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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 70-FM-15

February 16, 1970

**RTCC REQUIREMENTS FOR APOLLO 14:
XYZT AND FREE-RETURN MODES
OF THE TRANSLUNAR MIDCOURSE
CORRECTION PROCESSOR**

Lunar Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

The Flight Software Branch concurs with the above recommendations.

J. C. Stokes
James C. Stokes, Jr., Chief,
Flight Software Branch

Enclosure

Addressees:

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- ~~PM Library~~
- ~~PM/J. Hoskins (5)~~
 - ~~S. James (2)~~
 - ~~P. Hoffbeins~~
- ~~PM Library~~
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Mission Planning and Analysis Division
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

IN REPLY REFER TO 70-FMS4-37

Feb. 5, 1970

MEMORANDUM TO: See list below

FROM : FMS/Chief, Lunar Mission Analysis Branch

SUBJECT : RTCC requirements for Apollo 14 (H-3): XYEF and free-return modes of the translunar midcourse correction processor

The enclosed MSC Internal Note No. 70-FM-15 presents the requirements for computing options 1, 2, and 3 in the Translunar Midcourse Correction Processor. Option 1 is the X, Y, Z, T mode; option 2 is the free-return, fixed-orbit mode; option 3 is the free-return, free-orbit mode. The major changes included in this document are:

1. The weight on the post-midcourse flight path angle in TIMC has been changed to 6%.
2. In option 2, backward integration is used in lunar orbit to model IOI and DOI geometry.
3. In options 2 and 3, provision is made for computing plane changes ("bootstrap" photography) from a circular parking orbit following the first pass over the landing site.

This internal note supersedes MSC Internal Note No. 69-FM-289.

Ronald L. Barry
Ronald L. Barry

APPROVED BY:

John P. Mayer
John P. Mayer
Chief, Mission Planning
and Analysis Division

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Quentin A. Holmes and Kenneth T Zeller

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PROJECT APOLLO

RTCC REQUIREMENTS FOR APOLLO 14: XYZT AND FREE-RETURN
MODES OF THE TRANSLUNAR MIDCOURSE CORRECTION PROCESSOR

By Quentin A. Holmes and Kenneth T. Zeller
Lunar Mission Analysis Branch

February 16, 1970

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved: Ronald L. Berry
Ronald L. Berry, Chief
Lunar Mission Analysis Branch

Approved: John P. Mayer
John P. Mayer, Chief
Mission Planning and Analysis Branch

RICC REQUIREMENTS FOR APOLLO 14: XYE AND
FREE-RETURN MODES OF THE TRANSLUNAR
MIDCOURSE CORRECTION PROCESSOR

By Quentin A. Holmes and Kenneth T. Zeiler

1.0 SUMMARY

The purpose of this note is to document the formulation of the Apollo 14 translunar midcourse correction processor for the Real-Time Computer Complex (RTCC). The processor contains several midcourse correction and alternate lunar mission strategies. The options available in the program and the logic necessary for implementation are described in detail.

2.0 INTRODUCTION

During translunar coast phase of an Apollo mission, it is necessary that the RTCC have the capability either to correct dispersions in the nominal trajectory or to determine an alternate flight plan which is within the existent capability of the spacecraft. This capability is provided by the midcourse correction processor. The basic computation module in the program is the generalized iterator which has been documented previously in reference 1.

A number of requirements has been imposed upon the midcourse correction program. These requirements include the ability to correct a dispersed state vector to some nominal end conditions, to reoptimize a landing mission, or to generate a circumlunar flyby alternate mission.

These requirements are obtained through three computation modes.

- a. $x, y, z,$ and t targeting (XYE midcourse option)
- b. Best adaptive path (BAP) full mission reoptimization
- c. Free-return lunar flybys

One or more mission options are available under each mode. The mission options, listed below, are defined by manual entry device (MED) codes which specify the mode, type of return, lunar parking orbit (LPO) orientation constraints, and whether the mission is tied to a landing site.

1. x, y, z, and t targeting
2. Free-return, fixed LPO orientation, landing site
3. Free-return, free LPO orientation, landing site
4. Non-free-return, fixed LPO orientation, landing site
5. Non-free-return, free LPO orientation, landing site
8. Circumlunar free-return flyby specified H_{PC} and $INCL_{PR}$
- 9A. Fully optimized circumlunar flyby
- 9B. Optimized circumlunar flyby, specified $INCL_{PR}$

Each of these options can be flown in a docked or undocked configuration.

This document contains an operational flow chart (flow chart 1) delineating the above options and functional flow charts for options 1, 2, and 3. The supporting logic for these three options is described in the text. The logic for options 4 and 5 is presented in reference 2 while the logic for the flyby mode (options 8, 9A, and 9B) is presented in reference 3.

The input and output for the processor and definitions of the data table parameters are presented in tables I through III. Equations defining display parameters not presently computed by the midcourse processor are described in the appendix.

3.0 NOTATION

3.1 Abbreviations

BAF	best adaptive path
COS	consumables resulting from EROCOM based on timeline
CSM	command/service module

EECCM	electrical, environmental, and communications systems
FSB	Flight Software Branch
g_0	gravitational acceleration
g.e.t.	ground elapsed time
GF	guidance flag
G.M.T.	Greenwich mean time
I_{sp}	specific impulse
LM	lunar module
LGI	lunar orbit insertion
LPO	lunar parking orbit
M	mass
MCC	midcourse correction
MED	manual entry device
MPT	mission planning table
RCS	reaction control system (to be used in end of mission fuel reserve)
RTCC	Real-Time Computer Complex
SC	spacecraft
TEI	transearth injection
TLMC	first guess logic for ΔV , $\Delta \gamma$, $\Delta \theta$ of the midcourse maneuver

3.2 Symbols

H	height from surface
INCL	inclination
PC	CBM plane change

r	radial distance between vehicle and moon
Rtny Rng	reentry range
T	time
$\bar{\Delta V}$	characteristic velocity
V	magnitude of velocity
ψ	azimuth
γ	flight-path angle
ϕ	latitude
λ	longitude
δt	difference between the nominal and the predicted trans-lunar flight time
ΔV	scalar velocity

3.3 Subscripts

act	actual
cir	circularization burn
cont	contingency
d	desired
el	earth landing
exp	earth-moon plane
dy	dry
f	final
fr	free return
fr-rtny	reentry of free return
i	initial

ip earth impact point
 lo lunar orbit
 lof lunar orbit insertion
 lope lunar orbit plane change
 lc landing computed at earth
 lls lunar landing site
 ls lunar surface
 max maximum
 mcc midcourse correction
 min minimum
 mn mission, defined to be from the MCC to reentry
 nd node
 pl perilune
 pr powered return
 rem remaining
 rtry reentry
 t time
 te transearth (used with transearth flight time)
 tei transearth injection
 cal calibration

4.0 INPUT AND OUTPUT

Input for all midcourse modes is divided into two categories: those from the data table and those which are manually entered during the mission by a MFD. The data table contains variables which are needed to execute the different options. These variables may be target parameters used in the x, y, z, and t mode or first guesses for certain independent

variables. The table also contains parameters which change according to the nominal mission design and launch day (e.g., lunar landing site). If a WAF midcourse is transferred to the MPT, the data table is updated by the appropriate parameters. (Input updated in this way as well as those variables computed prior to TLI are referred to as current nominal.) Each time an option is to be computed, the appropriate independent and dependent variables are called from the data table. The data table and the MED quantities are defined in tables I and II, respectively.

Output from the MCC program is of three types: those displayed, those sent to the MPT, and those which update the data table. Displayed parameters, defined in reference 4 and shown in table III, are subject to revision. Output for the data table is shown in table I. WAF's are the only options that update the data table.

Only the first maneuver in a sequence is sent to the MPT. When a midcourse option is computed, only the midcourse maneuver is transferred to the MPT. The information sent to the MPT for the MCC includes the following orbital elements before and after the impulsive burn.

- a. X
- b. Y
- c. Z
- d. X
- e. Y
- f. Z
- g. Time of maneuver (G.M.T.)

The mass computation used in the trajectory computer was designed primarily to permit the iterator to optimize the mission. The mass computation described here will be called after all of the desired ΔV 's have been computed. The ΔV_{MCC} is an impulsive computation and is calculated after the integrated translunar trajectory. The ΔV_{1st} is computed based on the integrated translunar trajectory. The ΔV_{10pc} and ΔV_{1st} are impulsive calculations determined from conic trajectories. The ΔV_{01r} is computed internally by the MCC processor.

Only two types of expendables will be considered in this method of computation. These two expendables, KROM consumables and RCS propellant, will be deducted based on a timeline. This timeline will be determined by LM and PSB. The mass of the crew and their equipment that will be transferred to the LM will not be considered in computation of the ΔV_{lopc} . Results of a study showed that for a 200-fps ΔV at the LOPC there was a difference in mass of only 13 pounds between computations made with and without the crew and equipment. For a more accurate mass computation, a ΔV bias will be used for the MC, LOI, and TEI maneuvers. This bias represents the difference between an impulsive burn and integrated burn arc. The computation will be as follows.

$$T_{lopc} = T_{nd} \text{ (G.m.t.)} + T \text{ to first pass} + T \text{ from first pass to the lunar orbit plane change}$$

$$T_{cir} = T_{nd} \text{ (G.m.t.)} + T \text{ from LOI to circularization}$$

$$M_{lmc} = (M_1 - COW_t - RCS_t) / \exp \left[\frac{\Delta \bar{V}_{lmc} / g_0 * I_{sp}}{\Delta \bar{V}_{lof} + \Delta V_{lof_{cal}} / g_0 * I_{sp}} \right]$$

$$M_{lof} = (M_{lmc} - COW_t - RCS_t) / \exp \left[\frac{\Delta \bar{V}_{lof} + \Delta V_{lof_{cal}} / g_0 * I_{sp}}{\Delta \bar{V}_{cir} / g_0 * I_{sp}} \right]$$

$$M_{cir} = (M_{lof} - COW_t - RCS_t) / \exp \left[\frac{\Delta \bar{V}_{cir} / g_0 * I_{sp}}{\Delta \bar{V}_{lopc} / g_0 * I_{sp}} \right]$$

$$M_{lopc} = (M_{cir} - COW_t - RCS_t - M_{LM}) / \exp \left[\frac{\Delta \bar{V}_{lopc} / g_0 * I_{sp}}{\Delta \bar{V}_{tei} + \Delta V_{tei_{cal}} / g_0 * I_{sp}} \right]$$

$$M_f = (M_{lopc} - COW_t - RCS_t) / \exp \left[\frac{\Delta \bar{V}_{tei} + \Delta V_{tei_{cal}} / g_0 * I_{sp}}{\Delta \bar{V}_r} \right]$$

$$|\Delta V_r| = g_0 * I_{sp} * \ln \left[\frac{M_f}{M_{dy}} \right]$$

5.4 TLMC: FIRST GUESS LOGIC FOR MIDCOURSE CORRECTION

This logic is called with the time of perilune from the data table and converges to the midcourse correction position; that is, a trajectory is generated from a specified condition at the moon to the position vector for the midcourse maneuver. First guesses for the ΔV , Δy , and $\Delta \phi$ of the maneuver are then computed by calculation of the difference between the V , γ , and ψ of the current trajectory and the V , γ , and ψ of the trajectory generated by TLMC. Because it begins at the moon and propagates backward in time, this procedure is called backward iteration. The TLMC can be used with either conic or integrated propagation.

Because TLMC is a backward iterator, it requires a perilune state vector as a starting point for its trajectories to the midcourse position.

This perilune state vector is constructed based on both empirical equations and values from the data table.

The structure of TIMC is the same throughout the whole processor. The construction of the perilune state vector varies depending upon the mode which is used.

In general, the data table has two separate locations of data that are accessible to TIMC. One set of data consists of the perilune conditions for TLI planning, and the other set is composed of the LOI perilune conditions generated by the RAP modes. For convenience, the values in these locations will be distinguished by the subscripts 1 and 2 as shown below.

TLI perilune	Typical value	LOI perilune	Typical value
$H_1 (H_1 = H_1 + R_{\text{moon}})$	1850 n. mi.	$H_2 (H_2 = H_2 + R_{\text{moon}})$	60 n. mi.
ϕ_1	-2°	ϕ_2	+7°
λ_1	180°	λ_2	150°
T_1 (G.m.t. of perilune)	100 hr	T_2 (G.m.t. of perilune)	100 hr

The empirical first guess equations and the data table values associated with each mode are listed here.

a. Free-return RAP's

1. $V = [0.184 + 0.553/R_2]^{1/2}$
2. $\lambda = \text{fixed to } 180^\circ$
3. $\phi = \phi_2$
4. $\psi = \text{fixed to } 270^\circ$
5. $H = H_2$

where V is velocity at perilune, λ is longitude of perilune, ϕ is latitude of perilune, ψ is azimuth of perilune, and H is height of perilune.

b. Non-free-return BAP's

1. $V = [0.184 + 0.553/R_2]^{1/2} + [\lambda_2 - 180^\circ]13.5 \text{ fps/deg}$
 $- 0.0022 \text{ st (CORR)}$

where $\text{st (CORR)} = \delta(\Delta T) - \Sigma_2 \text{ ST(CORR)}$ is set equal to zero for midcourse maneuvers executed later than 30 hr g.e.t.

2. $\lambda = \lambda_2 - 0.025 \text{ ST(CORR)}$
3. $\phi = \phi_2$
4. $\psi = 270^\circ$
5. $H = H_2$

c. Free-return flyby modes

1. $V = [0.184 + 0.553/(R_1 + 20 \text{ n. mi.})]^{1/2}$
2. $\lambda = 180^\circ$
3. $\phi = \phi_1$
4. $\psi = 270^\circ$
5. $H = H_1$

For the flyby modes, a special equation is used for perilune height when maneuvers are executed near the moon. This equation appears in the flyby mode section.

d. XYET mode

1. $V = [0.184 + 0.553/R_2]^{1/2} + [\lambda_2 - 180^\circ]13.5 \text{ fps/deg}$
2. $\lambda = \lambda_2$
3. $\phi = \phi_2$
4. $\psi = 270^\circ$
5. $H = H_2$

In the following table, the independent and dependent variables of TLMC are shown with their respective weights and step sizes.

Independent variable	Value	Step size	Weight
Perilune velocity	Empirical equation	2^{-19}	512
Perilune azimuth	270°	2^{-19}	512
Perilune longitude	$\lambda_1, \lambda_2, 180^\circ$	2^{-19}	512
Perilune latitude	ϕ_1, ϕ_2	Fixed ^a	Fixed ^a
Perilune altitude	H_1, H_2	Fixed ^a	Fixed ^a
Perilune flight-path angle	0°	Fixed ^a	Fixed ^a
G.m.t. of perilune	T_1, T_2	Fixed ^a	Fixed ^a

Dependent variable	Minimum	Maximum	Class	Weight
X	Midcourse position -0.0657 n. mi.	Midcourse position +0.0657 n. mi.	1	--
Y	Midcourse position -0.0657 n. mi.	Midcourse position +0.0657 n. mi.	1	--
Z	Midcourse position -0.0657 n. mi.	Midcourse position +0.0657 n. mi.	1	--
γ_{mcc}^b	0°	92°	2	64

^aWhen an independent variable is given a first guess but not turned on its value remains constant during the computation.

^b γ_{mcc} is the flight-path angle of the post-midcourse trajectory. This variable is turned off in moon reference.

6.0 XYZ MIDCOURSE MODE

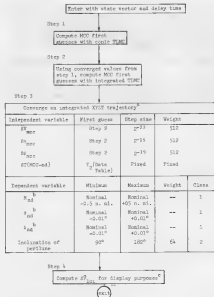
The XYZ midcourse mode will be used to correct a mildly dispersed state vector during translunar coast. The target objectives for this maneuver are generated either in the premission countdown or in earth parking orbit. These nodal targets are computed using either a free-return BAP (option 2 or 3) or a non-free-return BAP (options 4 or 5). The trajectory generated by this mode may or may not be free return.

The target objectives for the midcourse maneuver are as follows.

- a. The position vector that defines the node between the approach hyperbola plane and the desired LPO plane, where x , y , and z refer to the earth-moon plane longitude, latitude, and radius magnitude of the nodal point, respectively
- b. The nominal time of arrival (T) at this node

7-0 COMPUTATIONAL PROGRAM FOR XITE MISS

The computation procedure for this mode is as follows.



^aFor a detailed explanation of the program input in terms of independent and dependent variables, see ref. 1.

^bEarth-moon plane coordinates.

^cBeginning with the post-midcourse state vector, the trajectory is integrated to V_{nd} . The three components of the displayed LOI maneuver are as follows.

1. The value of V_{nd} from step 3
2. $|\Delta V_{LOI}|$ will be the difference between V of the approach hyperbola and V of the resultant lunar orbit at the transfer point.
3. A_{nd} will be obtained from the dot product of the angular momentum vectors of the lunar orbit and the approach hyperbola at the time of landing

8.0 BAP MIDCOURSE MODE

Excessive performance penalties associated with an XYZ correction may require reoptimization of the landing mission. This mode optimizes the mission for maximum spacecraft fuel reserves by computing the remaining CSM maneuvers (e.g., MCC, LOI, PC, and TEI) as a set.

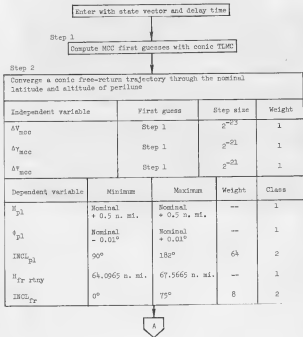
Two constraints can be applied to the reoptimization of the landing mission. The first constrains targeting of the midcourse correction so that the resultant trajectory is free return. The second constrains the approach azimuth to the lunar landing site so that the orientation of the LPO remains fixed. The alternative to these constraints is to relax the free-return requirement and to permit the approach azimuth to vary within defined bounds which enables the LPO to seek an optimum orientation. If the above constraints or alternatives are applied to the program, the landing missions proliferate into four types (options 2 through 5).

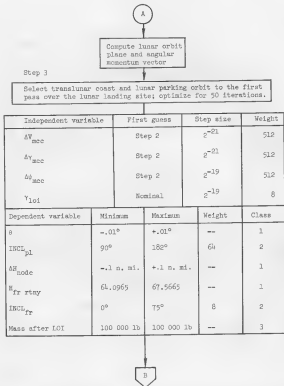
During the reoptimization process, the x , y , z , and t targeting parameters are computed for the new flight plan. The transfer of a BAP option to the NPT automatically updates the appropriate x , y , z , and t parameters in the data table (table I).

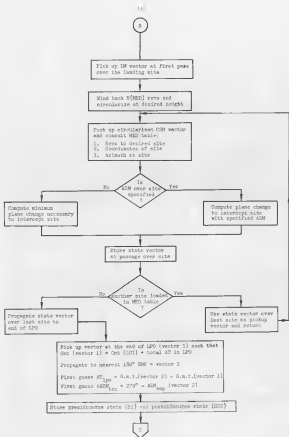
The calculation procedure for options 2 and 3 are considered in detail below. The midcourse program uses the same entry model for all BAP options. In these cases, entry is simulated by requiring the trajectory to maintain a constant flight-path angle at a constant height at entry. The desired λ_{ip} is a preflight constant and is obtained with a constant entry range and delta time from entry to landing. The accuracy in the λ_{ip} need not be iterated to greater than 0.2° . No cross range is necessary. Free-return transearth trajectories terminate on a constant flight-path angle at a constant height at entry. The transearth flight time terminates on this constant flight-path angle.

5.1 Option 2: Free-return, fixed LPO orientation

The free-return, fixed lunar orbit orientation is calculated as follows.







C

Compute transearth flight time
 $V_{te}(\text{nom}) = \Delta T_{te}(\text{nominal}) - \Delta T_{te}(\text{step 1}) + V_{te}(\text{nominal})$

Step 4

Select a coarse transearth trajectory with a specified flight time using state vector at end of LPO

Independent variable	Value	Step size	Weight	
V_{te}	Equation	2^{14}	10^{10}	
ΔT_{te}	2800 hrs	2^{13}	1	
ΔY_{te}	0°	2^{-14}	1	
$\Delta \theta_{te}$	Equation	2^{15}	1	
Dependent variable	Minimum	Maximum	Weight	Class
V_{te}	Nominal	Nominal	--	1
ΔT_{te}	-1.735 n. hr.	+1.735 n. hr.	5	2
ΔY_{te}	0°	10°	1	2
$\Delta \theta_{te}$	Equation	$\pm 0.1 \text{ hr}$	--	3

Step 5

Select a coarse transearth trajectory to land at the MFL.
 Optimize for 100 iterations.

Independent variable	Value	Step size	Weight	
V_{te}	Step 4	2^{13}	10^{10}	
ΔT_{te}	Step 4	2^{15}	1	
ΔY_{te}	Step 4	2^{15}	1	
$\Delta \theta_{te}$	Step 4	2^{15}	1	
Dependent variable	Minimum	Maximum	Weight	Class
Mass after DEI	Step 4 +6000 lb	Step 4 +6000 lb	--	3
V_{te}	Nominal	Nominal	--	1
ΔT_{te}	-1.735 n. hr.	+1.735 n. hr.	5	2
ΔY_{te}	0°	10°	1	2
$\Delta \theta_{te}$	Step 4 -0 hr	Step 4 $+0 \text{ hr}$	--	3
$\Delta \theta_{te}$	$0^{\circ} - 0.2^{\circ}(\text{MFL})$	$0^{\circ} + 0.2^{\circ}(\text{MFL})$	--	1

D

D

Compute MOC first guesses with integrated TLMC using perigee conditions from step 3

Step 6

Execute an integrated free-return trajectory to the same height and latitude of perigee as step 3

Independent variable	Value	Step size	Weight
ΔV_{MOC}	Integrated TLMC	2^{-23}	1
ΔY_{MOC}	Integrated TLMC	2^{-21}	1
$\Delta \theta_{MOC}$	Integrated TLMC	2^{-21}	1

Dependent variable	Minimum	Maximum	Weight	Class
R_{p1}	Step 3 - 0.5 n. mi.	Step 3 + 0.5 n. mi.	--	1
θ_{p1}	Step 3 - 0.01°	Step 3 + 0.01°	--	1
$INCL_{p1}$	90°	180°	GA	2
R_{T2}	61.0963	67.5663	--	1
$INCL_{T2}$	0°	90°	B	2

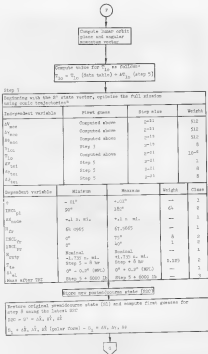
E

Store integrated MOC maneuvers
 $\Delta X_1, \Delta Y_1, \Delta Z_1$

State vector offset

Program needs
 X_1 - premaneuver state
 X_2 - postmaneuver state
 $\Delta X_1, \Delta Y_1, \Delta Z_1$ - integrated maneuver correction
 Compute state X^*
 $X^* = SOC = \Delta X_1, \Delta Y_1, \Delta Z_1$
 $SOC(\text{polar form}) - X^*(\text{polar form}) = \Delta V, \Delta Y, \Delta \theta$
 $\Delta V, \Delta Y, \Delta \theta$ are first guesses for step 7

F

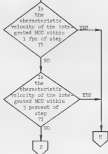


^aWithin the tabulatory computer, the time used for the state vector at the start of step 10 is biased by the difference between the time of pericenter passage in step 6 (integrated) and step 3 (orbit).

Step 6

Rewrite an integrated free-return trajectory to the same height and latitude of position as step 7				
Independent variable	First guess	Step size	Weight	
H_{acc}	Computed above	2^{*23}	1	
λ_{acc}	Computed above	2^{*23}	1	
$\Delta\lambda_{acc}$	Computed above	$2=21$	1	
Dependent variable	Minimum	Maximum	Weight	Class
H_{pl}	Step 7 - 0.5 n. mi.	Step 7 +0.5 n. mi.	--	1
λ_{pl}	Step 7 - 0.01°	Step 7 +0.01°	--	1
$INCL_{pl}$	90°	180°	64	2
H_{rv}	64,0965	67,5665	--	1
$INCL_{rv}$	0°	90°	8	2

Use integrated MCC maneuver
 $\Delta H_{pl}, \Delta \lambda_{pl}, \Delta INCL_{pl}$



H

Step 9

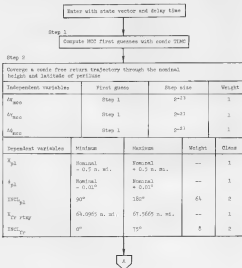
Determine the $\delta \bar{V}_{101}$ by calling the integrator and propagating from the MCC to the V_{101} from step 7. After the V_{101} is obtained, LIBRAT is called to obtain the EMF system and to calculate H_{nd} , t_{nd} , λ_{nd} , and t_{nd} .

EXIT

5.2 Option 3

The free-return, free-orbit orientation option, offers two methods. The first is to enter a specific azimuth over the lunar landing (not necessarily the nominal) by manually entering $\Delta\theta_{min} = \Delta\theta_{max}$ through the MEE to obtain the desired value. Both the select and optimized modes are solved with azimuth as a class 1 variable. The second method is to enter the desired azimuth range through the MEE. In the select mode, the azimuth is set as a class 2 variable, but in the optimized mode, the azimuth is set as a class 2 variable. A check will be made to determine whether the azimuth MEE will be a specific value or whether it will relax the azimuth range.

The free-return, free lunar orbit orientation is calculated as follows.



A

Step 3

Select translunar coast and lunar parking orbit through the LOPC maneuver, optimize for SO iterations.

Independent variable	First guess	Step size	Weight
ΔV_{msc}	Step 2	2^{-21}	510
Δy_{msc}	Step 2	2^{-21}	512
$\Delta \theta_{\text{msc}}$	Step 2	2^{-18}	510
V_{loc}	Nominal	2^{-15}	5
$\Delta \theta_{\text{loc}}$	Nominal	2^{-15}	1
ΔT_{lla}	Nominal	2^{-15}	10^{-7}

Dependent variable	Minimum	Maximum	Weight	Class
N_{pl}	40 n. wt.	100 n. wt.	5	2
ECC_{pl}	90°	120°	64	2
E_{lpe}	Nominal - 0.5 n. wt.	Nominal + 0.5 n. wt.	--	1
θ_{lla}	Nominal - 0.01 $^\circ$	Nominal + 0.02 $^\circ$	--	1
λ_{lla}	Nominal - 0.01 $^\circ$	Nominal + 0.01 $^\circ$	--	1
ϕ_{lla}	MD	MD	--	1
E_{tr}	04.0965	07.5668	--	1
ECC_{py}	0°	75°	5	2
Mass after LOPC	100 000 lb	100 000 lb	--	5

Pick up vector at the end of LPO (vector 1) such that
 G.S.T. (vector 1) = G.S.T. (LOI) + total ΔT in LPO
 Propagate to nearest 180 $^\circ$ $\Delta \theta$ = vector 2
 First guess ΔT LPO = G.S.T. (vector 2) - G.S.T. (vector 1)
 First guess $\Delta \theta_{\text{loc}}$ = $\Delta T \omega - \Delta \theta_{\text{msc}}$ (vector 2)

Store pre-iterative state (O1) and post-iterative state (O2)

B

B

Compute trans-earth flight time
 $\Delta T_{te} \text{ (new)} = \Delta T_{t1} \text{ (nominal)} - \Delta T_{t1} \text{ (step 3)} + \Delta T_{te} \text{ (nominal)}$

Step 4

Select a conic trans-earth trajectory with a specified flight time using state vector at end of LPO

Independent variables	Value	Step size	Weight	
T_{lo}	Equation above	2^{-19}	10^{-6}	
ΔV_{te1}	2800 fps	2^{-19}	1	
δy_{te1}	0°	2^{-19}	1	
$\delta \dot{y}_{te1}$	Equation above	2^{-19}	1	
Dependent variables	Minimum	Maximum	Weight	Class
H_{rnty}	Nominal - 1.735 n. mi.	Nominal + 1.735 n. mi.	--	1
$INCL_{pr}$	0°	40°	8	2
T_{te}	Equation above - 0.1 hr	Equation above + 0.1 hr	--	1

C

C

Step 5

Select a conic transearth trajectory to land at the MPL.
Optimize for 100 iterations.

Independent variable	Value	Step size	Weight	
T_{lo}	Step 4	2^{-19}	10 ⁻⁶	
ΔV_{te1}	Step 4	2^{-19}	1	
ΔY_{te1}	Step 4	2^{-19}	1	
$\Delta \phi_{te1}$	Step 4	2^{-19}	1	
Dependent variables	Minimum	Maximum	Weight	Class
Mass after TEI	Step 4 + 6000 lb	Step 4 + 6000 lb	--	3
R_{rnty}	Nominal - 1.735 n. mi.	Nominal + 1.735 n. mi.	--	1
$INCL_{pr}$	0°	40°	8	2
T_{te}	Step 4 - 8 hr	Step 4 + 8 hr	1	2
$\Delta \lambda_{el}$	0° - 0.2° (MPL)	0° + 0.2° (MPL)	--	1

D

D

Compute MCC first guesses with integrated TLMC using periscope conditions from step 3

Step 6

Execute an integrated free return trajectory to the same height and latitude of periscope as step 3

Independent variables	Value	Step size	Weight
ΔX_{acc}	Integrated TLMC	2^{-21}	1
ΔY_{acc}	Integrated TLMC	2^{-21}	1
$\Delta \theta_{acc}$	Integrated TLMC	2^{-21}	1

Dependent variables	Minimum	Maximum	Weight	Class
R_{pl}	Step 3 - 0.5 n. mi.	Step 3 + 0.5 n. mi.	--	1
θ_{pl}	Step 3 - 0.01°	Step 3 + 0.01°	--	1
$INCL_{pl}$	90°	180°	61	2
R_{pr}	61.0965	61.5665	--	1
$INCL_{pr}$	0°	90°	5	2

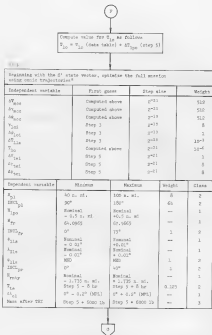
E

Store integrated MCC answers
 $\Delta X_1, \Delta Y_1, \Delta \theta_1$

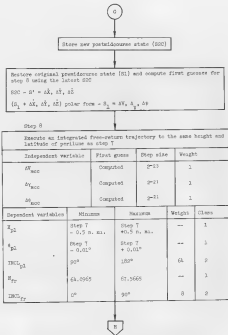
State vector offset

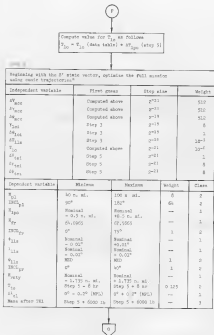
Program needs
 S_1 = preaidcourse state
 S_2 = postaidcourse state
 $\Delta X_1, \Delta Y_1, \Delta \theta_1$ = integrated aidcourse correction
 Compute state S^* $S^* = S_2 - \Delta X_1, \Delta Y_1, \Delta \theta_1$
 $S_2O(\text{polar form}) = S^*(\text{polar form}) + \Delta X, \Delta Y, \Delta \theta$
 $\Delta X, \Delta Y, \Delta \theta$ are first guesses for step 7

F

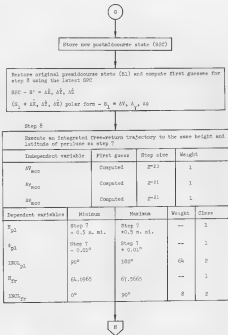


*Within the trajectory computer, the time used for the state vector at start of 170 is fixed by the difference between the time of perigee passage in step 6 (integrated) and step 5 (linear).





*Within the trajectory computer, the time used for the state vector at each of 100 is biased by the difference between the time of perigee passage in step 6 (integrated) and step 5 (assumed).



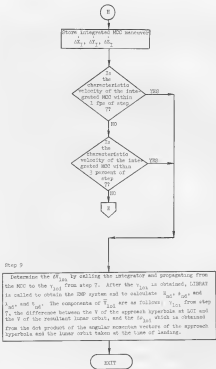


TABLE I.- INPUT/OUTPUT DATA TABLE^a WITH SPECIFIC STEP FROM WHICH
EACH VARIABLE WILL BE TAKEN TO UPDATE THE DATA TABLE

Input/output variable	Mission option											
	1	2		3		4		5		6	7	10
		Step		Step		Step		Step				
GM_{pc}	Y	$X_p Y$	P	$X_p Y$	T	$X_p Y$	G^b	$X_p Y$	G^b	Y	Y	Y
GM_{sd}	Y	X	G^c	X	9	X	5	X	6			
X_{sd}	Y	X	G^c	X	9	X	5	X	5			
t_{sd}	Y	X	G^c	X	9	X	5	X	5			
l_{sd}	Y	X	G^c	X	9	X	5	X	5			
X_{pc}	Y	$X_p Y$	T	$X_p Y$	T	$X_p Y$	G^b	$X_p Y$	5			
t_{pc}	Y	$X_p Y$	T	$X_p Y$	T	$X_p Y$	G^b	$X_p Y$	5			
V_{101}		$X_p Y$	T	$X_p Y$	T	$X_p Y$	5	X	5			
ΔV_{101}		$X_p Y$	T	$X_p Y$	T	$X_p Y$	5	X	5			
Δt_{11a}	Y	$X_p Y$	T	$X_p Y$	T	$X_p Y$	5	$X_p Y$	5			
V_{10}		$X_p Y$	T	$X_p Y$	T	$X_p Y$	5	$X_p Y$	5			
V_{11a}		T	T	$X_p Y$	T	Y	5	$X_p Y$	5			
Δt_{bd}		$X_p Y$	T	$X_p Y$	T	$X_p Y$	5	X	5			
ΔV_{bd}		$X_p Y$	T	$X_p Y$	T	$X_p Y$	5	$X_p Y$	5			
V_{1c}		$X_p Y$	T	$X_p Y$	T	$X_p Y$	5	$X_p Y$	5			
t_{11c}	P	P		P		P		P				
l_{11c}	P	P		P		P		P				
V_{12c}	P	P		P		P		P				

^aX - updated if option is set to NEW

Y - value drawn from data table

P - preflight constant

^bCall KNGTA and KNGTA to compute time from node to perilune.

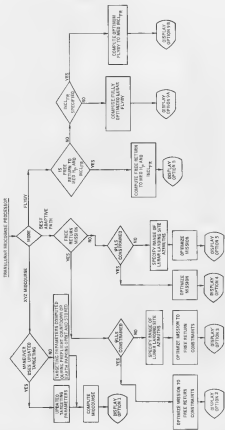
X_{pc} and t_{pc}

^cCall DUMSTA and KNGTA to compute time from perilune to the node.

X_{sd} , t_{sd} and l_{sd}

TABLE II.- MEO QUANTITIES

MEO	Mission option								
	1	2	3	4	5	6	9A	9B	
τ_{max}	X	X	X	X	X	X	X	X	
Configuration	X	X	X	X	X	X	X	X	
A_{min}			X		X				
A_{max}			X		X				
H_{pl}						X			
INCL_{pl}						X			
H_{pl} (for use by TME)						X	X	X	
Minimum g.e.t. of				X	X				
Maximum g.e.t. of				X	X				
τ_{slas}						X	X	X	
Minimum X_{pl}							X	X	
Maximum X_{pl}							X	X	
H_A first LPO		X		X					
H_C first LPO		X		X					
Beve first LPO		X		X					
H_A second LPO		X		X					
H_C second LPO		X		X					
Beve second LPO		X		X					
Site rotation second LPO		X		X					
Beve to circularization		X		X					
X_T of circularization		X		X					
Estimate of time anomaly of DOI on ellipse		X		X					



Flow Chart 1.—Operations / Five

TABLE III. - DISPLAY CHECK^a

Output	Machine options						
	L	B	S	A	D	G	T
Node	w	w	w	w	w	w	w
Return	NA	w	w	w	w	w	w
ΔZ_{sta}	NA	w	w	w	w	NA	NA
ΔZ_{sea}	NA	w	w	w	w	NA	NA
Coordinate	w	w	w	w	w	w	w
$\rho \cdot m \cdot h$ ^b	w	w	w	w	w	w	w
ΔV_{acc}	w	w	w	w	w	w	w
GM_{acc} ^b	w	w	w	w	w	w	w
K_{po}	w	w	w	w	w	w	w
$\rho \cdot D \cdot S_{int}$ ^b	w	w	w	w	w	NA	NA
ΔV_{int}	w	w	w	w	w	NA	NA
K_{sa}	w	w	w	w	w	NA	NA
SA	NA	w	w	w	w	NA	NA
$r_{A, LPO}$	NA	w	w	w	w	NA	NA
$r_{D, LPO}$	NA	w	w	w	w	NA	NA
ΔV_{LPO}	NA	w	w	w	w	NA	NA
$\rho \cdot h \cdot h_{cso}$	NA	w	w	w	w	NA	NA
ΔV_{del} ^b	NA	w	w	w	w	NA	NA
ΔV_{res}	NA	w	w	w	w	NA	NA
$\rho \cdot h \cdot h_{2a}$	NA	w	w	w	w	w	w
r_{12} ^b	NA	w	w	w	w	w	w
r_{12} ^b	NA	w	w	w	w	w	w

^aw = wanted, u = unwanted, NA = not applicable

^bInformation in the appendix ΔV_{acc} will be furnished by Pilech

Support Division and delivered to DBI

^c ΔV_{del} will be corrected by +0.5 Gpa

^dCoordinates of water loading will be Geostatic.

TABLE III.- DISPLAY OUTPUT^a - Concluded

Output	Mission options						
	1	2	3	4	5	6	7
R_{pc}	n	n	n	n	n	n	n
Az_{not}	NA	n	n	n	n	NA	NA
ΔV_{rom}^b	NA	n	n	n	n	NA	NA
STA ID ^c	w	w	w	w	w	w	w
G.m.t. V ^d	n	n	n	n	n	n	n
g.e.t. V ^e	n	n	n	n	n	n	n
CEM WT ^f	n	n	n	n	n	n	n
LM WT ^g	n	n	n	n	n	n	n

^an = number; w = word; NA = not applicable.

^bFormulation in the appendix.

^cSTA ID - Standard vector identification of the state vector used to compute the maneuver sequence.

^dG.m.t. V - G.m.t. time tag of the state vector, hr:min:sec.

^eg.e.t. V - g.e.t. time tag of the state vector, hr:min:sec.

^fCEM WT - Total CEM weight, lb.

^gLM WT - Total LM weight, lb.

REFERENCES

1. Hodge, John D.: RTCC Requirements: AS-304 Midcourse Correction Processing. Flight Control Division Memo, March 2, 1967.
2. Holmes, Quentin A.; and Zeiler, Kenneth T.: RTCC Requirements for Mission H-2 Non-free-return Modes of the Translunar Midcourse Correction Processor. MSC IN 69-FM-287, November 13, 1969.
3. Zeiler, Kenneth T.; and Holmes, Quentin A.: RTCC Requirements for Apollo 11 (Mission G) Lunar Flyby Mode of the Translunar Midcourse Correction Processor. MSC IN 69-FM-199, July 7, 1969.