .-

a. Post-retrofire coverage (track, telemetry, voice) is needed.

b. The darkness pass should be  $\geq 10$  minutes ( $\leq 89$  percent orbital sunlight) for inertial measurement unit (IMU) alignment in deorbit sequence.

c. The backup deorbit should be compatible with all primary deorbit medical experiment recovery constraints.

d. Maximize EREP lighting opportunities by judicious choice of lift-off times.

#### 3.3 Initialization Data

The initialization parameters used to generate trajectory data for SL-1/SL-2 are given in table 3-I.

# TABLE 3-I.- SL-1/SL-2 INITIALIZATION DATA

# Weights

SWS weight at CSM insertion, lb SWS weight at docking, lb SWS weight at undocking, lb	•								•		•	168 168 167	578.0 578.0 045.0
CSM weight at insertion, lb CSM weight at docking, lb CSM weight at undocking, lb	•	• • •	•	• • •	•			•	•		•	30 28 28	099.0 644.0 596.0
OA (SWS + CSM) at docking, lb . OA (SWS + CSM) at undocking, lb		•		•	•	•	:	•		•	•	197 195	222.0 641.0

# Areas ( $C_D = a_{2.0}$ )

SWS inertial area (average), ft <sup>2</sup>	2 996.8
CSM orbit rate area (frontal), ft <sup>2</sup>	129.4
OA inertial area. CSM end docked (average), ft <sup>2</sup>	3 157.4
S-IVB orbit rate area (frontal), ft <sup>2</sup>	436.7
S-IVB inertial area (average), ft <sup>2</sup>	976.0

# SPS steady state thrust

Maneuver	SPS steady statethrust, lb	SPS steady state flow rate, lb/sec
NCl	20 812.00	66.45
NC2	20 463.00	65.35
NCC	20 486.00	65.43
NSR	18 570.00	59.31
TPI	18 230.00	58.22
Shaping	21 113.00	67.44
Deorbit	20 860.00	66.64

#### SPS buildup

Impulse, 1b-sec .				•			•	•	•		•	•	•	•	450.0
Thrust, lb		 •								•		•	•		666.7
∆t, sec					 •					•	•				0.675
Weight flow rate,	lb/sec	 · .							•				•		2.14
I, sec		 •				•				•					312.0
sp															

# SPS tailoff

Single bore

Impulse, lb-sec	12 500.0
Thrust, 1b	20 833.3
Δt, sec	0.60
Weight flow rate, lb/sec	66.77
I <sub>sp</sub> , sec	312.0

 $^{\rm a}{\rm The}~{\rm C}_{\rm D}$  was adjusted by a factor of 0.95 for the modified JACCHIA atmospheric model.

TABLE 3-I.- SL-1/SL-2 INITIALIZATION DATA - Concluded

Dual bore	
<pre>Impulse, lb-sec</pre>	13 500.0 22 500.0 0.60 72.12 312.0
SM RCS 4 quad effective thrust, lb	380.1 1.42 277.3
Ullage AT	
2 quad	
Total $\Delta$ t, sec	21 20
4 quad	
Total $\Delta$ t, sec	15 14
SPS pitch trim and yaw trim angles	
For rendezvous, see reference 2, table 2.6-1, page 2-36 For deorbit, see reference 2, table 2.6-2, page 2-37	

CM end of mission entry aerodynamics

See reference 2, table 2.5-2, page 2-35

### 4.0 WORKSHOP LAUNCH (SL-1)

#### 4.1 Launch and Initial Activation

The Saturn V launches the workshop on April 30, 1973, at  $12^{h}30^{m}$  p.m. e.s.t. from pad 39A, Kennedy Space Center, Florida. The SL-1 launch has a flight azimuth • of 40.88° east of north and is targeted for a descending node argument of 153.25° measured from the space-fixed launch meridian at guidance reference release, T<sub>GRR</sub>. At  $9^{m}47.809^{s}$  ground elapsed time (g.e.t.), the SWS is inserted into a 233.8-n. mi. circular orbit inclined 50° to the equator. A sequence of events during launch is given in table 4-I (refs. 6 and 7).

After insertion, the S-II stage separates by retrorockets, and the SWS is pitched down by the thruster attitude control subsystem (TACS). As the SWS passes through the  $-90^{\circ}$  nose-down attitude, the payload shroud is jettisoned. The ATM and ATM solar arrays are deployed while the TACS orients the SWS to a solar inertial attitude. The orbital workshop (OWS) solar array is deployed, and activation of the control moment gyro subsystem (CMGS) begins (see ref. 8).

A Spaceflight Tracking and Data Network (STDN) tracking and lighting time line, including the activation sequence for 1 day from insertion, is shown in figures 4-1 and 4-2. The SWS activation events shown were obtained from references 8 and 9. The activation sequence given in figure 4-1 is a function of the time of lift-off; thus, it is subject to change if lift-off time is changed.

# 4.2 Mission Sequence

The time of day of the SL-l launch establishes the framework for the launch sequences on all subsequent missions that use the SL-l as a target and workshop. To provide SL-2 with required abort recovery lighting conditions on the following day, the SWS can be launched only between 5:15 a.m. to 2:00 p.m. e.s.t. For this document,  $12^{h}30^{m}$  p.m. e.s.t. was selected as the nominal time to launch SL-l. Appendix A-1.0 discusses the time of SL-l lift-off and the effects on the sequence for all subsequent missions.

The phase-plane relationship for the SL-2 launch the following day is controlled during the boost phase of the target. The longitude of the descending node determines the initial orientation of the workshop orbit relative to the earth and, in turn, determines the time of arrival of the northerly inplane SL-2 launch node the next day. The longitude of the descending node of the SL-1 orbit is shifted about 1° west of the optimum planar point by yaw steering during the Saturn V boost so that the rendezvous plane launch window is open during optimum phasing conditions.

For manned missions, nominal end-of-mission recovery in daylight is highly desirable; also highly desirable is daylight condition in the north Atlantic abort recovery areas. Acceptable end-of-mission recovery lighting limits are to land no earlier than civil sunrise and no later than 2 hours prior to civil sunset. The launch abort lighting limits are to launch no earlier than civil sunrise at KSC and to launch so that at least 3 hours remain before civil sunset at the end of the mode II abort area. In figure 4-3, a chronology of these lighting conditions is given for the launch site, for the west Atlantic recovery zone, and for the mid-Pacific recovery zone. Presented are times of northerly inplane launch opportunities and bands of recovery opportunities for each day after SL-l launch

for a 12<sup>h</sup>30<sup>m</sup> p.m. e.s.t., April 30, 1973, lift-off. Bands of recovery opportunities are shown because atmospheric drag uncertainties make it impossible to predict accurately for the entire Skylab mission the specific CSM passes over a recovery area. The total Skylab mission launch and recovery lighting conditions are shown in figure 4-4 for a 12:30 p.m. e.s.t. SWS launch. Launch opportunities are indicated within the abort recovery lighting limits, and the recovery areas are shown within end-of-mission lighting limits.

Another highly desirable constraint is to minimize change to the circadian rhythm of the crew and to maintain a nominal work-rest time line on deorbit day. This is a function of the deorbit preparation time required on deorbit day. To provide adequate time for recovery and postlanding medical requirements, landing should occur between 2100 G.m.t. and 2300 G.m.t. Confining recovery to a specified time, in addition to daylight, forces recovery to the Pacific. As can be noted in figure 4-3, the descending mid-Pacific band is at approximately 2000 G.m.t. on day 28 for the 12:30 p.m. launch time. However, because of the tracking coverage constraints, a descending pass closer to the west coast of the U.S. must be chosen and the landing time is only 1744 G.m.t.

For SL-2, a noon lift-off 1 day after SL-1 launch results in a morning [about  $9^{h}44^{m}$  a.m. local standard time (l.s.t.)] landing from a descending pass off the west coast of the U.S. after 28 CSM days (29 days after SWS launch).

The SL-3 mission is to be a 56-day mission launched between 84 to 96 days after the launch of SL-2. The launch-to-launch cycle of 90 ± 6 days is a mandatory constraint (section 3.2.1c). To choose a launch day for SL-3, lighting conditions must be examined for the nominal end-of-mission recovery area. The launch site daylight/ darkness cycles and the times of daily northerly inplane launch opportunities are presented in figure 4-4. Details of the SL-3 mission will be published separately.

The SL-4 launch day was selected by using the same criteria as for SL-3. The SL-4 mission is to be a 56-day mission launched 90  $\pm$  6 days after the launch of SL-3 with daylight in the end-of-mission recovery areas, and, if possible, in the launch abort areas. As can be seen in figure 4-4, days 229 through 251 would produce a recovery time providing daylight after landing in the mid-Pacific recovery zone from an ascending pass. Details of the SL-4 mission will be published separately.

The launches will be spaced as follows.
		Launch			Landing	
Mission	Day of year 1973, G.m.t.	c.d.t.	Time from SWS launch, days	Day of year 1973, G.m.t.	c.d.t.	Time from SWS launch, days
SL-1	120 (April 30)	12:30 p.m.	0			
SL-2	121 (May 1)	12 noon	1.0	149 (May 29)	12:44 p.m.	29.0
SL-3	206 (July 25)	1:43 a.m.	85.6	262 (Sept. 19)	3:15 p.m.	142.1
SL-4	(Oct. 26)	<sup>a</sup> l2 noon	179.0	355 (Dec. 21)	7:00 p.m.	235.3

<sup>a</sup>Approximate time.

The launch and recovery opportunities, with associated lighting conditions, are presented in reference 10 in a form that can be used to determine CSM launch and recovery times for an SL-1 launch at any given time on any given day. In addition, time histories of beta angle (incidence angle of the earth-sun line on the orbit plane) and percentage of orbital sunlight for the entire Skylab mission are presented in figure 4-5 for both the nominal SL-1 lift-off time (12:30 p.m.) and the SL-1 launch window closing time (2:00 p.m. e.s.t.).

## 4.3 Skylab Controlled Orbit

The Skylab orbit is designed to produce a repeating groundtrack pattern. An SL-1 orbit with a mean altitude of 233.8 n. mi. and orbital period of 93.237 minutes

has a ground trace that repeats every 71 earth-fixed revolutions  $(118^{h}00^{m}35^{s})$ . Figure 4-6 gives an example of the 71-revolution, or approximately 5-day (118 hr), repeating, groundtrack pattern. The heavy solid lines represent successive passes on the first day from launch through the fourteenth revolution. These traces are separated by 23.68° of longitude because of the rotation of the earth from orbit to orbit. The following day the ground traces (one revolution shown in a coded line) are offset to the east of the previous day's traces by 4.73°. This effect continues day by day with the ground trace of revolution 72 coinciding with that of revolution 1 as indicated.

To maintain this repeating pattern, however, small maneuvers are performed periodically [using the SM RCS +X translation thrusters with OA thruster attitude control subsystem (TACS) attitude control] to counteract the effects of drag and, possibly, small propulsive vents. The general criteria for scheduling the trim maneuvers established jointly by Flight Control Division/Crew Procedures Division/ Mission Planning and Analysis Division (FCD/CPD/MPAD; see ref. 11) are presented in their order of priority as follows.

a. Retrograde maneuvers (denoted as RN for retrograde, noon) will be performed at orbital noon and posigrade maneuvers (PM) at orbital midnight while the OA remains in solar inertial attitude. The maneuvers are made at these points in the orbit because the X-axis is essentially along the velocity vector at these times.

b. Maneuvers will be performed early in the crew work day to preclude interfering with other crew activities.

c. Maneuvers will control the cross-track error (referenced to the desired preflight pattern shown in fig. 4-6) so that it is less than 3 n. mi.

d. Maneuvers will be performed on a noninterference basis with accelerationlimited experiments, such as the crystal growth experiment and the boom experiment extended from the airlocks.

e. When possible, maneuvers will be performed over a tracking station for Mission Control Center - Houston (MCC-H) monitoring.

The details of each trim maneuver will be discussed in section 5.6. In the event the SL-1 insertion orbit is dispersed, the first trim maneuver performed early in the SL-2 mission will negate the insertion errors and return the groundtrack pattern to a reference location. For further details on philosophy and techniques of the controlled orbit, see appendix A-2.0.

The orbital decay history is shown in figure 4-7, which indicates the change in mean altitude and mean semimajor axis for the Skylab missions from SL-1 lift-off through the end of the SL-2 mission. The drag control furnished by the trim maneuvers is evident. The atmospheric drag model used is the Modified 1970 Jacchia (refs. 12 and 13).

## 4.4 TACS Propellant Analysis

The following are the criteria for the TACS analysis:

a. TACS system performance data are based on an in-orbit operating temperature of  $10\,^{\rm o}{\rm F}$  .

b. System capacity, as computed on a loading temperature of 62.5°F and a loading pressure of 3100 psia, is 72 500 lb-sec of impulse down to a usable thrust level of 14 pounds.

c. Switchover from TACS to TACS-CMG nested control is assumed to occur when the control moment gyros (CMG's) have reached 25 percent of rated speed.

d. TACS usage resulting from discrete vent disturbances has been included.

e. TACS usage during nominal nested TACS-CMG operation has been identified for EREP, SM RCS orbit trim burns, and momentum dump inhibits.

No situations have been identified in which standard vent profiles have caused the CMG capability to be exceeded.

Table 4-II is a TACS budget summary. The SL-1 TACS usage through initial CMG activation is 6082 lb-sec of impulse, or 109 pounds of gaseous nitrogen (GN2) propellant. For SL-2, the TACS usage is 2017 lb-sec of impulse, or 36 pounds of GN2. This includes 366 lb-sec for 14 Z-LV(E) EREP passes and 867 lb-sec for attitude control during the docked orbit trim maneuvers. The TACS usage for the SL-3 mission is 1944 lb-sec of impulse, or 35 pounds of GN2. This includes 700 lb-sec for 25 Z-LV(E) EREP passes and 375 lb-sec for attitude control during the orbit trim maneuvers. The TACS usage for the SL-4 mission is 250 lb-sec of impulse, or 44 pounds of GN2. This includes 1277 lb-sec for 20 Z-LV(E) EREP passes and 392 lb-sec for attitude control during the orbit trim maneuvers. The total TACS required for the Skylab mission is approximately 12 500 lb-sec, with another 16 500 lb-sec allotted for dispersions and systems tolerances.

TABLE 4-I.- SL-1 LAUNCH VEHICLE SEQUENCE OF EVENTS

Time, sec	Event
-17.25	Guidance reference release
0.0	First motion
0.4	Lift-off signal; initiate time base 1 (TB1)
11.0	Initiate constant pitch rate program
20.4	Terminate pitch program; pitch angle of attack set to zero
75.2	Maximum dynamic pressure
142.1	S-IC inboard engine cutoff signal
142.2	Initiate time base 2 (TB2)
154.7	Initiate attitude arrest
158.2	S-IC outboard engine cutoff signal
158.3	Initiate time base 3 (TB3)
160.0	S-IC/S-II physical separation
160.6	S-II sequence start command
163.6	S-II 90-percent thrust
189.9	Jettison S-IC/S-II aft interstage
196.0	Terminate attitude arrest; initiate guidance
299.2	S-II center engine cutoff signal
500.5	S-II mixture ratio shift
577.8	S-II guidance cutoff signal
578.0	End thrust decay; initiate time base 4 (TB4)
579.8	S-II/SWS separation
587.8	Orbital insertion

Mission	Required impulse, lb-sec
SL-1	6 082
SL-2	2 017
SL-3	l 944
SL-4	2 501
Rescue allocation	2 600
Anomalies	13 924
Total	29 068
Capacity	72 500
Remaining	43 432

TABLE 4-II.- TACS BUDGET SUMMARY



(a) Lift-off through 1 hour and 15 minutes.

Figure 4-1. - SL-1/SL-2 time line from SL-1 lift-off through 7 1/2 hours.



Teactivate AM deploy buses (TB4 + 1.5 hr)

.

(b) 1 hour and 15 minutes through 3 hours and 45 minutes.

Figure 4-1. - SL-1/SL-2 time line from SL-1 lift-off through 7 1/2 hours - Continued.

27







Figure 4-1. - SL-1/SL-2 time line from SL-1 lift-off through 7 1/2 hours - Continued.



.

.

.

.



Figure 4-1. - SL-1/SL-2 time line from SL-1 lift-off through 7 1/2 hours - Concluded.



Send PFA, TPF, ΔVP





Figure 4-2. - SL-1/SL-2 time line from 7 1/2 hours through time of SL-2 launch.



.



(b) 12 hours and 30 minutes through 17 hours and 30 minutes.

Figure 4-2. - SL-1/SL-2 time line from 7 1/2 hours through time of SL-2 launch - Continued.

31



(c) 17 hours and 30 minutes through 22 hours and 30 minutes.

Figure 4-2. - SL-1/SL-2 time line from 7 1/2 hours through time of SL-2 launch - Continued.



.

<sup>(</sup>d) 22 hours and 30 minutes through 25 hours.







Figure 4-3. - Relationship between ground lighting and launch and recovery opportunities for Skylab program (SWS launch at 12:30 p.m. e.s.t., April 30, 1973).



.

.

.

F

Figure 4-4. - Launch and recovery data for SWS launch 12:30 p.m. e.s.t., April 30, 1973.



Figure 4-5 - Time history of beta angle and percent of orbital sunlight for SWS launch at 12:30 p.m. and 2:00 p.m. e.s.t., April 30, 1973.



5 13. 5

н н т

Figure 4-6.- Ground traces for SWS in circular orbit of 233.8 nautical miles and 50 degree inclination for 71 revolutions.



Figure 4-7.- Orbital decay and mean semimajor axis for SL-1/SL-2.

## 5.0 FIRST MANNED VISIT

#### 5.1 Mission Summary

The SL-1/SL-2 mission is primarily concerned with a series of medical experiments related to the extension of manned space flight. The time line provides a sequence of crew activities that will permit a correlation of task performance with the resulting physiological effects and will reveal overall body responses to extended periods in space. The SL-1/SL-2 mission also has objectives associated with solar astronomy, earth resources, and technical experiments. The SL-1/SL-2 mission is planned for a duration of up to 28 days from the launch of the SL-2 CSM.

After completion of the scheduled experiments, the SWS is left in the solar inertial attitude and is prepared for orbital storage. The CSM is undocked from the SWS, and the deorbit maneuvers are performed with the SPS. With the planned mission duration and deorbit, recovery will occur in the Pacific Ocean on a descending pass off the west coast of the United States.

#### 5.2 SL-2 Prelaunch Phase

Prior to launch of the SL-2 CSM, the SWS will be checked by telemetry for compliance with the launch commit criteria in the mission requirements document (the MRD, ref. 5). To launch SL-2 into the SL-1 target plane with desired cutoff conditions, the S-IB launch vehicle digital computer (LVDC) must be provided targeting parameters. These parameters are as follows.

a.  $T_{GRR} = 121^{d} 16^{h} 59^{m} 19.0^{s}$  G.m.t. (17 sec prior to lift-off)

b. V = 25 705.81 fps

- c.  $\gamma = 0.0^{\circ}$
- d. R = 21 417 907 ft
- e. θ = 155.021°
- f.  $\theta = -0.004237 \text{ deg/sec}$

The time base convention is days:hours:minutes:seconds from  $0^{h}0^{m}0^{s}$ January 1, 1973. The day notation is Gregorian calendar day with January 1 being day one; hence, May 1 is day 121, and the time of day is in terms of G.m.t. (see ref. 14). [Note that the U.S. will be on daylight savings time during the SL-1/SL-2 (and SL-3) missions; hence, eastern standard time is equivalent to central daylight (Houston) time.]

The operational sequence involved in targeting the SL-2 launch is discussed in references 15 and 16. Significant prelaunch targeting events are indicated in figure 4-2.

#### 5.3 Launch

The launch of SL-2 (Saturn IB) is scheduled for May 1, 1973 at  $11^{h}59^{m}36.0^{s}$  a.m. e.s.t. from pad 39B at Kennedy Space Center, Florida. The exact launch time chosen for SL-2 was based on M=5 optimum phasing conditions. The SL-2 rendezvous launch window is presented in figure 5-1. The upper portion of the graph represents the plane launch window showing payload loss as a function of SL-2 lift-off time. The payload loss reaches a minimum at the inplane launch node or when the launch site passes under the target orbit plane. An SL-2 launch at any other time requires Saturn IB propellant for yaw steering into the target plane. For the orbital inclination of 50°, a 700-pound payload decrement (in combination with an LV variableflight azimuth program) is allowed for yaw steering, which yields a daily 15.5-minute plane launch window, 7.5 minutes prior to and 8.0 minutes after the optimum payload point (refs. 17 and 18).

The daily phase patterns are shown in the lower portion of figure 5-1. The phase angle between the two vehicles at the time of the CSM insertion is a function of the position of the SL-1 in its orbit at the time of SL-2 lift-off. The magnitude of the phase angle at insertion affects the type and duration of the rendezvous. The phase panes within the daily launch window are indicated as the intervals of time during which SL-2 lift-off would result in insertion phasing favorable for rendezvous from the fifth through eighth revolutions (early rendezvous, M=5 through M=8). It is mandatory that rendezvous and docking occur early enough in the SL-2 mission to allow first-day medical samples to be placed in the OWS freezer within  $2^4$  hours of collection of the first sample.

The times of phase pane openings ( $\Delta V_{\rm NCC} = 30$  fps) for early rendezvous are indicated on the topside of the phase pane bar; times of phase pane closings ( $\Delta V_{\rm NC1} = 30$  fps) are indicated on the bottomside and are given for information only. The white numbers inside the phase pane bars designate the lift-off time which will result in an onboard tracking range limit of 300 n. mi. between the CSM and the workshop at 36 minutes prior to NCC (NCC -  $36^{\rm m}$ ). In the event of a more than nominal launch delay, the rules for selecting the M number for rendezvous (ref. 19)

are as follows:

a. All phase panes open when  $\Delta V_{\rm NCC}$  = 30 fps

b. All phase panes, except M=5, close when range at NCC - 36 min = 300 n. mi.

c. The M=5 pane closes when the M=6 pane opens

d. When any two panes overlap the lower M number is used

An SL-1 nodal shift performed during the Saturn V launch (section 4.2) causes the nominal lift-off time for SL-2 (opening of the M=5 phase pane) to occur midway within the 15.5-minute plane window of May 1, 1973. In addition to the nominal lift-off time indicated in figure 5-1, the plane-phase conditions also can be observed if a slip in launch time occurs. A launch azimuth limit of 37.7° defines the maximum launch delay. On May 1, a launch slip of 10.5 minutes will result in a launch azimuth of 37.7°, an M=7 rendezvous, and a 780-pound payload loss for booster yaw steering. More than a 10.5-minute slip would require recycling until the next day. On May 2, only 0.5 minute of launch time remains within the early phase pane, and an M=8 rendezvous is required unless more than 700 pounds is allocated from the performance margin to permit an earlier launch. For example, 2000 pounds of propellant would allow launch 5.2 minutes prior to the 700-pound plane window opening and an M=7 rendezvous. If delay extends past the M=8 closing, recycling to days 126 and 127 (May 6 and 7) will be necessary.

The launch configuration shown in figure 1-2 is typical for each manned CSM launch. The SL-2 mission is launched along a northerly flight azimuth of 47.0° and is targeted for descending node argument of 155.021° measured from the space-fixed launch meridian at guidance reference release,  $T_{\rm GRR}$ . The CSM (fig. 1-3) and second stage S-IVB are inserted into an 81- by 120-n. mi. orbit inclined 50° to the equator. Orbital insertion occurs  $9^{\rm m}49.77^{\rm s}$  after lift-off. A sequence of events during launch is given in table 5-I (refs. 7 and 20).

## 5.4 Rendezvous Phase

The nominal rendezvous of SL-2 with SL-1 occurs as follows.

SL-2 launch occurs at  $11^{h}59^{m}36.0^{s}$  a.m. e.s.t. on May 1, 1973, with orbital insertion occurring at  $9^{m}49.77^{s}$  CSM g.e.t. The opening of the M=5 phase pane requires an insertion phase angle of  $47.7^{\circ}$ , with the CSM in an 81- by 120-n. mi. orbit.

About 6 minutes after insertion, the CSM separates from the S-IVB with a 3-fps posigrade maneuver using the SM RCS thrusters (ref. 21). This maneuver occurs at  $16^{m}$  CSM g.e.t., and the CSM resultant orbit is 81 by 122 n. mi. Table 5-II gives the REFSMMAT, target load, and gimbal angles for this maneuver. A plot of the relative trajectory in the S-IVB curvilinear coordinate system is shown in figure 5-2 for the CSM from separation through the first phasing maneuver.

Approximately 2 hours 4 minutes after the separation maneuver, the first

phasing (NC1) maneuver is performed near second apogee at  $2^{h}20^{m}12^{s}$  CSM g.e.t. This SPS maneuver imparts a AV of 218.8 fps and results in a 121- by 205-n. mi. orbit. NC1 and all other maneuvers through the coelliptic maneuver (NSR) are performed in the heads-down attitude. This is a technique needed to minimize the maneuver from onboard tracking attitude to burn attitude for NC2, NCC, and NSR. NC1 is performed in the heads-down attitude simply for consistency of crew procedures.

A plane change (NPC) maneuver nominally is not performed. However, the decision of whether the maneuver is to be performed depends on the size of the yaw gimbal angles at the times of the combination phase/height/out-of-plane (NCC) maneuver and the coelliptic (NSR) maneuver if the plane change maneuver is not performed. If the yaw gimbal angles for NCC and/or NSR are  $\leq 60^{\circ}$ , the maneuver is omitted and any out-of-plane error remaining would be cancelled during the NCC and NSR maneuvers. If a plane change maneuver is required, it will be performed between the first and second phasing maneuvers. The time of NPC is controlled by forcing a common node to occur 90° after NCl; that is, an anti-node is created at NCl. The NPC will then be executed at the second common node after NCl, or approximately 270° of orbital travel after NCl. One and one-half revolutions after the first phasing maneuver, the second phasing (NC2) maneuver is performed at  $4^{h}36^{m}03^{s}$  g.e.t. This SPS maneuver provides a  $\Delta V$  of 160.7 fps and results in a 204- by 214-n. mi. orbit.

At  $5^{h}22^{m}12^{s}$  CSM g.e.t., the corrective combination (NCC) maneuver is performed one-half revolution after NC2. This SPS maneuver imparts a  $\Delta V$  of 30.6 fps and results in a 213- by 223-n. mi. orbit. The range to the SWS 36 minutes prior to NCC is approximately 219 n. mi., and VHF ranging and optical tracking could be performed to permit computation of the NCC maneuver by the CSM using onboard navigation knowledge. Onboard maneuver computation will continue throughout the terminal phase.

The coelliptic (NSR) maneuver is performed 37 minutes after NCC at  $5^{h}59^{m}12^{s}$  CSM g.e.t., creating a coelliptic orbit 10 n. mi. below that of the SWS. This SPS maneuver provides a  $\Delta V$  of 19.1 fps. Because of the small  $\Delta V$  requirements for NSR (and TPI), these burns are not long enough for the SPS to attain steady-state conditions. In simulating these burns, the short-burn thrust parameters as presented in table 3-I were used. These parameters were computed from a minimum impulse curve contained in reference 22.

Approximately 50 minutes after NSR, the terminal phase initiation (TPI) maneuver is performed at  $6^{h}49^{m}01^{s}$  CSM g.e.t. This SPS maneuver, which imparts 20.6 fps, will be performed when the elevation angle to the SWS reaches 27.0°. The range at this time is approximately 22 n. mi., and the vehicles will be approximately 16 minutes into darkness.

At  $7^{h}18^{m}59^{s}$  CSM g.e.t., when the CSM is approximately l n. mi. from the SWS, the braking approach will begin. The theoretical terminal phase finalization (TPF) maneuver would require 27.9 fps. However, the nominal operational cost for braking, stationkeeping, and docking will be approximately 55 fps. During stationkeeping the SWS will be photographed and television coverage transmitted through the GWM STDN site (ref. 23). This TV activity is not scheduled over GDS STDN site because the coverage occurs too close to sunset. Immediately following the GWM pass the CSM will dock axially with the SWS, at port 5 of the multiple docking adapter (MDA) at  $7^{h}40^{m}$  CSM g.e.t.

All SPS maneuvers except TPI are preceded by a 2-jet, 20-second ullage plus a l-second overlap with the main engine burn. TPI is preceded by a 4-jet, 14-second ullage with a l-second overlap because the 4-jet ullage provides proper quad configurations for midcourse corrections and terminal phase braking. Table 5-III gives the REFSMMAT, target loads, and gimbal angles for the rendezvous maneuvers through TPI. A detailed summary of major maneuver and trajectory events is presented in table 5-IV.

The SPS propellant budget presented in table 5-V indicates that a propellant margin of 944 pounds exists. This is equivalent to approximately 315 fps at the start of mission and is available for variations in the mission plan and contingencies allowance.

For SL-2, the total SM RCS propellant available is 2587.1 pounds. Nominal mission requirements are 638.4 pounds, allocations for usage above nominal total 340 pounds, and 1300 pounds are reserved for backup deorbit. Resulting margins are 229.2 pounds in the quad systems and 79.5 pounds in the propellant storage module. Nominal CM RCS usage is 46 pounds of a usable quantity of 202.7 pounds. Additional detail is provided in tables 5-VI and 5-VII.

A time line of STDN coverage and lighting during rendezvous is given in figure 5-3. In table 5-VIII STDN stations are listed with their locations and equipment noted (ref. 24). Data in table 5-IX show STDN acquisition of signal (AOS) and loss of signal (LOS) times during the rendezvous using a minimum radar elevation angle of 0° considering terrain masking and keyholes. Also included in the table are duration of pass; maximum radar elevation, altitude, and ground range at the time of closest approach to the radar site; and latitude and longitude at the time of AOS and LOS. A plot of CSM ground traces from insertion through the end of revolution 5 showing maneuver points is given in figure 5-4. The rendezvous orbital geometry is shown in figure 5-5. The relative trajectory for the CSM from insertion to rendezvous is shown in the SWS curvilinear coordinate system in figure 5-6. The CSM range and range rate are shown in figure 5-7 with respect to the SWS from a range of 300 n. mi.

In figure 5-8, 5 days of ground traces are shown for the OA following rendezvous (revolutions 6 through 77). The ground traces repeat on a 71-revolution (118 hr) or approximately a 5-day cycle. For example, revolution 77 retraces the path of revolution 6. The ground traces in figure 5-8 can be used to predict the land masses that will be covered by identifying any revolution of interest and adding multiples of 71 revolutions to estimate the desired trace. The times of the ascending crossing of the equator are indicated. Also indicated in figure 5-8 are the network ground stations with terrain masked tracking areas shown for radar AOS and LOS at a  $3^{\circ}$  elevation above the horizon.

Estimates of the location of the regions of Skylab encounter with the trapped radiation belts defining the South Atlantic Anomaly (SAA) and high latitude electron bands (ref. 25) at OA orbital altitude are also shown in figure 5-8. The OA passes through the SAA region approximately nine times per day. The duration of earth transit is 10 minutes or more. Two passes per day are extensive; that is, SL-2 revolutions 18 and 19 encounter the northern trapped electron belt and then traverse a long arc (approximately 30 min) through the SAA, which contains both trapped electrons and protons. Revolutions 20 through 23 are moderately long passes, and 24 through 26 much shorter. The time of passage through these areas of trapped radiation are of concern when scheduling radiation experiments such as D008, extravehicular activities (EVA), and film handling.

## 5.5 Orbital Assembly Activation

The crew will remain on the premission work-rest cycle (ref. 9). Hence, the noon lift-off of SL-2 comes midway in the crew workday. The current planning is to schedule an eat-sleep-eat period immediately following docking. Entry and activation of the MDA, AM, and OWS are then scheduled for the next work period. Details of the sequence are presented in the SLM-1 Preliminary Skylab Flight Plan (ref. 26). According to estimate, the OWS activation procedures will achieve conditions adequate for safe access to the OWS freezer within 23 to 24 hours from lift-off in order to stow first-day medical samples.

## 5.6 Controlled-Orbit Trim Maneuvers

The philosophy and techniques for the controlled-orbit trim maneuvers are presented in appendix section A-2.0. If the SL-1 insertion is nominal, the SL-2 trim 1 is not performed. Trim 2, scheduled at about  $7^{d}19^{h}$  CSM g.e.t., is a posigrade burn of 0.4 fps, 6.4 seconds duration, and is designed to counteract drag. Figure 5-9 shows the detail of how closely the groundtrack holds the reference pattern for SL-2, deviating by less than 3 n. mi. throughout most of the mission. Since cross-track error varies with latitude (that is, 1° cross-track error at the equator is equivalent to 60 n. mi.; whereas, 1° cross-track error at 50° latitude is 39 n. mi.), a cross-track reference of 25°N was chosen to evaluate the stability

of the groundtrack for U.S. EREP passes. Trim 3, scheduled for about  $23^{d}19^{h}$  CSM g.e.t., is a 49.8-second posigrade burn of 3.09 fps designed to compensate for drag between SL-2 and SL-3, and control the location of the groundtrack for the SL-3 EREP passes which, with the exception of one pass, begin 19 days into the SL-3 mission. Trim 3 is performed 4 days prior to deorbit. Over this period of time from the trim 3 to deorbit the groundtrack moves to the west of the reference pattern by approximately 25 n. mi.

#### 5.7 Experiments Phase

From habitation of the OA to preparation of the SWS for orbital storage, mission activities, other than normal crew functions and systems operations, will consist primarily of experiments work. The experiments are divided into three areas of investigation: medical, Apollo telescope mount (ATM), and the earth resources experiments package (EREP). A complete summary and description of the experiments are included in Volume I of the Operational Data Book (ODB), reference 27. The detailed test objectives for EREP are given in reference 28. A complete time line of the experiment sequence is given in the SLM-1 Preliminary Skylab Flight Plan (ref. 26).

The medical and ATM experiments, both of high priority, are not affected by the earth position trajectory (except for earth occultation of the ATM experiments). However, the trajectory has direct impact on the EREP experiments. The experiments require a knowledge of earth-relative position at specified times and a knowledge of constraints concerning sun position relative to the OA and to the observed surface position.

The EREP passes described are based on the controlled-period orbit, which repeats its groundtrack every 71 earth-fixed revolutions. The criteria and procedures used in pass selection are discussed, and tabular and graphical data concerning the passes themselves are included.

The Skylab program is presently allotted 65 scheduled EREP passes; five of these are solar-inertial (SI) attitude passes (ref. 29). The passes are allocated by mission in the following manner:

	Z-LV	SI
First Skylab mission	15	0
Second Skylab mission	25	3
Third Skylab mission	20	<u>2</u> 5

However, because of an excessively crowded experiment schedule in the flight plan and the moon calibration procedure, one EREP pass has been tentatively dropped, leaving  $l^4$  passes in the SL-2 mission. This pass will be rescheduled for a later mission, resulting in the deletion of one solar inertial EREP pass.

The controlled orbit procedure was approved primarily to allow more efficient EREP planning and real-time operations. This procedure consists of performing a small number (3 or  $\frac{1}{4}$  per mission) of docked service module reaction control system (SM-RCS) maneuvers to attain and maintain a near-constant period orbit with a groundtrack which repeats every 71 earth-fixed revolutions (approximately  $\frac{1}{4}$  days and 22 hr). The mean altitude above the equator of this orbit is 233.8 n. mi. The inertial period is approximately 93.237 minutes. Section 5.6 should be consulted for more details of the orbit-keeping technique.

The EREP premission pass planning, assuming the controlled, repeating groundtrack, consists of two principal tasks:

a. The selection of a groundtrack pattern which optimizes coverage of the EREP sites. This result feeds back into the trajectory planning itself since effectively it defines the basic SL-1 orbit.

b. The selection of the EREP passes themselves, assuming the proper sun angle,  $\beta$ -angle, and scheduling constraints, in such a manner as to maximize the number of sites covered by the required sensors during the allocated number of passes (14 for SL-2).

5.7.1 <u>Selection of SL-1 groundtrack pattern.</u> - Once the controlled, repeatinggroundtrack orbit was incorporated into the mission planning cycle, the positioning of the repeating groundtrack for SL-2 necessitated one of the following two options:

a. Shift the groundtrack from the insertion-established pattern to a more optimum one by changing the insertion orbit and/or using RCS maneuvers to shift the track to the desired position.

b. Control the orbit period such that the nominal insertion-established repeating groundtrack pattern is maintained throughout the mission.

During the Reference Trajectory Planning (ref. 3) the decision was made to insert the OWS into the repeating orbit (biased slightly high to counter the drag effect) and to maintain the established pattern with the RCS maneuvers. This pattern has been carried over into the operational trajectory and is shown in figure 4-6.

Present studies of positioning of the groundtrack for EREP may determine that a shift from the present pattern is desirable. The shift could consist of simply repositioning the track pattern, which would be maintained throughout the three manned missions, or it could call for shifts from mission to mission or even inmission repositioning. However, preliminary shift studies (ref. 30) have revealed no significant advantage in such a shift and, because of the mission planning impact, of a groundtrack shift such a change is improbable, at least for SL-2. 5.7.2 <u>Selection of SL-2 prime passes</u>.- The fixed-groundtrack pattern was evaluated, track by track, to determine the optimum 14 passes (which consist of portions of the fixed tracks). The overall philosophy used in pass selection was as follows:

a. Concentrate on the coverage over the U.S., and incorporate into the operational trajectory passes, when possible, extensions that permit coverage of foreign sites; one all-foreign pass, included in the reference trajectory, has been at least temporarily dropped to ease the crowded flight plan.

b. Do not schedule repeat passes on the same mission over the same track; this permits coverage of more sites per mission. Covering the same track on different missions, however, was planned in order to satisfy many seasonal repeat requirements.

c. Satisfy operational constraints and requirements such as the following:

- 1. Inclusion of a crew rest day about every 7 days
- 2. No passes where the sun angle is less than 20° and/or the  $|\beta$  angle is greater than 65°

The concept of track was important in defining a particular EREP pass with respect to geographical area covered. Based on the 71-revolution repeating orbit, there are 71 tracks which define all geographical coverage, neglecting, of course, other constraints such as lighting,  $\beta$ -angle, crew activities, and so forth. The tracks are numbered from 1 to 71, the first starting in the mid-Atlantic ( $25^{\circ}W$ ) on SL-1 revolution 1 and ending at the same longitude on revolution 2. This starting and ending longitude in the mid-Atlantic is chosen rather than the usual revolution counter reference of the Cape Kennedy longitude in order to avoid ambiguity in track number covering the many sites located about longitude  $80^{\circ}W$ . The track, then, is the SL-1 earth-fixed revolution number (through rev 71) with the reference longitude in the mid-Atlantic.

The tracks through the U.S. were evaluated based on the numbers of sites which were contacted by a least one of the sensors considered mandatory by the proposer of that site. Minimum seasonal constraints were also considered; that is, a site whose proposal specifies minimally acceptable seasons which are outside of the SL-2 duration was not counted as a contacted site. The OT EREP pass evaluation was based on the Strawman 7 simulation data package. The entire site array, including the sensor performance sites, were included in the OT EREP pass digitals; however, the sensor performance sites were not counted in the pass ranking process discussed in the following paragraph since these sites have not yet been approved by the Skylab Program Office.

The 33 potential U.S. pass tracks consisted of both ascending and descending tracks through the U.S., with some of the descending tracks having possible extension by beginning over Japan or by carrying into South America. Each of these tracks occur 5 or 6 times during the SL-2 mission; 2 to 4 of these passes have proper lighting over the U.S. for EREP (sun angle >  $30^{\circ}$ ). Lighting condition for SL-2 U.S. passes is shown as a function of SL-1 lift-off time in figure 5-10. Based on the present 12:30 p.m. e.s.t. SL-1 launch time, SL-2 encounters acceptable (>30° sun angle with respect to the nadir point local horizontal) U.S. lighting

for ascending passes through mission day 12; good lighting for descending passes begins on day 10 and continues the remainder of the mission. A launch delay (later than 12:30 e.s.t.) results in a longer period of acceptable ascending U.S. passes, but delays the start of acceptably-lighted descending passes.

The task now consisted of selecting from these candidate tracks a group of 14 passes which occur on revolutions with proper lighting and  $\beta$ -angle and which are within flight planning and operational constraints. An attempt was made to incorporate these best 14 passes into the flight plan. However, because of conflicts in operational constraints and other considerations, three exceptions to the ranking were made in selecting the 14 prime tracks. Track 58 was included even though it ranked number 19 because it includes many sites not covered on other tracks and because it represents an opportunity to exercise the capability for an early EREP pass (rev 58-9). Track 1 was chosen, even though it ranked number 17, because it too covers sites not acceptably covered on other tracks, and no other acceptablylighted track was available during that period. Track 62 was chosen, despite ranking number 15, because an extension allows excellent coverage of sites in South America. Tracks 20, 33, and 47 were not included even though their respective rankings were 12th, 14th, and 13th; most of the sites covered on these tracks are covered by other prime tracks; also, these tracks will probably be used on SL-3 and/or SL-4. The selected passes, their track number, and evaluation ratings are as follows:

Pass number	SL-1 revolution number of the pass	Track number	Evaluation rating
1	58-9	58	19
2	72-3	l	17 (tie)
3	87–8	16	5 (tie)
4	114-5	43	2
5	132-3	61	3
6	157-8	15	7
7	171-2	29	l
8	172-3	30	8
9	205-6	63	10 (tie)
10	247-8 (calibration on 248)	34	5 (tie)
11	261-2	48	4
12	275-6	62	15 (tie)
13	303–4	19	10 (tie)
1 <sup>4</sup>	361-2	6	9

A more complete description of the geometry of these passes is given in figure 5-11, including the Z-LV angular position and length with respect to orbital noon, geographical area covered, and data-take begin and end times. The Z-LV angular length includes the data-take period and arc length required for attitude transient damping after reaching initial Z-LV, and the period following data take ends prior to initiation of reorientation back to solar inertial attitude. The transient damping time and the post-data-take Z-LV period are assumed to be 3 minutes and 1 minute, respectively. The passes are shown graphically in figure 5-12. Each groundtrack is bordered by the S190 (multispectral photographic facility) sensor field of view swath (approximately 44 n. mi. on either side of the nadir).

A moon calibration of the EREP sensors takes place on the night side following the May 17 pass. This calibration period is constrained by the requirement of a full moon and by the requirement that the angle off solar inertial necessary to point the EREP instruments at the moon be less than  $10^{\circ}$ . The calibration would be performed at this time even if weather or some other problem cancelled the Z-LV EREP pass on that revolution.

#### 5.8 Separation and Deorbit

The deorbit sequence is initiated by IMU alinements, undocking, fly-around inspection and then a separation maneuver. The IMU alinements occur in night passes prior to undocking and the remaining operations begin at daybreak and occupy one daylight pass. The first deorbit maneuver (SPS-1) occurs in the darkness period following separation. The second deorbit maneuver (SPS-2) occurs two orbits later at the same orbital position and attitude as SPS-1. The deorbit sequence can be found in table 5-IV and figure 5-13.

IMU alinements P51 and P52 will be performed during the two night passes preceding undocking. The SL-2 CSM will undock from the workshop May 29 at  $12^{h}41^{m}00^{s}$ G.m.t. [15<sup>h</sup>37<sup>m</sup>58.97<sup>s</sup> deorbit reference time (DRT)]. The undocking impulse will initiate a workshop circumnavigation sequence which will allow the crew to photograph and inspect the workshop. A typical CSM circumnavigation relative motion profile around the SWS is presented in figure 5-14 and table 5-X. The relative motion is based on a computer simulation of the circumnavigation sequence described in the Skylab entry checklist (ref. 37). The sequence begins with undocking at sunrise and ends with a separation maneuver 35 to 59 minutes later. A c.g.-toc.g. range between the SWS and CSM of 150 feet is maintained by monitoring the SWS through the crew optical alinement sight (COAS) and using small (0.5 sec) +X and + or - Z translations as necessary. The angular rate of travel around the SWS will also be monitored and maintained at 10° per 50 to 75 seconds. The circumnavigation will provide a visual and photographic inspection of the SWS. During the next night period, the IMU may be fine alined. At 13<sup>h</sup>40<sup>m</sup>00<sup>s</sup> G.m.t. (16<sup>h</sup>36<sup>m</sup>58.97<sup>s</sup> DRT), a 5-fps SM-RCS retrograde maneuver will be employed to evade the workshop.

Two deorbit systems are available in the CSM. The primary system is the SPS, and the backup system is the SM-RCS. The SL-2 SPS deorbit will be discussed herein; details concerning the SM-RCS backup deorbit are in section A-3.0 and table A-3-I of the appendix. The control mode for the SPS firings is primary guidance and navigation control system (PGNCS) in a horizon-monitor, heads-down attitude. Burn attitude is such that the line of sight to the horizon in a heads-down attitude is  $5^{\circ}$  from the spacecraft longitudinal axis, corresponding to a local pitch attitude of approximately  $-15^{\circ}$ . This is an optimum attitude for controlling the effect of pointing errors on the landing point and results in a relatively low propellant requirement (ref. 31).

The SPS retrofire will be accomplished in two stages (see ref. 32). The first of these maneuvers (SPS-1) will occur at  $14^{h}01^{m}22^{s}$  G.m.t.  $(16^{h}58^{m}21.41^{s}$  DRT). A 20-second (plus 1-sec overlap) two-quad SM-RCS ullage precedes the SPS-1 burn. The burn will establish a 90-n. mi. perigee at an orbital position identical to the post-retrofire (SPS-2) perigee position. Duration of the SPS-1 maneuver is 10.6 seconds and the AV applied (including ullage) is 264.1 fps. During the approximately two orbits which separate the two SPS burns the spacecraft state vector can be updated and IMU realined.

The SPS-2 retrofire occurs at  $17^{h}03^{m}01^{s}$  G.m.t.  $(20^{h}00^{m}00^{s}$  DRT). A 20-second (plus 1-sec overlap) two-quad SM-RCS ullage maneuver precedes the SPS-2 burn. The initiation of the SPS-2 maneuver occurs at longitude 93.2°E and geodetic latitude 11.78°N. No communications will be available during the deorbit burn. Duration of the SPS-2 burn is approximately 7.7 seconds, and the  $\Delta V$  applied, including that for the ullage maneuver, is 193.8 fps. Table 5-XI gives the REFSMMAT, target loads, and gimbal angles for the two deorbit maneuvers. The SPS deorbit  $\Delta V$  was controlled to produce entry conditions near the SPS low-speed target line (ref. 33).

After SPS shutdown, the CSM begins a coast to entry. During this coast, it will be necessary to jettison the SM by yawing the vehicle  $45^{\circ}$  to the south of the orbit plane while maintaining line of sight to the horizon using the 5° window mark. Upon completion of the yaw maneuver, the modules will be separated by -X SM-RCS thrusting.

#### 5.9 SL-2 Entry Following SPS Deorbit

Following an SPS deorbit (SPS-2), the SL-2 entry interface will occur at  $44.01^{\circ}N$  geodetic latitude and  $156.92^{\circ}W$  longitude approximately  $25^{m}15^{s}$  after SPS-2 retrofire. The ground trace from deorbit to landing is shown in figure 5-15 with pertinent events indicated. Landing of the CM following the nominal entry will occur at  $28^{d}00^{h}44^{m}28^{s}$  CSM g.e.t. (May 29  $17^{h}44^{m}04^{s}$  G.m.t. or  $20^{h}41^{m}03^{s}$  DRT) at  $26.94^{\circ}N$  geodetic latitude and  $130.09^{\circ}W$  longitude. The CM maneuver envelope for this prime recovery area is shown in figure 5-16. The drogue chutes are deployed  $10^{m}19^{s}$  after entry interface with the main chutes deployed about 42 seconds later. Landing occurs about  $4^{m}47^{s}$  after main chute deployment and about  $15^{m}48^{s}$  after entry interface.

Figure 5-17 presents the entry interface velocity and flight-path angle for the end-of-mission SPS deorbit mode within the entry corridor (ref. 34). The entry state vector is presented in table 5-XII and the trim aerodynamic coefficients for Mach 0.4 through 29.5 are shown in table 5-XIII. Figure 5-18 presents the altitude and range profile of the entry trajectory with significant trajectory and guidance events noted. Table 5-XIV presents a more detailed CM sequence of events for entry after the SPS-2 deorbit. The maximum load factor experienced for this trajectory was 3.3g. The maximum total reference heating rate obtained was 61.8 (Btu/ft<sup>2</sup>)/sec, and the total reference heat load was 13 704 Btu/ft<sup>2</sup>.

The normal command module computer (CMC) display and keyboard (DSKY) quantities for the final phase of entry program P67 are shown in figures 5-19 and 5-20. Presented in these figures are the dynamic flight parameters of CMC-commanded bank angle, cross-range error, down-range error, inertial velocity, and load factor as functions of time from 400 000 feet.

Figure 5-21 shows the velocity-load factor profile that can be expected on the entry monitoring system (EMS) display during the nominal guided entry. Also shown is the CMC-commanded bank angle and the EMS-computed range-to-go as a function of EMS velocity.

TABLE 5-I.- SL-2 LAUNCH VEHICLE SEQUENCE OF EVENTS

Time, sec	Event
-17.0	Guidance reference release
-3.1	Initiate S-IB main stage ignition sequence
0.0	First motion
0.2	Lift-off signal; initiate time base 1 (TB1)
10.2	Initiation pitch and roll program
73.6	Maximum dynamic pressure
130.5	Initial attitude arrest
134.6	Propellant level sensor activation; initiate time base 2 (TB2)
137.6	Inboard engine cutoff (IECO) signal
140.6	Outboard engine cutoff (OECO) signal; initiate time base 3 (TB3)
142.0	Physical S-IB/S-IVB separation
143.3	S-IVB ignition signal
146.7	S-IVB 90-percent thrust
153.9	Ullage rocket cases jettison
165.6	Launch escape system jettison
170.6	Terminate attitude arrest; initiate guidance
466.5	Mixture ratio shift signal
579.8	S-IVB guidance cutoff signal (GCS)
580.0	Initiate time base 4 (TB4)
589.8	Orbital insertion

TABLE 5-II.- LAUNCH REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES

# (a) Applicable maneuver

1. CSM/S-IVB separation (SEP)

(b) Definition of REFSMMAT XIX XIY XIZ Y Y YIX YIY YIZ ZIX ZIY ZIZ Ζ ECI(Mean of 1950) SPACECRAFT PLATFORM STABLE MEMBERS (c) REFSMMAT components XIZ = +.59823678 XIX = -.67807975XIY = +.42699013 YIY = +.76146425YIZ = -.64231659YIX = -.08718694ZIZ = -.47910554 ZIY = -.48770032ZIX = -.72979879(d) Target load for SEP maneuver [Propulsion system: CSM RCS] 00:16:00.0 2.9993 0.0000  $\Delta V_{7}$ , fps.... -0.0118 30 099.30 (e) Gimbal angles at t<sub>TC</sub> 316.9 358.5 180.3 OGA, deg . . . . . . . . . . . . . . . • . . . . . . . .

TABLE 5-III.- RENDEZVOUS REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES

(a) Applicable maneuvers

```
1. Phasing 1 (NCl)
```

- 2. Phasing 2 (NC2)
- 3. Corrective combination (NCC)
- 4. Coelliptic (NSR)
- 5. Terminal phase initialization (TPI)

(b) Definition of REFSMMAT



29 440.04

TABLE 5-III.- RENDEZVOUS REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES - Continued

# (g) Gimbal angles at t<sub>IG</sub>

IGA,	deg				÷								ų.									•			156.2
MGA,	deg		•	•	•			•	•	•		•			•	•		•			•		•	•	1.0
OGA,	deg	•	•	•	•	•	•	•	•	•	•	•	÷	•	•	•	•	•	•	•		•	•	•	180.3

# (h) Target load for NCC maneuver

# [Propulsion system: SPS; guidance: external $\Delta V$ ]

t <sub>IG</sub> ,	hr:r	nir	1:5	sec	2,	g	.e	.t	•	•		•	•		•	•	•	•	•		•			•	•	05:22:12.3
ΔV <sub>X</sub> ,	fps	•	•	•	•		•		•				•		•	•	•		•	,	•	•		•	,	30,5868
ΔV <sub>γ</sub> ,	fps			•	•		•		•		•		•		•		•	•	•	•	•	•			•	-0.0217
ΔV <sub>z</sub> ,	fps		•		•		•	•	÷			•		•				•	•		•			•	•	-0.9561
Mass	, lb	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	28 971.87

# (i) Gimbal angles at t<sub>IG</sub>

IGA,	deg	•	•								•		•								•		337.9
MGA,	deg	•							•		•		•						•	•			1.4
OGA,	deg	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•		179.8

# (j) Target load for NSR maneuver

[Propulsion system: SPS; guidance: external  $\Delta V$ ]

t <sub>IG</sub> ,	hr:n	nir	1:5	sec	2,	g	e	.t.					•		•	•		•	•		•	•	•	•	•	05:59:12.3
∆V <sub>X</sub> ,	fps	•		•	•	•	•	•	•	•	•	•	•	•	•	•			•	÷	•	•		•		19.1132
ΔV <sub>y</sub> ,	fps	•	•	•	•	•				•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	0.1573
ΔV <sub>Z</sub> ,	fps	•		•		•			•	•	•	•		•	•	•	•	•		•						-1.2202
Mass,	, lb										•		•			•	•							•		28 881.69
										(k)	)	G	iml	a.	Lε	ang	gle	es	a	t †	t I(	3				
IGA,	deg	•		•		•	•	•	•		•	•				•		•		•						196.0
MGA,	deg	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	1.6
OGA,	deg																•									180.2

# (1) Target load for TPI maneuver

## [Propulsion system: SPS, guidance: external $\Delta V$ ]

t <sub>TG</sub> ,	hr:n	nir	1:5	sec	2,	g	.e	.t	•	•	•	•	•	•	•	•	•		•	•	•	•	•		06:49:01.3
ΔV <sub>x</sub> ,	fps			•	•	•			•	•						•	•	•	•		•	•		•	18.7830
۵V <sub>v</sub> ,	fps				•	•	•	•	•	•							•		•	•	•			•	0.6801
ΔV <sub>z</sub> ,	fps					•	•		•			•	•				•	•		•				•	-8.3553
Mass	, lb			•																•	•				28 824.70

TABLE 5-III.- RENDEZVOUS REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES - Concluded

(m) Gimbal angles at  $t_{IG}$ 

IGA,	deg					•					•		•	•				•			•	•	•	•		25.0
MGA,	deg				•	•		•		•	•		•		•								•		•	0.7
OGA,	deg	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	·	•	•	•	2	•	359.1

			Time of burn initiation					Burn		Altitude	Geocentric	Townshinds	Resultant h
Event	Date	Calendar daw <sup>a</sup>	G.m.t., hr:min:sec	CSM g.e.t., d:hr:min:sec	SWS g.e.t., d:hr:min:sec	SWS rev	ΔV, fps	duration, sec	Lighting	n. mi. <sup>b</sup>	latitude, deg	deg	perigee/apogee", n. mi.
		uuy									08.115	80.60	
SL-1 lift-off	April 30	120	17:30:00.0	-00:23:29:36.0	00:00:00:00.0				Day		20.49	-00.00	222 0/221 8
Insertion	April 30	120	17:39:47.8	-00:23:19:48.2	00:00:09:47.8	ı			Day	233.9	39.41	-00.10	232.0/234.0
SL-2 lift-off	May 1	121	16:59:36.0	00:00:00:00.0	00:23:29:36.0	15			Day		20.47	-00.02	93 0 (300 3
Insertion	May 1	121	17:09:25.8	00:00:09:49.8	00:23:39:25.8	15			Day	81.0	39.01	-65.32	01.0/120.1
CSM/S-IVB separation <sup>C</sup>	May 1	121	17:15:36.0	00:00:16:00.0	00:23:45:36.0	15	3.0	7.4	Day	83.0	49.10	-33.98	81.0/121.6
Phasing 1 (NCl)	May 1	121	19:19:47.9	00:02:20:11.9	01:01:49:47.9	16	218.8	9.6	Night	121.4	-34.37	73.68	121.4/204.7
Phasing 2 (NC2)	May 1	121	21:35:39.1	00:04:36:03.1	01:04:05:39.1	17	160.7	6.9	Day	204.6	34.56	-140.61	203.8/213.5
Corrective combination (NCC)	May 1	121	22:21:48.3	00:05:22:12.3	01:04:51:48.3	18	30.6	1.2	Night	213.3	-34.73	27.92	213.2/223.1
Coelliptic (NSR)	May 1	121	22:58:48.3	00:05:59:12.3	01:05:28:48.3	18	19.1	0.7	Day	223.4	9.09	170.64	222.3/223.6
Terminal phase ini- tialization (TPI)	May 1	121	23:48:37.3	00:06:49:01.3	01:06:18:37.3	19	20.6	0.7	Night	224.2	-18.98	-12.97	224.1/234.2
Terminal phase final-	May 2	122	00:22:14.8	00:07:22:38.8	01:06:52:14.8	19	<sup>d</sup> 27.9	65.5	Day	232.8	-18.59	125.31	232.0/235.2
ization (TPF)										022 6	21.16	167 80	232 0/235 2
Docking	May 2	122	00:39:36.0	00:07:40:00.0	01:07:09:36.0	19			Day	233.6	31.10	107.00	232.0/235.2
Orbit trim 1-PM	May 2	122	15:22:59.7	00:22:23:23.7	01:21:52:59.7	28	0	0	Night	234.1	-26.70	117.69	232.0/233.2
Orbit trim 1-RN°	May 2	122	16:09:35.7	00:23:09:59.7	01:22:39:35.7	29	0	0	Day	233.4	26.80	-14.03	232.0/235.2
Orbit trim 2-PM	May 9	129	12:08:42.4	07:19:09:06.4	08:18:38:42.4	127	0.4	6.4	Night	233.8	-47.92	167.94	231.2/231.0
Orbit trim 2-RNC	May 9	129	12:55:20.2	07:19:55:44.2	08:19:25:20.2	128	0	0	Day	232.4	48.01	-23.41	231.2/237.0
Orbit trim 3-PMC	May 25	145	12:02:00.6	23:19:02:24.6	24:18:32:00.6	358	3.1	49.8	Night	231.5	-14.95	171.08	227.8/240.6
Undocking (see table 5-X)	May 29	149	12:41:00.0	27:19:41:24.0	28:19:11:00.0	416			Dawn	227.0	42.30	-160.35	227.0/241.1
Separation <sup>C</sup>	May 29	149	13:40:00.0	27:20:40:24.0	28:20:10:00.0	417	5.0	11.5	Dusk	237.6	-46.06	74.19	224.5/240.4
Shaping (SPS-1)	May 29	149	14:01:22.4	27:21:01:46.4	28:20:31:22.4	417	264.1	10.6	Night	227.9	9.02	137.05	90.4/229.6
Deorbit (SPS-2)	May 29	149	17:03:01.0	28:00:03:25.0	28:23:33:01.0	419	193.8	7.7	Night	226.8	11.71	93.19	-12.7/229.6
Landing	May 29	149	17:44:04.0	28:00:44:28.0	29:00:14:04.0	419			Day		26.78	-130.09	

#### TABLE 5-IV.- MAJOR MANEUVER AND TRAJECTORY EVENTS SUMMARY FOR SL-2

 $a_{\text{Time base convention - G.m.t. with days beginning 0}^{h_0m_0s}$  January 1 (day 120 is April 30)(ref. 14).

<sup>b</sup>Above a spherical earth of radius 3443.93-n. mi. radius.

°RCS.

<sup>d</sup>Theoretical cost, actual cost for line-of-sight control, stationkeeping, flyaround, and docking in an additional 26 fps.
	Burn duration, sec	Required, lb	Remaining, lb
Total loaded <sup>a,b</sup>			4996
Trapped and unavailable <sup>b</sup>		355	
Outage (fuel)		10	е. -
Available for mission requirements	ai -		4631
Nominal mission requirements <sup>c,d</sup>			
Phasing 1 (NCl)	9.6	650	3981
Phasing 2 (NC2)	6.9	469	3512
Corrective combination (NCC)	1.2	90	3422
Coelliptic (NSR)	0.7	57	3365
Terminal phase initiation (TPI)	0.7	55	3310
Deorbit shaping (SPS-1)	10.6	725	2585
Deorbit (SPS-2)	7.7	521	2064
Nominal remaining			2064
PVT gaging (leak detection) <sup>b</sup>		1013	1051
Dispersion <sup>e</sup>		107	944
Margin <sup>f</sup>			944

TABLE 5-V.- SL-2 SPS PROPELLANT USAGE SUMMARY

 $^{\rm a}{\rm Based}$  on loading SPS control weight. Spacecraft initial orbit weight = 30 099.0 lb.

<sup>b</sup>Reference 22.

<sup>c</sup>Includes start losses (100.8 lb, 7 starts at 14.4 lb/start).

<sup>d</sup>Ullages 2-jet, 20 sec, except for TPI 4-jet, 15 sec.

eReference 35.

 ${\rm f}_{\rm Margin}$  is available for contingencies and is equivalent to 315 fps abort to orbit.

	Quad	loors	Propellant s	upply module
Item	Propellant required, lb	Propellant remaining, lb	Propellant required, lb	Propellant remaining, lb
Nominal loaded		1342.4		1517.6
Trapped and unavailable	22.0	1320.4	47 <b>.</b> 1	1470.5
Mixture ratio uncertainty	48.8	1271.6	1.0	1469.5
Gaging inaccuracy	64.0	1207.6	90.0	1379.5
Available for mission requirements		1207.6		1379.5
Nominal mission requirements	<sup>a</sup> 638.4	569.2		
Nominal remaining		569.2		
Dispersions and allocations for mission flexibility	340.0	229.2		1379.5
SM RCS backup deorbit (SCS control mode)			1300.0	79.5
Margin		229.2		79.5

TABLE 5-VI.- SM RCS PROPELLANT USAGE SUMMARY FOR SL-2

.

.

<sup>a</sup>Includes usage of 77.5 lb SM RCS propellant for two orbit trim maneuvers (total  $\Delta V$  = 3.5 fps).

Item	Propellant required, lb	Propellant remaining, lb
Loaded		245.0
Loading uncertainty	5.9	239.1
Trapped	36.4	202.7
Available for mission planning		202.7
Nominal usage		
Prior to 400 000 feet	11.6	191.1
400 000 feet to drogue deployment	34.5	156.6
Nominal remaining		156.6

TABLE 5-VII.- CM RCS PROPELLANT USAGE SUMMARY FOR SL-2

-		Loca	tion			U: find	C. Laud			1/1	
Tracking station	Abbr.	Geocentric latitude, deg	Longitude, deg	USB type, <sup>a</sup> ft	CMD	TLM	TRK	Voice	CMD	TLM	Voice
Ascension	ACN	7.9 S	14.3 W	30 dual	х	Х	х	Х	Х	Х	Х
Bermuda	BDA	32.2 N	64.7 W	30 dual	x	х	х	х	х	х	х
Carnarvon	CRO	24.8 S	113.7 E	30 dual	x	х	х	х	х	х	х
Goldstone	GDS	35.2 N	116.9W	85 dual	х	х	х	x	х	х	х
Grand Canary	CYI	27.6 N	15.6 W	30 dual	х	x	х	x	x	х	х
Guam	GWM	13.2 N	144.7 E	30 dual	х	x	х	x	x	х	х
Hawaii	HAW	22.0 N	159.7 W	30 dual	×	х	х	x	х	х	Х
Honeysuckle Creek	нѕк	35.4 S	149.0 E	85 dual	x	x	x	x	x	х	х
Madrid	MAD	40.3 N	4.2 W	85 dual	x	x	х	x	x	х	x
Merritt Island	MIL	28.3 N	80.7 W	30 dual	x	x	x	х	x	x	х
Newfoundland <sup>b</sup>	NFL	47.7 N	52.7 W	_	-	-	-	-	xc	xc	х
Texas	TEX	27.5 N	97.4 W	30 dual	x	х	×	x	x	x	х
Vanguard SA <sup>e</sup>	VAN SA	37.9 S	58.0 W	30 dual	х	х	d	х	x	х	х

TABLE 5-VIII.- STDN STATIONS AND EQUIPMENT

<sup>a</sup>Network will also include C-band at MIL and CRO.

<sup>b</sup>Operational only for approximately first 24 hr of each mission.

<sup>C</sup>Operational only for SL-1 and SL-2.

<sup>d</sup>No tracking capability required.

 $e_{SA} = South Atlantic.$ 

## TABLE 5-IX.- STDN COVERAGE FOR SL-2 DURING RENDEZVOUS (0° ELEVATION ANGLE AT ACQUISITION AND LOSS OF SIGNAL)

				CLOSEST	T APPROACH	ACQUISITION	LOSS
GAP STATION	REV	GET ACQ	GET LOSS	DELTA T MAX EL ALT	TITUDE GND RANGE	LAT LON	LAT LON
BDA 30 USB	1.01	0 C 6 9.8	0 0 11 38.8	0 5 29.0 10.5	84.34 351.54	29.6 -78.8	42.9 -57.3

SEPARATION MANEUVER HAS BEEN PERFORMED AT 121<sup>d</sup>17<sup>h</sup>15<sup>m</sup>36<sup>s</sup> G.m.t., 0<sup>d</sup>00<sup>h</sup>16<sup>m</sup>00<sup>s</sup> g.e.t.

													CL	OSEST APPRO	ACH	ACQUIS	SITION	L	OSS
GAP STATIC	N	REV	G	SET /	ACQ		GET	L	OSS	D	EL	TAT	MAX EL	ALTITUDE	GND RANGE	LAT	LON	LAT	LON
NFL		1.04	0	0 '	9 48.2	0	0	16	6.8	0	6	18.5	26.3	87.82	164.23	38.9	-65.5	49.2	-33.4
4 MAC 85	USB	1.20	0	C 1	9 55.7	0	0	23	33.2	0	3	37.5	6.4	92.75	500.31	49.5	-10.1	45.3	10.2
68 TEX 30	USB	1.92	0	1 3	47.5	0	1	37	27.5	0	5	40.0	18.0	84.20	230.68	22.2	-109.0	37.7	-90.1
4 NFL		2.03	0	1 4	1 32.8	0	1	48	2.4	0	6	29.5	39.1	89.60	106.01	45.9	-71.3	49.5	-33.0
3 MAD 85	USB	2.18	0	1 5	1 10.1	0	1	56	19.8	0	5	9.7	42.6	97.49	101.82	46.2	-15.2	35.6	7.8

PHASING 1 MANEUVER HAS BEEN PERFORMED AT 121<sup>d</sup>19<sup>h</sup>19<sup>m</sup>48<sup>s</sup> G.m.t., 0<sup>d</sup>02<sup>h</sup>20<sup>m</sup>12<sup>s</sup> g.e.t.

					CLOSEST APPRO	ACH	ACQUISITION	LOSS
GAP STATION	REV	CET ACQ	GET LOSS	DELTA T	MAX EL ALTITUDE	GND RANGE	LAT LON	LAT LON
GDS 85 (	JSB 2.86	0 3 1 20.3	0 3 10 20.7	0 9 .5	85.7 207.88	15.08	23.5 -130.4	44.6 -98.3
TEX 30 1	JSB 2.9C	0 3 5 31.9	0 3 9 46.6	0 4 14.7	4.1 206.20	947.76	34.5 -117.7	43.6 -100.9
1 TEX 30 U	JSB 2.96	0 3 11 11.8	0 3 11 21.9	0 0 10.1	.6 202.72	1127.64	45.9 -94.2	46.2 -93.4
2 NFL	3.00	0 3 13 33.7	0 3 23 30.1	0 9 56.4	62.9 193.21	93.69	48.7 -81.8	42.6 -27.9
8CA 30 1	JSB 3.02	0 3 14 48.3	0 3 16 .2	0 1 12.0	.8 196.89	1101.98	49.6 -74.8	50.0 -67.9
1 BDA 30 U	JSB 3.05	0 3 17 4.9	0 3 17 48.5	0 0 43.7	.9 192.70	1083.49	49.9 -61.6	49.7 -57.4
7 CYI 30 0	USB 3.16	0 3 24 22.9	0 3 31 32.3	0 7 9.5	19.7 164.38	382.29	40.8 -24.1	22.6 .1
MAD 85 U	JSB 3.17	0 3 25 53.7	0 3 30 12.6	0 4 18.7	10.8 166.15	575.04	37.4 -18.1	26.3 -3.7
37 HSK 85 U	JSB 3.60	0 4 7 16.1	0 4 14 34.5	0 7 18.3	41.9 161.60	167.98	-44.1 136.8	-27.0 164.3
11 HAW 30 U	JSB 3.76	0 4 25 51.6	0 4 34 33.9	0 8 42.2	40.9 203.49	213.92	6.2 -168.1	30.8 -145.5

PHASING 2 MANEUVER HAS BEEN PERFORMED AT 121<sup>d</sup>21<sup>h</sup>35<sup>m</sup>39<sup>s</sup> G.m.t., 0<sup>d</sup>04<sup>h</sup>36<sup>m</sup>03<sup>s</sup> g.e.t.

				CL	DSEST APPROACH	ACQUISITION	LOSS
GAP STATION	REV	GET ACO	GET LOSS	DELTA T MAX EL	ALTITUDE GND RANGE	LAT LON	LAT LON
1 GDS 85 USB	3.85	0 4 37 14.6	0 4 44 3.9	0 6 49.4 13.7	207.19 599.20	37.4 -136.3	48.8 -104.6
4 N FI	3.99	0 4 47 53.7	0 4 58 8.2	0 10 14.6 39.3	211.20 232.03	49.8 -82.5	33.3 -35.0
864 30 USB	4.01	0 4 48 52.4	0 4 50 48.8	0 1 56.4 2.5	207.53 1032.42	49.3 -76.9	47.6 -66.3
1 BDA 30 USB	4.05	0 4 51 19.1	0 4 56 11.2	0 4 52.0 5.6	208.45 884.83	46.9 -63.7	38.0 -42.0
2 CYT 30 USB	4.13	0 4 58 1.3	0 5 6 44.9	0 8 43.6 17.8	210.55 501.69	33.6 -35.4	9.3 -11.6
ACN 30 USB	4.19	0 5 6 34.3	0 5 13 49.0	0 7 14.6 8.8	210.91 755.50	9.8 -12.1	-11.7 4.5

CORRECTIVE COMBINATION HAS BEEN PERFORMED AT 121<sup>d</sup>22<sup>h</sup>21<sup>m</sup>48<sup>s</sup> G.m.t., 0<sup>d</sup>05<sup>h</sup>22<sup>m</sup>12<sup>s</sup> g.e.t.

				CLC	DSEST APPROACH	ACQUISITION	LOSS
GAP STATION	RFV	GET ACQ	GET LOSS	DELTA T MAX EL	ALTITUDE GND RANGE	LAT LON	LAT LON
18 CRO 30 USB	4.55	C 5 40 17.4	0 5 44 25.3	0 4 8.0 3.4	221.12 1019.14	-42.3 117.9	-33.1 133.5
0 HSK 85 USB	4.60	C 5 44 42.4	0 5 49 26.3	0 4 43.8 12.2	224.15 670.55	-32.4 134.4	-19.6 148.0

#### TABLE 5-IX.- STDN COVERAGE FOR SL-2 DURING RENDEZVOUS (0° ELEVATION ANGLE AT ACQUISITION AND LOSS OF SIGNAL) - Concluded

.

# COELLIPTIC MANEUVER HAS BEEN PERFORMED AT 121<sup>d</sup>22<sup>h</sup>58<sup>m</sup>48<sup>s</sup> G.m.t., 0<sup>d</sup>05<sup>h</sup>59<sup>m</sup>12<sup>s</sup> g.e.t.

														CL	OSEST APPRO	ACH	ACQUIS	SITION	1	-055
GAP	ST	AT ION	REV		GETA	00		GET	ΓL	055	C	DEL	ТА Т	MAX EL	ALTITUDE	GND RANGE	LAT	LON	LAT	LON
4	HAW	30 USB	4.73	0	6 3	21.2	0	6	9	28.5	0	6	7.3	10.1	224.55	743.29	21.1	-179.3	37.0	-160.5
1	HAW	30 USB	4.79	0	€ 10	18.0	0	6	11	18.6	0	1	.6	2.1	224.59	1099.22	38.8	-157.4	41.0	-153.4
4	GDS	85 USB	4.85	0	6 1 9	5 37.4	0	6	20	42.4	0	5	5.1	6.8	227.13	882.13	47.9	-133.0	49.7	-104.3
3	MIL	30 USB	4.98	0	6 23	36.5	0	6	24	1.9	0	0	25.4	1.1	226.78	1160.97	47.2	-88.5	46.7	-86.3
0	BDA	30 USB	4.99	0	6 24	29.9	0	6	35	8.0	0	10	38.1	39.5	227.90	249.65	46.0	-84.0	21.6	-45.6
	NFL		4.99	0	6 24	48.1	0	6	33	3.0	0	8	14.8	8.5	230.78	810.30	45.6	-82.5	27.3	-51.4
	MIL	30 USB	5.01	0	6 20	5 2.8	0	6	30	32.7	0	4	30.0	5.7	227.12	923.80	43.5	-76.7	33.8	-59.2

## TPI MANEUVER HAS BEEN PERFORMED AT 121<sup>d</sup>23<sup>h</sup>48<sup>m</sup>37<sup>s</sup> G.m.t., 0<sup>d</sup>06<sup>h</sup>49<sup>m</sup>01<sup>s</sup> g.e.t.

TRACKING TABLE

					CLU	DSEST APPRO	ACH	ACQUIS	ITION	LC	DSS
GAP	STATION	REV	GET ACQ	GET LOSS	DELTA T MAX EL	ALTITUDE	GND RANGE	LAT	LON	LAT	LON
	ACN 30 USB	5.14	0 6 41 52.0	0 6 51 36.1	0 9 44.1 27.6	224.27	367.00	2.0	-29.6	-26.2	-6.1

TPF MANEUVER HAS BEEN PERFORMED AT 122<sup>d</sup>00<sup>h</sup>22<sup>m</sup>15<sup>s</sup> G.m.t., 0<sup>d</sup>07<sup>h</sup>22<sup>m</sup>39<sup>s</sup> g.e.t.

TRACKING TABLE

															C	LOSEST APPRO	ACH	ACQUIS	SITION	L	055
GAP	STA	TION	REV		GET	AC	Q		GE	T L	OSS		DEL	TAT	MAX EL	ALTITUDE	GND RANGE	LAT	LON	LAT	LON
	CRD	30 USB	5.50	0	7	14	9.0	0	7	24	39.3	0	10	30.3	43.2	234.62	226.71	-40.2	98.7	-12.8	130.2
3	GWM	30 USB	5.60	0	7	27	35.7	0	7	37	39.3	0	10	3.5	39.0	234.03	258.30	-4.2	136.9	25.0	160.9
16	GDS	85 USB	5.86	0	7	53	16.0	0	8	0	6.0	0	6	50.0	10.7	237.87	755.72	49.8	-130.3	41.5	-95.8
	TEX	30 USB	5.92	0	7	57	23.0	0	8	5	51.4	0	8	28.4	10.7	237.45	754.20	46.2	-108.1	27.9	-75.7
	MIL	30 USB	5.96	0	7	59	55.2	0	8	10	8.3	0	10	13.0	52.4	237.87	168.87	41.8	-96.5	16.0	-64.3
	BDA	30 USB	5.98	0	8	1	47.3	0	8	9	53.5	0	8	6.1	14.8	238.59	628.05	37.9	-89.1	16.7	-64.9
1	BDA	30 USB	6.05	0	8	10	46.2	0	8	11	34.2	0	0	48.0	1.3	238.78	1159.21	14.2	-62.8	. 11.9	-60.9
41	CRO	30 USB	6.48	0	18	52	24.1	0	8	59	26.4	0	7	2.3	10.0	234.86	767.03	-28.0	92.4	-8.1	110.2
7	GWM	30 USB	6.57	C	9	6	29.9	0	9	12	36.3	0	6	6.4	9.2	234.13	798.91	12.7	126.2	29.7	142.3

Undocking         .4         0:00         240           1         {2.5 sec +X, }         .         .	Maneuver númber	Type of <u>maneuver</u>	Delta velocity (fps)	Time from undocking (min:sec)	Coast time to next maneuver (seconds)
1 $\{2.5 \text{ sec } + X, \}$ (Initiation) $1.5 \text{ sec } -2$ .6304:00902.5 sec +X.1085:30903.5 sec +X.1087:202604.5 sec +X.10811:40206.5 sec +X.10812:00307.5 sec +X.10812:301608.5 sec +X.10815:10409.5 sec +X.10815:5012010.5 sec +X.10817:503011.5 sec +X.10818:2010012.5 sec +X.10820:002013.5 sec +X.10821:304015.5 sec +X.10821:304016.5 sec +X.10821:304017.5 sec +X.10823:104018.5 sec +X.10823:104017.5 sec +X.10823:104018.5 sec +X.10823:104017.5 sec +X.10823:104018.5 sec +X.10823:104019.5 sec +X.10823:104022.5 sec +X.10833:501024.5 sec +X.10833:501025.5 sec +X.10833:501026.5 sec +X.10833:501025.5 sec +X.10835:4020 <td></td> <td>Undocking</td> <td>.4</td> <td>0:00</td> <td>240</td>		Undocking	.4	0:00	240
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1	(2.5 sec +X,)			
2.5 sec -Z.108 $5:30$ 903.5 sec +X.108 $7:00$ 204.5 sec +X.108 $7:20$ 2605.5 sec -Z.108 $11:40$ 206.5 sec +X.108 $12:30$ 307.5 sec +X.108 $12:30$ 1608.5 sec +X.108 $15:10$ 409.5 sec +X.108 $15:50$ 12010.5 sec +X.108 $17:50$ 3011.5 sec +X.108 $20:00$ 2013.5 sec +X.108 $20:20$ 7014.5 sec +X.108 $21:30$ 4015.5 sec +X.108 $22:10$ 6016.5 sec +X.108 $23:10$ 4017.5 sec +X.108 $23:50$ 7018.5 sec +X.108 $25:50$ 9020.5 sec +X.108 $25:50$ 9021.5 sec +X.108 $30:40$ 4023.5 sec +X.108 $31:20$ 12024.5 sec +X.108 $33:50$ 11026.5 sec +X.108 $33:50$ 11026.5 sec +X.108 $37:00$ 5029.5 sec +X.108 $37:50$ 5030.5 sec +X.108 $37:50$ 5030.5 sec +X.108 $37:50$ 50	(Initiation)	1.5 sec -Z	.630	4:00	90
3 $.5 \sec + X$ $.108$ $7:00$ $20$ 4 $.5 \sec + X$ $.108$ $7:20$ $260$ 5 $.5 \sec - Z$ $.108$ $11:40$ $20$ 6 $.5 \sec + X$ $.108$ $12:00$ $30$ 7 $.5 \sec + X$ $.108$ $12:30$ $160$ 8 $.5 \sec + X$ $.108$ $15:10$ $40$ 9 $.5 \sec + X$ $.108$ $15:50$ $120$ 10 $.5 \sec + X$ $.108$ $17:50$ $30$ 11 $.5 \sec + X$ $.108$ $18:20$ $100$ 12 $.5 \sec + X$ $.108$ $20:00$ $20$ 13 $.5 \sec + X$ $.108$ $20:20$ $70$ 14 $.5 \sec + X$ $.108$ $21:30$ $40$ 15 $.5 \sec + X$ $.108$ $23:10$ $40$ 16 $.5 \sec + X$ $.108$ $23:50$ $70$ 18 $.5 \sec + X$ $.108$ $23:50$ $50$ 19 $.5 \sec + X$ $.108$ $25:50$ $90$ 20 $.5 \sec + X$ $.108$ $25:50$ $90$ 21 $.5 \sec + X$ $.108$ $30:40$ $40$ 23 $.5 \sec + X$ $.108$ $31:20$ $120$ 24 $.5 \sec + X$ $.108$ $33:50$ $110$ 26 $.5 \sec + X$ $.108$ $33:50$ $110$ 26 $.5 \sec + X$ $.108$ $37:00$ $50$ 29 $.5 \sec + X$ $.108$ $37:50$ $50$ 30 $.5 \sec + X$ $.108$ $37:50$ $50$ 30 $.5 \sec + X$ $.108$ <td>2</td> <td>.5 sec -Z</td> <td>.108</td> <td>5:30</td> <td>90</td>	2	.5 sec -Z	.108	5:30	90
4.5 sec +x.108 $7:20$ 2605.5 sec -2.108 $11:40$ 206.5 sec +x.108 $12:00$ 307.5 sec +x.108 $12:30$ 1608.5 sec +x.108 $15:10$ 409.5 sec +x.108 $15:50$ 12010.5 sec +x.108 $17:50$ 3011.5 sec +x.108 $18:20$ 10012.5 sec +x.10820:002013.5 sec +x.10821:304015.5 sec +x.10822:106016.5 sec +x.10823:104017.5 sec +x.10823:104018.5 sec +x.10823:507018.5 sec +x.10825:005020.5 sec +x.10827:205021.5 sec +x.10830:404023.5 sec +x.10831:2012024.5 sec +x.10833:203025.5 sec +x.10833:203026.5 sec +x.10835:402027.5 sec +x.10835:402028.5 sec +x.10837:005029.5 sec +x.10837:505030.5 sec +x.10838:4030	3	.5 sec +X	.108	7:00	20
55sec-Z10811:402065sec+X10812:003075sec+X10812:3016085sec+X10815:104095sec+X10815:50120105sec+X10817:5030115sec+X10820:2070125sec+X10821:3040155sec+X10823:1060165sec+X10823:1040175sec+X10825:0050195sec+X10827:2050205sec+X10830:4040235sec+X10833:2030245sec+X10833:2030255sec+X10833:2030255sec+X10833:4020265sec+X10835:4020275sec+X10835:4020285sec+X10837:0050295sec+X10837:5050305sec+X108 <t< td=""><td>4</td><td>.5 sec +X</td><td>.108</td><td>7:20</td><td>260</td></t<>	4	.5 sec +X	.108	7:20	260
6       .5 sec +X       .108       12:00       30         7       .5 sec +X       .108       12:30       160         8       .5 sec +X       .108       15:10       40         9       .5 sec +X       .108       15:50       120         10       .5 sec +X       .108       17:50       30         11       .5 sec +X       .108       18:20       100         12       .5 sec +X       .108       20:20       .00         13       .5 sec +X       .108       20:20       .00         14       .5 sec +X       .108       21:30       40         15       .5 sec +X       .108       23:10       40         17       .5 sec +X       .108       23:10       40         17       .5 sec +X       .108       23:50       .00         18       .5 sec +X       .108       25:50       .00         20       .5 sec +X       .108       .25:50       .00         21       .5 sec +X       .108       .30:40       .40         23       .5 sec +X       .108       .31:20       .120         24       .5 sec +X       .108       .31:20	5	.5 sec -Z	.108	11:40	20
7       .5 sec +X       .108       12:30       160         8       .5 sec +X       .108       15:10       40         9       .5 sec +X       .108       15:50       120         10       .5 sec +X       .108       17:50       30         11       .5 sec +X       .108       18:20       100         12       .5 sec +X       .108       20:00       20         13       .5 sec +X       .108       20:20       70         14       .5 sec +X       .108       21:30       40         15       .5 sec +X       .108       23:10       60         16       .5 sec +X       .108       23:10       40         17       .5 sec +X       .108       23:50       70         18       .5 sec +X       .108       25:50       90         20       .5 sec +X       .108       25:50       90         21       .5 sec +X       .108       30:40       40         23       .5 sec +X       .108       30:40       40         24       .5 sec +X       .108       31:20       120         24       .5 sec +X       .108       33:50	6	.5 sec +X	.108	12:00	30
8         .5 sec +X         .108         15:10         40           9         .5 sec +X         .108         15:50         120           10         .5 sec +X         .108         17:50         30           11         .5 sec +X         .108         18:20         100           12         .5 sec +X         .108         20:00         20           13         .5 sec +X         .108         20:20         70           14         .5 sec +X         .108         21:30         40           15         .5 sec +X         .108         23:10         60           16         .5 sec +X         .108         23:50         70           18         .5 sec +X         .108         25:00         50           19         .5 sec +X         .108         25:50         90           20         .5 sec +X         .108         26:10         150           21         .5 sec +X         .108         30:40         40           23         .5 sec +X         .108         31:20         120           24         .5 sec +X         .108         33:50         110           25         .5 sec +X         .108 <td>7</td> <td>.5 sec +X</td> <td>.108</td> <td>12:30</td> <td>160</td>	7	.5 sec +X	.108	12:30	160
9 $.5 \sec + X$ $.108$ $15:50$ $120$ 10 $.5 \sec + X$ $.108$ $17:50$ $30$ 11 $.5 \sec + X$ $.108$ $18:20$ $100$ 12 $.5 \sec + X$ $.108$ $20:00$ $20$ 13 $.5 \sec + X$ $.108$ $20:20$ $70$ 14 $.5 \sec + X$ $.108$ $21:30$ $40$ 15 $.5 \sec + X$ $.108$ $22:10$ $60$ 16 $.5 \sec + X$ $.108$ $23:10$ $40$ 17 $.5 \sec + X$ $.108$ $23:50$ $70$ 18 $.5 \sec + X$ $.108$ $25:50$ $90$ 20 $.5 \sec + X$ $.108$ $27:20$ $50$ 21 $.5 \sec + X$ $.108$ $30:40$ $40$ 23 $.5 \sec + X$ $.108$ $31:20$ $120$ 24 $.5 \sec + X$ $.108$ $33:50$ $110$ 26 $.5 \sec + X$ $.108$ $35:40$ $20$ 27 $.5 \sec + X$ $.108$ $35:40$ $20$ 28 $.5 \sec + X$ $.108$ $37:00$ $50$ 29 $.5 \sec + X$ $.108$ $37:50$ $50$ 30 $.5 \sec + X$ $.108$ $38:40$ $30$	8	.5 sec +X	.108	15:10	40
10.5 sec +X.108 $17:50$ $30$ $11$ .5 sec +X.108 $18:20$ $100$ $12$ .5 sec +X.108 $20:00$ $20$ $13$ .5 sec +X.108 $20:20$ $70$ $14$ .5 sec +X.108 $21:30$ $40$ $15$ .5 sec +X.108 $22:10$ $60$ $16$ .5 sec +X.108 $23:10$ $40$ $17$ .5 sec +X.108 $23:50$ $70$ $18$ .5 sec +X.108 $25:50$ $90$ $20$ .5 sec +X.108 $25:50$ $90$ $20$ .5 sec +X.108 $27:20$ $50$ $21$ .5 sec +X.108 $28:10$ $150$ $22$ .5 sec +X.108 $31:20$ $120$ $24$ .5 sec +X.108 $31:20$ $30$ $25$ .5 sec +X.108 $33:50$ $110$ $26$ .5 sec +X.108 $35:40$ $20$ $27$ .5 sec +X.108 $36:00$ $60$ $28$ .5 sec +X.108 $37:50$ $50$ $29$ .5 sec +X.108 $37:50$ $50$ $30$ .5 sec +X.108 $38:40$ $30$	9	.5 sec +X	.108	15:50	120
11.5 sec +X.10818:2010012.5 sec +X.10820:002013.5 sec +X.10820:207014.5 sec +X.10821:304015.5 sec +X.10822:106016.5 sec +X.10823:104017.5 sec +X.10823:507018.5 sec +X.10825:005020.5 sec +X.10825:509020.5 sec +X.10828:1015021.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:203025.5 sec +X.10833:5011026.5 sec +X.10835:402027.5 sec +X.10837:005028.5 sec +X.10837:505030.5 sec +X.10838:4030	10	.5 sec +X	.108	17:50	30
12.5 sec +X.108 $20:00$ $20$ $13$ .5 sec +X.108 $20:20$ $70$ $14$ .5 sec +X.108 $21:30$ $40$ $15$ .5 sec +X.108 $22:10$ $60$ $16$ .5 sec +X.108 $23:10$ $40$ $17$ .5 sec +X.108 $23:50$ $70$ $18$ .5 sec +X.108 $25:50$ $90$ $20$ .5 sec +X.108 $25:50$ $90$ $20$ .5 sec +X.108 $28:10$ $150$ $20$ .5 sec +X.108 $28:10$ $150$ $21$ .5 sec +X.108 $30:40$ $40$ $23$ .5 sec +X.108 $31:20$ $120$ $24$ .5 sec +X.108 $33:50$ $110$ $26$ .5 sec +X.108 $35:40$ $20$ $27$ .5 sec +X.108 $36:00$ $60$ $28$ .5 sec +X.108 $37:50$ $50$ $29$ .5 sec +X.108 $37:50$ $50$ $30$ .5 sec +X.108 $38:40$ $30$	11	.5 sec +X	.108	18:20	100
13.5 sec +X.10820:207014.5 sec +X.10821:304015.5 sec +X.10822:106016.5 sec +X.10823:104017.5 sec +X.10823:507018.5 sec +X.10825:005019.5 sec +X.10825:509020.5 sec +X.10827:205021.5 sec +X.10828:1015022.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:5011026.5 sec +X.10835:402027.5 sec +X.10835:402028.5 sec +X.10837:005029.5 sec +X.10837:505030.5 sec +X.10838:4030	12	.5 sec +X	.108	20:00	20
14.5 sec +X.108 $21:30$ $40$ $15$ .5 sec +X.108 $22:10$ $60$ $16$ .5 sec +X.108 $23:10$ $40$ $17$ .5 sec +X.108 $23:50$ $70$ $18$ .5 sec +X.108 $25:00$ $50$ $19$ .5 sec +X.108 $27:20$ $50$ $20$ .5 sec +X.108 $27:20$ $50$ $21$ .5 sec +X.108 $28:10$ $150$ $22$ .5 sec +X.108 $30:40$ $40$ $23$ .5 sec +X.108 $31:20$ $120$ $24$ .5 sec +X.108 $33:50$ $110$ $26$ .5 sec +X.108 $35:40$ $20$ $27$ .5 sec +X.108 $36:00$ $60$ $28$ .5 sec +X.108 $37:50$ $50$ $29$ .5 sec +X.108 $37:50$ $50$ $30$ .5 sec +X.108 $38:40$ $30$	13	.5 sec +X	.108	20:20	70
15.5 sec +X.10822:106016.5 sec +X.10823:104017.5 sec +X.10823:507018.5 sec +X.10825:005019.5 sec +X.10825:509020.5 sec +X.10827:205021.5 sec +X.10828:1015022.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:5011026.5 sec +X.10835:402027.5 sec +X.10836:006028.5 sec +X.10837:005029.5 sec +X.10837:505030.5 sec +X.10838:4030	14	.5 sec +X	.108	21:30	40
16.5 sec +X.10823:104017.5 sec +X.10823:507018.5 sec +X.10825:005019.5 sec +X.10825:509020.5 sec +X.10827:205021.5 sec +X.10828:1015022.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:5011025.5 sec +X.10835:402027.5 sec +X.10835:402028.5 sec +X.10837:005029.5 sec +X.10837:505030.5 sec +X.10838:4030	15	.5 sec +X	.108	22:10	60
17.5 sec +X.10823:507018.5 sec +X.10825:005019.5 sec +X.10825:509020.5 sec +X.10827:205021.5 sec +X.10828:1015022.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:5011025.5 sec +X.10835:402027.5 sec +X.10835:402028.5 sec +X.10837:005029.5 sec +X.10837:505030.5 sec +X.10838:4030	16	.5 sec +X	.108	23:10	40
18.5 sec +X.10825:005019.5 sec +X.10825:509020.5 sec +X.10827:205021.5 sec +X.10828:1015022.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:203025.5 sec +X.10833:5011026.5 sec +X.10835:402027.5 sec +X.10837:005028.5 sec +X.10837:505029.5 sec +X.10838:4030	17	.5 sec +X	.108	23:50	70
19.5 sec +X.10825:509020.5 sec +X.10827:205021.5 sec +X.10828:1015022.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:5011025.5 sec +X.10833:5011026.5 sec +X.10835:402027.5 sec +X.10836:006028.5 sec +X.10837:505030.5 sec +X.10838:4030	18	.5 sec +X	.108	25:00	50
20       .5 sec +X       .108       27:20       50         21       .5 sec +X       .108       28:10       150         22       .5 sec +X       .108       30:40       40         23       .5 sec +X       .108       31:20       120         24       .5 sec +X       .108       33:20       30         25       .5 sec +X       .108       33:50       110         26       .5 sec +X       .108       35:40       20         27       .5 sec +X       .108       36:00       60         28       .5 sec +X       .108       37:00       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	19	.5 sec +X	.108	25:50	90
21.5 sec +X.10828:1015022.5 sec +X.10830:404023.5 sec +X.10831:2012024.5 sec +X.10833:203025.5 sec +X.10833:5011026.5 sec +X.10835:402027.5 sec +X.10836:006028.5 sec +X.10837:005029.5 sec +X.10837:505030.5 sec +X.10838:4030	20	.5 sec +X	.108	27:20	50
22       .5 sec +X       .108       30:40       40         23       .5 sec +X       .108       31:20       120         24       .5 sec +X       .108       33:20       30         25       .5 sec +X       .108       33:50       110         26       .5 sec +X       .108       35:40       20         27       .5 sec +X       .108       36:00       60         28       .5 sec +X       .108       37:50       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	21	.5 sec +X	.108	28:10	150
23       .5 sec +X       .108       31:20       120         24       .5 sec +X       .108       33:20       30         25       .5 sec +X       .108       33:50       110         26       .5 sec +X       .108       35:40       20         27       .5 sec +X       .108       36:00       60         28       .5 sec +X       .108       37:00       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	22	.5 sec +X	.108	30:40	40
24       .5 sec +X       .108       33:20       30         25       .5 sec +X       .108       33:50       110         26       .5 sec +X       .108       35:40       20         27       .5 sec +X       .108       36:00       60         28       .5 sec +X       .108       37:00       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	23	.5 sec +X	.108	31:20	120
25       .5 sec +X       .108       33:50       110         26       .5 sec +X       .108       35:40       20         27       .5 sec +X       .108       36:00       60         28       .5 sec +X       .108       37:00       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	24	.5 sec +X	.108	33:20	30
26       .5 sec +X       .108       35:40       20         27       .5 sec +X       .108       36:00       60         28       .5 sec +X       .108       37:00       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	25	.5 sec +X	.108	33:50	110
27       .5 sec +X       .108       36:00       60         28       .5 sec +X       .108       37:00       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	26	.5 sec +X	.108	35:40	20
28       .5 sec +X       .108       37:00       50         29       .5 sec +X       .108       37:50       50         30       .5 sec +X       .108       38:40       30	27	.5 sec +X	.108	36:00	60
29.5 sec +X.10837:505030.5 sec +X.10838:4030	28	.5 sec +X	.108	37:00	50
30 .5 sec +X .108 38:40 30	29	.5 sec +X	.108	37:50	50
	30	.5 sec +X	.108	38:40	30

TABLE 5-X.- MANEUVER TABLE FOR TYPICAL FLYAROUND SEQUENCE

TABLE 5-XI.- DEORBIT REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES

(a) Applicable maneuvers

- 1. Shaping (SPS-1)
- 2. Deorbit (SPS-2)

(b) Definition of REFSMMAT

[X]	XIX	XIY	XIZ	[x]
Y	= YIX	YIY	YIZ	У
Z SPACECRAFT PLATFORM STABLE MEMBERS	ZIX	ZIY	ZIZ	Z <sub>ECI</sub> (Mean of 1950

(c) REFSMMAT components

XIX = +.46843281	XIY =44162421	XIZ = +.76520503
YIX = +.54711378	YIY =53505759	YIZ =64372347
ZIX = +.69371262	ZIY = +.72019540	ZIZ =00901984

(d) Target load for SPS-1 maneuver

	[Propulsion system									:	S	PS	5	gui	ida	and	ce	:	e	cte	eri	na.	1 /	AV ]		
t <sub>rc</sub> ,	hr:	ni	n::	sec	с,	DI	RT			÷										•		•				16:58:21.0
$\Delta V_{\mathbf{x}},$	fps				•				•									•			•			•	•	-256.0
$\Delta V_{v}$ ,	fps		•								•			•	•	•	•	•		•		•				0.0
$\Delta V_{7}$ ,	fps						•				•					•		•		•	•					65.0
Mass	, lb																	•						•		28 149.0
								,							-											

### (e) Gimbal angles at t<sub>TG</sub>

IGA,	deg											•											•	182.6
MGA,	deg							•	•		•	•	•	•	•		•	•	•			•		358.9
OGA,	deg	•	•		•	•	•	•	•	•						•	,	•	•	•	•	•		359.5

#### (f) Target load for SPS-2 maneuver

[Propulsion system: SPS; guidance: external  $\Delta V$ ]

t <sub>TG</sub> ,	hr:n	nir	1:5	sec	;,	DI	RT	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	20:00:00.0
ΔV <sub>x</sub> ,	fps			•			•		•	•					•		•	•		•		•	•		-187.9
$\Delta V_{v}$ ,	fps		•				•							÷	•						•		•		0.0
ΔV <sub>7</sub> ,	fps			•					•		•		•								•				47.4
Mass	, lb																				•				27 420.0

## (g) Gimbal angles at t<sub>IG</sub>

IGA,	deg					•																	•		•	179.6
MGA,	deg		•	•	•	•	•	•	•			•	•	•		•	•			•		•	•	•	•	358.9
OGA,	deg	•	•	•	•	•		•	•	•	÷	•	•	•	•	•	•	•	•	•	•	•	٠	•	٠	0.0

## TABLE 5-XII.- SL-2 (400 000 FT) ENTRY STATE VECTOR AND

TARGET LOCATION FOR SPS DEORBIT MANEUVER

Earth-fixed position	
Geodetic latitude, deg	N
Longitude, deg	W
Inertial velocity vector	
Velocity, fps	8
Flight-path angle, deg	6
Azimuth angle, deg	0
Target location	
Geodetic latitude, deg	N
Longitude, deg	W
Guidance erasable load quantities	
Ladpad	5
Lodpad	5



+X



### AERODYNAMIC COEFFICIENTS AT TRIM ANGLE OF ATTACK AS A FUNCTION OF MACH NUMBER

		Contraction of the second s	Contrastence and the local data in the second se	Constanting of the local day in the loca
MACH NO.	<b>α</b> , DEG	сL	с <sub>D</sub>	L/D
.40 .70 .90 1.10 1.20 1.35 1.65 2.00 2.40 3.00 4.00 10.00 29.50	167.33 164.86 162.25 155.69 155.86 154.70 153.99 154.04 154.60 155.07 156.90 157.53 160.76	.24055 .25789 .31291 .48094 .46707 .54999 .53988 .52417 .49809 .46971 .43265 .42010 .37814	.85371 .98831 1.06956 1.17941 1.16495 1.28716 1.27525 1.28908 1.25930 1.23632 1.22913 1.23945	.28177 .26094 .29256 .40778 .40094 .42729 .42336 .40662 .39553 .37993 .35199 .33894
			1.50254	. 2 /0 /1

Center of gravity location in body coordinates

$$X_{cg} = 1039.45$$
 in.  
 $Y_{cg} = -0.21$  in.  
 $Z_{cg} = 5.86$  in.  
Weight = 12 809.62 lb

	DRT, deorbit reference time, hr:min:sec	G.m.t., time from midnight May 29, hr:min:sec	Entry time from 400 000 ft, min:sec	Geodetic latitude, deg	Longitude, deg	Altitude, ft
Undocking	15:37:59	12:41:00	-287:16			
Separation	16:36:59	13:40:00	-228:16			
SPS-1 ignition	16:58:21	14:01:22	-206:54			
SPS-2 ignition	20:00:00	17:03:01	-25:15	11.78 N	93.19 E	1 382 209
Entry interface	20:25:15	17:28:16	0:00	44.01 N	156.92 W	400 000
0.05g begin P64	20:27:39	17:30:40	2:24	38.82 N	146.01 W	282 428
Enter S-band communi- cations blackout	20:27:59	17:31:00	2:44	38.01 N	144.63 W	267 144
Begin final phase steering P67	20:28:11	17:31:12	2:56	37.52 N	143.82 W	258 265
Exit S-band communi- cations blackout	20:31:23	17:34:24	6:08	30.08 N	133.31 W	172 575
Maximum load factor	20:32:35	17:35:36	7:20	28.14 N	131.29 W	142 452
Guidance termination	20:34:39	17:37:40	9:24	26.97 N	130.12 W	56 150
Drogue parachute deployment	20:35:34	17:38:55	10:19	26.94 N	130.09 W	23 500
Main parachute deployment	20:36:16	17:39:17	11:01	26.94 N	130.09 W	10 500
Landing	20:41:03	17:44:04	15:48	26.94 N	130.09 W	0

#### TABLE 5-XIV.- SL-2 SEQUENCE OF EVENTS FROM UNDOCKING TO LANDING



Figure 5-1. - Phase-plane launch window for northerly SL-2 launch (early rendezvous case, M = 5 through 8 only).



Figure 5-2, - Relative motion of SL-1/SL-2 in S-IVB curvilinear coordinate system from separation through first phasing maneuver.



۶

E

.



(a) Lift-off through 5 hours.

Figure 5-3. - SL-1/SL-2 time line from lift-off through rendezvous.





(b) 5 hours through 10 hours.

Figure 5-3. - SL-1/SL-2 time line from lift-off through rendezvous - Concluded.



.

Figure 5-4. - SL-1/SL-2 ground traces from lift-off through rendezvous.



Figure 5-5.- SL-1/SL-2 rendezvous orbital geometry.



ŗ

Figure 5-6. - Relative motion of CSM in SWS curvilinear coordinate system from insertion to rendezvous.



Figure 5-7. - CSM range and range rate to SWS from 300 n. mi. to rendezvous.





Figure 5-8. - Skylab orbital assembly ground traces for SL-1/SL-2 (CSM revolutions 6 through 77, SWS revolutions 20 through 91).



(b) CSM revolutions 13 through 19.

Figure 5-8. - Continued.



8

(c) CSM revolutions 20 through 26.



(d) CSM revolutions 27 through 33.



(e) CSM revolutions 34 through 40.



(f) CSM revolutions 41 through 47.

Figure 5-8. - Continued.



.

8

(g) CSM revolutions 48 through 54.



(h) CSM revolutions 55 through 61.

Figure 5-8. - Continued.



.

1

-

Figure 5-8. - Continued.

<sup>(</sup>i) CSM revolutions 62 through 68.



(j) CSM revolutions 69 through 77.

Figure 5-8. - Concluded.





. .



Figure 5-10.- SL-1/SL-2 U.S. EREP lighting conditions.

Pass no.	Rev no.	Track no.	Date	Geographic region	Darkness					Attitude mode transition Z-LV	Beta angle, deg	Begin data pass, G.m.t., d:hr:min:sec	End data pass, G.m.t., d:hr:min:sec
1	58/59	58	May 4	U.S.							-21.9	124:17:48:17	124:18:10:34
2	72/73	1	May 5	U.S.						//	-24.6	125:17:08:56	125:17:27:51
3	87/88	16	May 6	U. S.						<b></b> - //	-27.1	126:18:00:30	126:18:19:14
4 :	114/115	43	May 8	Night/dawn U. S.							-30.4	128:14:39:00	126:15:10:08
5	132/133	61	May 9	U. S.	///X//X/.						-31.7	129:20:47:30	126:20:57:14
6	157/158	15	May 11	U.S.	///////////////////////////////////////						-32.1	131:14:27:14	131:14:43:55
7	171/172	29	May 12	U.S.	///////////////////////////////////////						-31.6	132:13:42:38	132:14:01:02
8	172/173	30	May 12	U.S.	(//////////////////////////////////////						-31.5	132:15:17:37	132:15:37:01
9	205/206	63	May 14	Japan - U.S.							-28.3	134:21:37:00	134:22:04:20
10	247/248	34	May 17	U.S.			•				-20.8	137:19:48:52	137:20:01:06
11	261/262	48	May 18	U.S.							-17.7	138:19:06:01	138:19:20:13
12	275/276	62	May 19	U.S S. America	<i>\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\</i>						-14.3	139:18:22:11	139:18:50:45
13	303/304	19	May 21	U.S S. America						<b></b> \$	-6.9	141:16:57:47	141:17:23:36
14	361/362	6	May 25	U.S S. America							+10.4	145:17:17:14	145:17:44:44
					20 60	100	140	180	220	260 3	00		
						Angula	ar position a	bout orbital	noon, deg				

.

Figure 5-11. - SL-1/SL-2 EREP pass information.





Figure 5-12.- SL-1/SL-2 operational trajectory EREP passes showing S190 swath.



4

## (b) Pass 2.

Figure 5-12.- Continued.





Figure 5-12.- Continued.



.

(d) Pass 4.

Figure 5-12.- Continued.


(e) Pass 5.

Figure 5-12.- Continued.



(f) Pass 6.

Figure 5-12.- Continued.



# (g) Pass 7.

Figure 5-12.- Continued.



(h) Pass 8.

Figure 5-12.- Continued.



(i) Pass 9.

Figure 5-12.- Continued.



.

1

.







(k) Pass 11.

Figure 5-12.- Continued.

4









## (m) Pass 13. Figure 5-12.- Continued.





Figure 5-12.- Concluded.

0° radar elevation angle at AOS and LOS xxxxx Limited capability (see table 5-VIII)





(a) 12 hours to 17 hours.

Figure 5-13. - End of mission sequence for SL-1/SL-2 SPS deorbit.



(b) 17 hours to 19 hours 30 minutes.

Figure 5-13. - End of mission sequence for SL-1/SL-2 SPS deorbit - Concluded.



Figure 5-14.- Relative motion of the CSM for a typical flyaround sequence.







Figure 5-16. - CM maneuver envelope from an SPS deorbit for SL-1/SL-2.

.

ŧ

1

.

108

.



Figure 5-17.- Low-speed entry corridor for SL-1/SL-2.



Figure 5-18.- Altitude and range profile for SL-1/SL-2 entry.



Figure 5-19.- Program 67 DSKY displayed CMC commanded bank angle, cross-range error, and down-range error time histories for SPS deorbit.



Figure 5-20.- Program 67 DSKY displayed CMC commanded bank angle, inertial velocity, and load factor time histories for SPS deorbit.



.

ŧ

(b) CMC commanded bank angle and EMS range-to-go versus inertial velocity.

Inertial velocity, V,, fps

Figure 5-21. - SL-1/SL-2 SPS EMS parameters.



#### APPENDIX - TRAJECTORY PLANNING CONSIDERATIONS

#### A-1.0 SELECTION OF SKYLAB LIFT-OFF TIMES

The guidelines which most significantly affect the selection of SL-1 lift-off times are

a. The highly desirable requirement for daylight in the end-of-mission recovery areas for all CSM missions (section 3.2.2b)

b. The highly desirable requirement for daylight in the launch abort recovery areas (section 3.2.2a).

The end-of-mission lighting limits are

- a. Land no earlier than civil sunrise
- b. Land not later than 2 hours prior to civil sunset.

For launch abort, there must be 3 hours of daylight remaining in the mode II abort recovery area to allow for aircraft access and collar attachment. The mode II

abort area local time is 3<sup>h</sup>20<sup>m</sup> later than Cape time. Whenever the lighting limits are satisfied for the mode II abort area, the mode III discrete point abort recovery area will be within acceptable limits. The aircraft access time for the mode III area is 1 hour rather than 3 hours (mode II), which favors the sunset limit. Also, the sunrise limit is less restrictive for mode III than mode II since the mode III time zone is an hour later. In fact, the launch abort sunrise limit is set in the launch site area. Therefore, CSM lift-off cannot occur any earlier

than civil sunrise at KSC nor later than a KSC time corresponding to  $6^{h}20^{m}$  prior to civil sunset in the abort recovery area,  $50^{\circ}N$  latitude.

For May 1, the earliest possible CSM launch is 4:51 a.m. e.s.t. and the latest is 1:37 p.m. e.s.t. This, then, sets the launch limits of the SL-1 on the previous day (April 30) to be between 5:15 a.m. to 2 p.m. e.s.t. These time limits will vary with the season of the year. For example, the limits for a CSM launch at a summer solstice are 4:30 a.m. to 2:40 p.m. e.s.t.; CSM launch limits at a winter solstice are 6:25 a.m. to 10:20 a.m. e.s.t.

In choosing the exact time of SL-1 lift-off, there is a further mandatory ground rule to be applied which is to provide SL-1 with a 1.5-hour launch window (section 3.2.1b). The effect of this ground rule is to bias back 1.5 hours from the latest time at which a nominal SL-1 lift-off can be planned, i.e., 2 p.m. -  $1^{h}30^{m}$  = 12:30 p.m. e.s.t. In real time, the function of SL-1 launch window is to allow 1.5 hours slip-time for SL-1 lift-off. If the entire window is used, the next-day launch of SL-2 will still be ensured nominal lighting conditions.

The earliest that SL-1 can be launched and retain the highly desirable lighting in the abort recovery area is 5:15 a.m. e.s.t. However, if the end-of-mission recovery passes are restricted to the nominal descending Atlantic or ascending Pacific, a 5:15 SL-1 launch will result in unacceptable lighting at the end of SL-2 and marginal lighting at the end of SL-3. Considering the three mandatory ground rules of 90  $\pm$  6 day launch-to-launch centers, early rendezvous phasing and end-of-mission lighting in the prime recovery area, the earliest SL-1 launch advisable is 10:15 a.m.

For the final selection of SL-1 lift-off time there is little to recommend one time over any others within the interval of 10:15 a.m. to 12:30 p.m. e.s.t. However, 12:30 p.m. was selected since it does yield slightly better abort lighting conditions for SL-3. It also offers an improvement in SL-2 EREP opportunities of approximately 20 percent.

The current SL-2, SL-3, and SL-4 lift-off and landing schedule shown in figure A-1-1 is valid for the 12:30 p.m. e.s.t. SL-1 launch. SL-2 is launched the day following SL-1. Subsequent groups of launch opportunities within the abort recovery constraint are days 174 to 199 and then days 236 to 256. Since the mandatory 90 ± 6 day launch cycle ground rule carries a higher priority than the abort lighting ground rule, the entire group of days available for SL-3 launch is completely outside the abort recovery lighting limit. Days 302 to 314 furnish excellent launch and recovery lighting conditions for SL-4.

Figure A-1-1 can be used in a similar manner to estimate the CSM launch and recovery sequences for cases where the SL-1 is launched at a time between 5:15 a.m. and 12:30 p.m. e.s.t.



Figure A-1-1. - Launch opportunities and available recovery opportunities for 5:15 a.m. e.s.t. and 12:30 p.m. e.s.t. SL-1 lift-off times on April 30, 1973.

#### A-2.0 CONTROLLED-ORBIT ANALYSIS

The Skylab orbit of 233.8-n. mi. mean altitude (93.236-min period) is designed to provide a repeating groundtrack, which is an advantage in scheduling many groundrelated activities such as launch window planning, Flight Control pad message preparation, EREP operations, aircraft truth site support, and alternate recovery planning for weather avoidance. Small translational SM-RCS trim burns are performed while docked with the SWS to counteract the effects of drag or dispersions and maintain the reference location of the groundtrack pattern. The trim burns are all inertial orbital period adjustments performed with the +X SM-RCS thrusters. No separate attitude maneuvers are needed for the trim burns because the trims are scheduled when the OA in the nominal solar inertial mode arrives at the desired local horizontal attitude. That is, posigrade maneuvers (denoted as PM for posigrade at midnight) are scheduled at orbital midnight and retrograde maneuvers (RN, for retrograde at noon) at orbital noon.

The 5-day (71-revolution) repeating orbit was selected because of minimum impact to the current planning. The mean altitude of the nominal Skylab orbit was lowered by approximately 2 n. mi. The 4- and 6-day repeating orbits would require a -11 n. mi. or a +5-n. mi. altitude adjustment, respectively. In addition, the 4-day repeating orbit would encounter more drag and the resultant pattern would cover a smaller portion of the earth within the instrument swaths. The 6-day repeating orbit results in fewer repeating passes during the days available for EREP and requires an altitude which taxes the available SM-RCS for backup deorbit.

Once a repeating pattern is established, the effects of drag can be negated to within 2-n. mi. cross-range error by adding 0.5 fps every 20 days.

Location of the reference pattern is established at insertion of the SWS. For convenience, the initial pattern chosen was the one resulting from the descending nodal parameter,  $\theta$ , of 153.25° used in the Preliminary Reference Trajectory generated by Marshall Space Flight Center (MSFC). In subsequent planning it may be determined that some other reference location is more optimum. To relocate the pattern in orbit, a l-fps trim will cause approximately a lo-sec/day difference in orbital period, which results in a 2-n. mi./day change in cross range measured at 25°N latitude.

In this document, the trim burns were performed to maintain a repeating pattern during the EREP passes. The last trim burn on SL-2 and SL-3 are designed to control the groundtrack pattern during the EREP passes on the subsequent missions, SL-3 and SL-4, respectively. These EREP passes occur relatively late in each of these missions. If, for any reason, it becomes important to set up the repeating pattern earlier in the missions, the controlling trim burns can be redesigned. Likewise, any error in the estimated drag (or venting effects) will result in slightly different trim burns.

In the event of an SL-1 insertion dispersion equivalent to approximately 3 fps  $(3\sigma)$ , the trim 1 correction for SL-2 could be as great as 4 to 4.5 fps. If needed, this maneuver would be performed at either  $22^{h}23^{m}$  or  $23^{h}09^{m}$  CSM g.e.t. depending on whether the SL-1 dispersion was retrograde or posigrade, respectively. Trim 1 is scheduled allowing time to activate the workshop and gain access to the TACS control panel for the maneuver. Trim 1-PM or trim 1-RN will return a dispersed orbit trace to the reference location; then, a coupled trim 2-RN or trim 2-PM, respectively, is required to establish the repeating period of 93.236 minutes.

#### A-3.0 CONTINGENCY SM-RCS DEORBIT AND ENTRY FOR SL-2

In this section, events are described which would be applicable if the SPS deorbit maneuvers could not occur. The discovery of some system failure just before the first SPS deorbit maneuver is assumed which would prevent the SPS from being used to deorbit the CSM. The attitude is selected to minimize  $\Delta V$ .

In this case, two SM-RCS burns will be performed to deorbit the CSM. Reasons for employing a two-impulse deorbit are as follows.

a. The probability of quad failure caused by overheating is lessened.

b. The burn is more efficient and the capture is more certain when the arc of the burn is shortened by splitting the burn and over-laying the components.

c. Backup deorbit planning is simpler because it employs the same basic philosophy as the primary deorbit.

Reference 32 discusses the Skylab end-of-mission sequencing which ensures that two RCS burn opportunities will occur. The RCS savings is approximately 10 fps over the one-step method. This is the primary backup deorbit scheme. Schemes have been developed for both deorbiting with a disabled SM-RCS and completing SPS burns with the SM-RCS. These schemes are discussed in reference 36.

In an SM-RCS propellant-critical situation a hybrid deorbit maneuver could replace the previously mentioned second SM-RCS burn. The hybrid deorbit maneuver consists of a planned SM-RCS four-quad burn pitch-engine burn to complete the deorbit burn as shown in figure A-3-1. The AV obtainable from the CM-RCS deorbit burn is limited to 80 fps, thus ensuring sufficient CM-RCS propellant remains for a guided entry. To ensure atmospheric capture, a lift-vector-down attitude is maintained until an aerodynamic load factor of 1.0g is reached. No separate discussion will be provided for this alternate deorbit maneuver since the trajectory and subsequent entry will be similar to the SM-RCS deorbit maneuver and entry.

#### A-3.1 SL-2 SM-RCS Deorbit

The alinement, undocking, flyaround, and separation will occur as in the SPS mode. The first burn will occur May 29,  $15^{h}21^{m}12^{s}$  G.m.t.  $(18^{h}18^{m}11^{s}$  DRT). The total AV is 251.8 fps, and the burn lasts 570.0 seconds. The burn is targeted to lower perigee to 90 n. mi. The second burn occurs at  $16^{h}55^{m}28^{s}$  G.m.t.  $(19^{h}52^{m}27^{s}$  DRT). The AV applied is 111.3 fps, and the burn lasts 246.6 seconds. This burn is targeted for the SM-RCS target line. Table A-3-I gives the REFSMMAT, target loads, and gimbal angles for the two SM-RCS deorbit maneuvers. After the second RCS shutdown the CSM begins a 29.5-minute coast to entry interface. CM/SM separation is designed as in the SPS deorbit case. Figure A-3-2 shows the end-of-mission time line for the SL-2 SM-RCS deorbit.

#### A-3.2 SL-2 Entry Following SM-RCS Deorbit

Entry interface will occur at 46.71°N geodetic latitude and 165.72°W longitude. The entry state vector for the backup SM-RCS deorbit is given in table A-3-II. The subsequent ground trace and pertinent geographic locations of various entry events are shown in figure A-3-3.

Following a nominally controlled entry (lift vector down manually to 1.0g, and then guided entry), CM landing will occur at  $28^{d}00^{h}47^{m}04^{s}$  g.e.t. (May 29,  $17^{h}46^{m}40^{s}$  G.m.t., or  $20^{h}43^{m}39^{s}$  DRT) at 26.44°N geodetic latitude and 130.14°W longitude. The CM maneuver envelope for this recovery area is shown in figure A-3-4.

Figure A-3-5 shows the velocity-load factor profile along with CMC-commanded bank angle and the EMS-computed range-to-go as a function of EMS velocity that can be expected for the EMS during the nominal guided entry. The maximum load factor experienced for this trajectory was 3.2g. The CM position in the entry corridor is shown in the nominal SPS deorbit figure, 5-17. TABLE A-3-I.- DEORBIT REFSMMAT, TARGET LOAD, AND GIMBAL ANGLES

```
(a) Applicable maneuvers
```

Shaping (RCS-1)
 Deorbit (RCS-2)

(b) Definition of REFSMMAT

X		XIX	XIY	XIZ	[X]	
Y	=	YIX	YIY	YIZ	Y	
Z	SPACECRAFT PLATFORM STABLE MEMBERS	ZIX	ZIY	ZIZ	[z]	ECI(Mean of 1950)

(c) REFSMMAT components

XIX = +.46843281	XIY =44162421	XIZ = +.76520503
YIZ = +.54711378	YIY =53505759	YIZ =64372347
ZIX = +.69371262	ZIY = +.72019540	ZIZ =00901984

(d) Target load for RCS-1 maneuver

[Propulsion system: SPS; guidance: external  $\Delta V$ ]

t <sub>IG</sub> ,	hr:n	nir	1:5	ec	;,	DI	RΤ	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	18:18:11.0
ΔV <sub>X</sub> ,	fps	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		,	•	•	•	•		-251.8
۵V <sub>Y</sub> ,	fps	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	0.0
۵v <sub>z</sub> ,	fps	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•		•	2.7
Mass,	, lb	•	•	•	•	•	•	•	•	•		•	•	•	•	÷	•	÷	•	•	•	÷		•		28 149.0

## (e) Gimbal angles at t<sub>IG</sub>

IGA,	deg	•		•	•	•								•		•	•		•			•	•			201.2
MGA,	deg	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•		•	•	359.9
OGA,	deg	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	÷	•	•	359.7

## (f) Target load for RCS-2 maneuver

### [Propulsion system: SPS; guidance: external $\Delta V$ ]

t <sub>IG</sub> ,	hr:	niı	1:8	seq	с,	D	RT	••			•	•	•	•		•	,	•		•	•	•				19:52:27.0
∆v <sub>x</sub> ,	fps	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•		-111.3
∆v <sub>y</sub> ,	fps	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•		0.0
∆v <sub>z</sub> ,	fps	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•		•				1.8
Mass,	1b	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•				27 339.0
									(8	;)	(	Gir	nba	al	aı	ngl	Les	58	at	t.	IG					
IGA,	deg			•	•						•	•								•						197.4
MGA,	deg	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•		•	•	•				0.0
OGA,	deg	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	0.0

TABLE A-3-II.- SL-2 ENTRY (400 000 FT) STATE VECTOR AND TARGET

### LOCATION FROM A SM-RCS DEORBIT MANEUVER

Earth-fixed position	
Geodetic latitude, deg	46.71 N 165.72 W
Inertial velocity vector	
Velocity, fps	25 958.5 -1.167 110.88
Target location	
Geodetic latitude, deg	26.44 N 130.14 W
Guidance erasable load quantities	
Ladpad	0.25 0.225



\*  $\Delta V$  limited to 80 fps



#### 0° radar elevation angle at AOS and LOS xxxxx: Limited capability (see table 5-VIII)



(a) 12 hours to 17 hours.

Figure A-3-2, - End of mission sequence for SL-1/SL-2 SM RCS deorbit.



C

(b) 17 hours to 19 hours 30 minutes.

Figure A-3-2, - End of mission sequence for SL-1/SL-2 SM RCS deorbit - Concluded.



Figure A-3-3. - SL-1/SL-2 entry ground trace for SM RCS deorbit maneuver.



Figure A-3-4. - CM maneuver envelope from a SM RCS deorbit for SL-1/SL-2.



(a) Load factor versus inertial velocity.



6

(b) CMC commanded bank angle and EMS range-to-go versus inertial velocity.

Figure A-3-5. - SL-1/SL-2 RCS EMS parameters.

## REFERENCES

9

.

<ol> <li>Moore, Ronny H.; and Reini, William A.: Skylab Mission Trajectory Tapes. MSC IN 72-FM-131, May 12, 1972.</li> <li>Skylab Operational Data Book, Vol. II - Mission Mass Properties, Revision Oct. 1972.</li> <li>Orbital Mission Analysis Branch; and Flight Performance Branch: Skylab Revision erence Trajectory. MSC IN 72-FM-143, June 7, 1972.</li> </ol>	B, ef- zvous 70. '1. ;urn
<ol> <li>Skylab Operational Data Book, Vol. II - Mission Mass Properties, Revision Oct. 1972.</li> <li>Orbital Mission Analysis Branch; and Flight Performance Branch: Skylab Revision erence Trajectory. MSC IN 72-FM-143, June 7, 1972.</li> </ol>	B, ef- zvous 70. 71. ;urn
<ol> <li>Orbital Mission Analysis Branch; and Flight Performance Branch: Skylab Re erence Trajectory. MSC IN 72-FM-143, June 7, 1972.</li> </ol>	ef- zvous 70. 71. ;urn
	zvous 70. 71. Jurn
4. Catterson, A. D., M.D.: Medical Directorate Position Regarding Pre-Render and Docking Phases of Skylab Missions. MSC memo DA-70-M190, Apr. 1, 19	l.
5. Mission Requirements: Skylab Mission SL-1/SL-2. I-MRD-001D, Apr. 30, 19	urn
6. Moore, V. V.: Skylab 1 (SA-513) Launch Vehicle Reference Trajectory. Sat Engineering Report (Boeing) 5-9409-H-197, May 14, 1971.	
7. Hardage, O. M., Jr.: Skylab Insertion Vectors and Sequence of Events for SL-1, -2, and -3. MSFC memo S&E-AERO-MF-79-72, Apr. 25, 1972.	
<ol> <li>Skylab Mission, SL-1 Attitude Timeline and Vent Schedule. NASA document no. 71-MPP-1, Jan. 3, 1972.</li> </ol>	
<ol> <li>Shaffer, P. C.: Workshop Activation Review of July 8, 1971, Data Priority Coordination. MSC memo KA(71-S-29), July 16, 1971.</li> </ol>	r
<ol> <li>Condon, S. P.: Skylab Mission CSM Launch and Recovery Opportunities for S Orbital Inclination of 50° and a Circular Altitude of 235 n. mi. MSC me 70-FM64-109, Sept. 15, 1970.</li> </ol>	SL-1 mo
<pre>ll. Shaffer, P. C.: Skylab Data Priority Review of February 17, 1972. MSC me KA(72-S-3), Feb. 22, 1972.</pre>	mo
12. Kenyon, E. J.: Logic for Earth Orbital AEG with Jacchia Dynamic Atmospher MSC IN 70-FM-166, Oct. 29, 1970.	'es.
13. Mathematical Physics Branch: RTCC and MOPS Requirements for: Modified 19 Jacchia Atmosphere Model. MSC IN 70-FM-202, Jan. 26, 1971.	970
14. Kranz, E. F.: Skylab Operations Timebase. MSC memo FC54(72-46), Apr. 12,	1972.
15. Bennett, W. J.: Meeting on Skylab Real-Time Targeting. MSC memo FM13(72- Apr. 14, 1972.	168),
16. Preliminary Skylab Prelaunch Targeting and Rendezvous Mission Techniques. MSC no. 04389, June 15, 1971.	
<pre>17. Crafts, J. L.: SL-2 (206) Launch Window Performance Data. MSFC memo S&amp;E-AERO-MFP-143-72, Sept. 14, 1972.</pre>	
18. Crafts, J. L.: Optimization of Target Node for a 50° Inclination Orbit. MSFC memo S&E-AERO-MFP-159-72, Oct. 5, 1972.	
- 19. Shaffer, P. C.: Skylab Mission Techniques Review of October 18, 1972. Data Priority Coordination. MSC memo KA(72-S-24), Oct. 24, 1972.
- 20. Wharton, T. J.: Skylab 2 Launch Vehicle Preoperational Flight Trajectory. Chrysler TN-AP-71-499, Apr. 1, 1971.
- 21. Fraley, C. W.; and Williamson, M. L.: SL-2 CSM/S-IVB Nominal Separation and Relative Motion. MSC memo 70-FM37-153, Oct. 26, 1970.
- 22. Skylab Operational Data Book, Volume III CSM Performance Data. May 1970.
- 23. Shaffer, P. C.: Skylab Mission Techniques Review of November 1, 1972. Data Priority Coordination. MSC memo KA(72-S-25).
- 24. Flight Software Branch: Station Characteristics for Apollo Mission Support. May 1967 (updated Feb. 25, 1972).
- 25. Everett, R. K.: Request for Radiation Analysis and Recommendations on Skylab EVA Operations. MSC memo 72-FD37-129, July 5, 1972.
- 26. SIM-1 Preliminary Skylab Flight Plan. MSC CPD document dated Nov. 15, 1972.
- 27. Skylab Program Operational Data Book, Volume 1 Experiments Performance Data. Revision 4. Oct. 1972.
- 28. Mission Requirements Document: EREP Investigation DTO Section. Document no. 1-MRD-001E, Jan. 17, 1972.
- 29. Skylab Mission Requirements Document Appendix B Earth Resources Requirements. 1-MRD-001, joint MSC/MSFC document dated Dec. 1972.
- DeAtkine, D. D.; and Kilbourn, M. B.: Analysis of the Effects of Skylab Groundtrack Shifts on EREP Site Contacts for SL-2. MSC memo FM22(72-254), Nov. 20, 1972.
- Benney, A. H.: Selection of Deorbit Attitude and AV for the Earth Orbital Missions Planned for the Apollo Applications Program. MSC memo 68-FM64-138, Apr. 30, 1968.
- 32. Benney, A. H.: RCS Completion for SPS Deorbits. MSC memo FM64(71-74), June 25, 1971.
- 33. Hill, O.; and Griffith, D. J.: RCS and SPS Target Lines for the Low Speed Reentry Corridor. MSC memo 67-FM53-168, May 9, 1968.
- 34. Flight Performance Branch: Skylab Entry Corridor and Target Line Definitions. MSC IN 72-FM-238, Sept. 28, 1972.
- 35. Nelson, D. A.: Recommended SPS Propellant Budgeting Philosophy for Skylab. MSC memo FM21(72-102), May 16, 1972.
- 36. Benney, Alexie H.: Summary of Skylab Deorbit Analyses. MSC IN 72-FM-92, Apr. 11, 1972.
- 37. Rippey, J. O.: Skylab Entry Checklist, Revision A. CPD document dated June 21, 1972.
  NASA — MSC