

UNITED STATES GOVERNMENT

# Memorandum

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Mission Planning & Analysis Division  
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TO : See list below

DATE:

25 JUL 1968

FROM : FM/Mission Planning and Analysis Division

68-FM61-230

SUBJECT: Transmittal of detailed programming requirements

The enclosed changes to MSC Internal Note No. 68-FM-23 present additional detailed requirements for the real-time computer program to be employed in support of the Apollo missions beginning with the lunar landing mission. The changes are necessary for the computation of two additional maneuver sequences. These change sheets should be inserted into MSC Internal Note No. 68-FM-23.

*Edgar C. Lineberry*  
Edgar C. Lineberry, Chief  
Orbital Mission Analysis Branch

*John R. Mayer*  
John R. Mayer  
Chief, Mission Planning  
and Analysis Division

The Flight Software Branch concurs with the above recommendation.

*J. C. Stokes, Jr.*  
James C. Stokes, Jr., Chief  
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## Enclosure

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## CHANGE HISTORY FOR 68-FM-23

Change no.	Date	Description
1	7/15/68	Replace pages 3, 7, 12, 21, 27, 47 and 58 and add pages 42A, 42B, 62A, and 62B. The revised pages satisfy an additional RTCC requirement specified by the Flight Control Division; i.e., that a sequence be included that computes a combination circularization and plane change maneuver at a specified altitude or an input time.

File FMK

NASA - Manned Spacecraft Center  
RELEASE APPROVAL

1. Type of Document

2. Identification

68-PM-23  
Page 1 of 1 Pages

TO:

3. FROM:  
Division  
Branch Mission Planning and Analysis  
Section Orbital Mission Analysis Branch

4. Title or Subject  
LOGIC AND EQUATIONS FOR THE REAL-TIME COMPUTATION OF THE LUNAR MODULE DESCENT PLANNING TABLE

Date of Paper  
Change, July 15, 1968

5. Author(s)

By William A. Sullivan

6. Distribution

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CHANGE SHEET

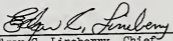
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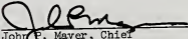
MSC INTERNAL NOTE 68-FM-23 DATED JANUARY 26, 1968  
LOGIC AND EQUATIONS FOR THE REAL-TIME COMPUTATION  
OF THE LUNAR MODULE DESCENT PLANNING TABLE

By William A. Sullivan

Change 1

July 15, 1968

  
\_\_\_\_\_  
Edgar C. Lineberry, Chief  
Orbital Mission Analysis Branch

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

Page 1 of 10  
(with enclosures)

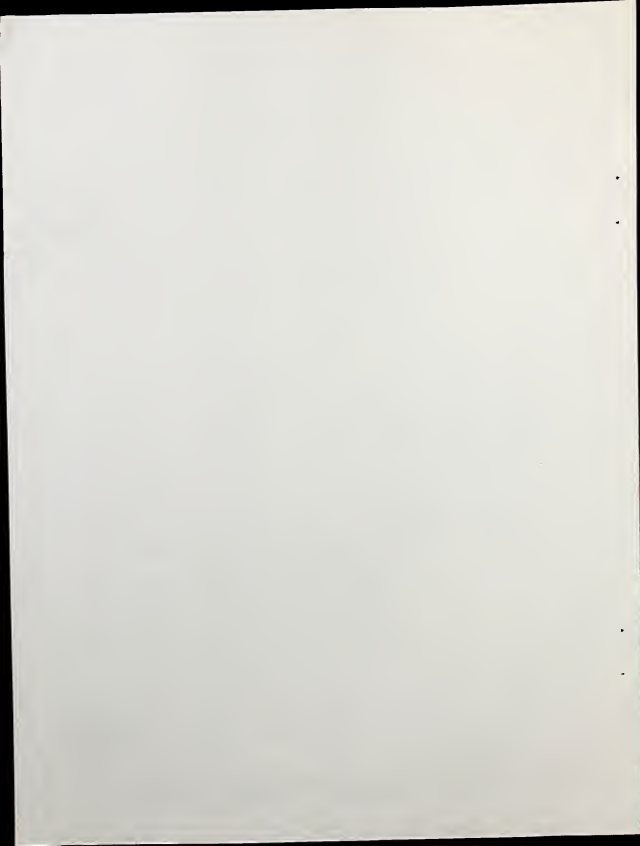
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NOTE: A black bar in the margin indicated the area of change.

After the attached enclosure, which is a replacement, has been inserted, place this CHANGE SHEET between the cover and title page and write on the cover "CHANGE 1 inserted".

**ORIGINAL DESTROYED**

DATE: 5/22/70





Mode	Maneuver	Sequence				
		1	2	3	4	5
1	1	PC	PCC	ASP	PCC	PCC
	2	DOI	DOI	CIA	DOI	DOI
	3	--	--	DOI	--	--
2	1	ASH	CIR	--	--	--
	2	DOI	DOI	--	--	--
3	1	ASH	--	--	--	--
	2	CIA	--	--	--	--
	3	DOI	--	--	--	--
4	1	DOI	--	--	--	--
5	1	PC	HO1	HO1	--	--
	2	HO1	PC	HO2	--	--
	3	HO2	HO2	PC	--	--
	4	DOI	DOI	DOI	--	--
6		Go to powered descent			--	--
7	1	PPC	--	--	--	--

These maneuver sequences are designed to give the flight controller the ability to correct a non-nominal CSM orbit after lunar orbit insertion and to place the CSM orbital plane over the LM landing site before LM lift-off. The LDPP has the capability to compute maneuvers to change the apocynthion and pericynthion heights, shift the line-of-apsides and place the CSM orbital plane over a desired landing site with or without an azimuth being specified. The processor also computes a LM DOI maneuver based on a desired landing site position. To compute these maneuvers the LDPP assumes that the vehicles are docked for all maneuvers prior to DOI and are undocked for DOI and all following maneuvers.

When computing in modes 1 through 5, the flight controller is given the option of simulating powered descent; in mode 6, however, only a powered descent simulation is available. Mode 7 is used to compute a maneuver to place the CSM orbital plane over the IM landing site at the time of IM lift-off. To compute these maneuvers, the LDPP calls three specialized subroutines. The subroutines are SAC (spacecraft apsis and circularization), CHAPLA (change spacecraft plane), and LLTPR (lunar landing time prediction routine). Flow charts for the LDPP, SAC, CHAPLA, and LLTPR are presented in appendices A, B, C, and D, respectively. After all computation is completed in the LDPP, the IM descent planning table (LDPT) is then displayed. The LDPT displays maneuvers and descent trajectory parameters. From these displayed quantities the flight controller can decide whether or not the total maneuver plan is acceptable. If the plan is acceptable, the flight controller can transfer it to the mission plan table where it becomes an integral part of the over-all mission plan.

Subroutine SAC computes a maneuver to shift the line-of-apsides and change apocynthion and pericynthion height or circularize the CSM orbit.

Subroutine CHAPLA computes a maneuver to place the CSM orbital track over a desired landing site with or without a specified azimuth.

Subroutine LLTPR (ref. 2) computes the time of the DOI maneuver based on a desired landing site and a CSM vector before the maneuver.

The LDPP uses the lunar satellite analytic ephemeris generator, ISAEG, (ref. 3) for vehicle ephemeris prediction and IM descent guidance equations of reference 3 for powered descent simulation. Several other special purpose trajectory subroutines are called. These are APPLY (ref. 4), CNODE (ref. 5), STAP, STLO, STCIR (ref. 6), TLMA (ref. 7), and LATLON (ref. 8).

## SYMBOLS FOR LDPP FLOW CHART

## Input Constants

$\pi$	3.141592...
$\mu$	lunar gravitational potential
$R_{\text{moon}}$	mean lunar radius
$\zeta_{\theta}$	angular iteration tolerance
$\zeta_t$	time iteration tolerance
$\bar{g}$	average acceleration of gravity

## Input Variables

MODE	maneuver routine flag; if
MODE = 1,	compute CSM phase change sequence
MODE = 2,	compute single CSM maneuver sequence
MODE = 3,	compute double CSM maneuver sequence
MODE = 4,	compute LM maneuver sequence
MODE = 5,	compute double Hohmann plane change CSM maneuver sequence
MODE = 6,	compute LM powered-descent trajectory
MODE = 7,	compute CSM prelaunch plane-change maneuver sequence
IDO	maneuver sequence flag; when
MODE = 1 and	
IDO = -1,	compute plane-change maneuver only
IDO = 0,	compute plane change and circularization maneuver
IDO = 1,	compute plane-change maneuver combined with the first maneuver of a CSM two-maneuver sequence to circularize the CSM orbit at an input altitude.
IDO = 2,	compute plane change and circularization maneuver at a specific altitude
IDO = 3,	compute plane change and circularization maneuver at an input time
MODE = 2 and	

IDO = 0,    compute CSM maneuver to establish an  
               apsis and an input altitude at the DOI  
               maneuver point  
 IDO = 1,    compute CSM maneuver to circularize orbit  
               at an input altitude  
 MODE = 3 and  
 IDO = -1,   compute CSM two-maneuver sequence with  
               the first maneuver performed at an input  
               time and the second maneuver performed at  
               an input altitude to circularize the orbit  
 IDO = 1,    compute CSM two-maneuver sequence with the first  
               maneuver performed at an apsis and the second  
               maneuver performed at an input altitude to cir-  
               cularize the orbit  
 MODE = 5 and  
 IDO = -1,   compute CSM three-maneuver sequence so that  
               the first maneuver is a plane change and the  
               following pair is a double Hohmann to a  
               circular orbit at an input altitude  
 IDO = 0,    compute CSM three-maneuver sequence so that  
               the first maneuver initiates a double Hohmann,  
               the second is a plane change, and the third  
               completes the double Hohmann to a circular  
               orbit at an input altitude.  
 IDO = 1,    compute CSM three-maneuver sequence so that  
               the first two maneuvers constitute a double  
               Hohmann to a circular orbit at an input  
               altitude and the third is a plane change.

$I_{PD}$

powered-descent simulation flag

IPD = 0,    simulate powered descent  
 IPD = 1,    do not simulate powered descent

$I_{AZ}$

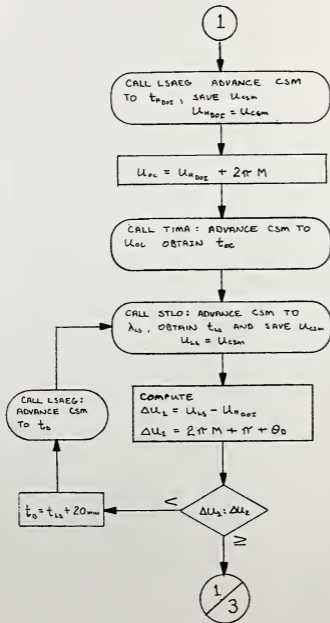
descent azimuth flag

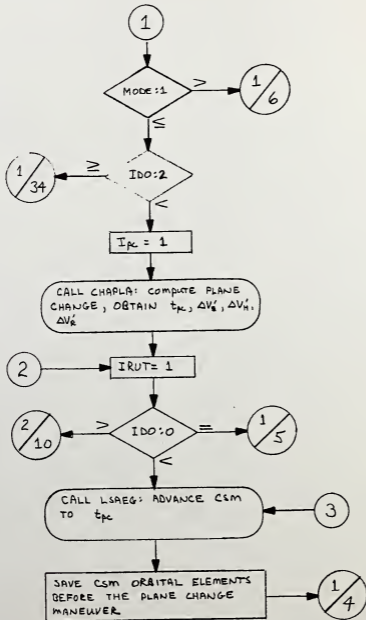
$I_{AZ}$  = 0,    descent azimuth is not specified  
 $I_{AZ}$  = 1,    descent azimuth is specified

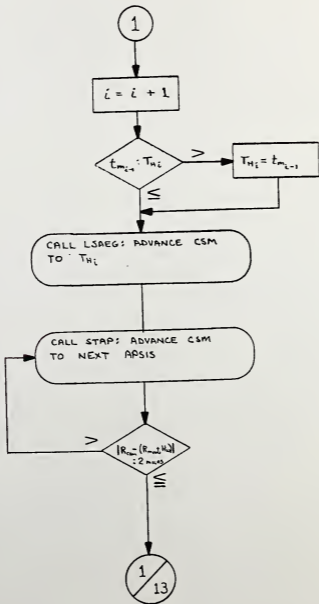
$I_{TPD}$

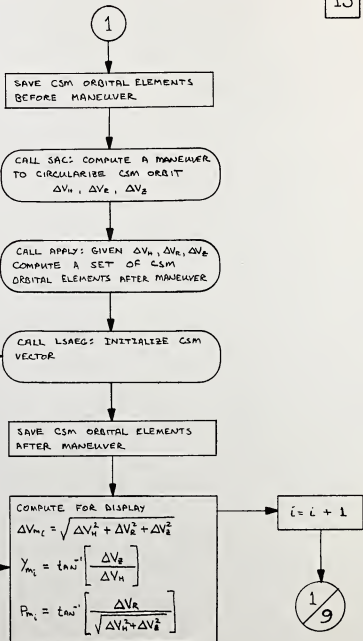
powered-descent time flag

$I_{TPD}$  = 0,    let powered descent compute time to ignite  
 $I_{TPD}$  = 1,    input time for powered-descent ignition











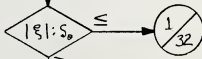
1

COMPUTE  $\hat{r}_p$ , A UNIT VECTOR THROUGH THE POINT OF CLOSEST APPROACH, WHICH IS THE PROJECTION OF  $\vec{r}_{L1}$  IN THE LM PLANE

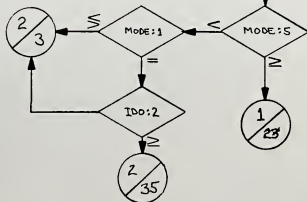
$$\hat{r}_{L1} = \frac{\vec{r}_{L1}}{|\vec{r}_{L1}|} \quad , \quad \vec{Q} = \hat{r}_{L1} \times \hat{h}_{LM}$$

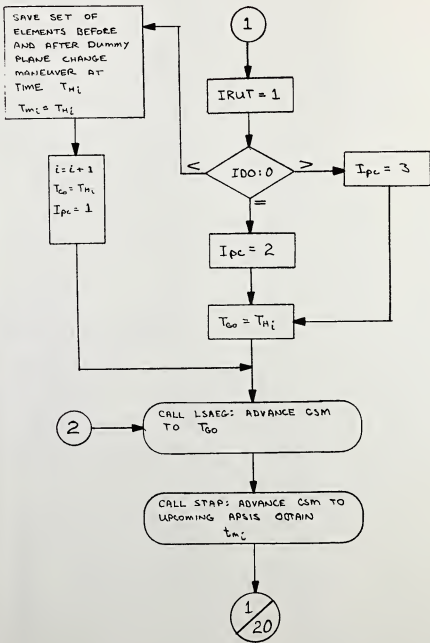
$$\hat{c} = \frac{|\vec{Q}|}{|\vec{Q}|} \quad , \quad \hat{r}_p = \hat{h}_{LM} \times \hat{c}$$

$$\hat{r}_p = \frac{\vec{r}_p}{|\vec{r}_p|} \quad , \quad \xi = \cos^{-1}[\hat{r}_p \cdot \hat{r}_{L1}]$$



CALL CHAPLA; COMPUTE NEW PLANE CHANGE MANEUVER, OBTAIN  $t_{pc}$ ,  $\Delta V'_1$ ,  $\Delta V'_R$





1

$$C_1 = \frac{R_B}{R_A} \quad , \quad C_2 = \frac{2\mu}{R_B(1+C_1)}$$

$$V_{Hn} = \sqrt{C_2} \quad , \quad V_n = \sqrt{V_{Hn}^2}$$

$$\gamma_n = \tan^{-1} \left[ \frac{R_A}{V_{Hn}} \right] \quad , \quad \alpha_n = \frac{R_B}{2 - R_B \frac{V_n^2}{\mu}}$$

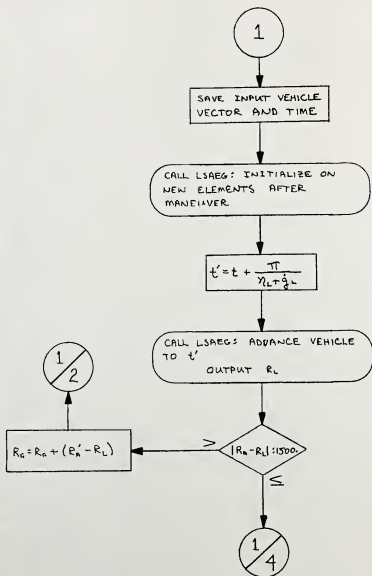
$$C_3 = \frac{R_B V_n^2}{\mu} - 1 \quad , \quad C_4 = \frac{R_B V_n \sin(\gamma_n)}{\sqrt{\mu \alpha_n}}$$

$$e_n = \sqrt{C_3^2 + C_4^2} \quad , \quad E = \tan^{-1} \left[ \frac{C_4}{C_3} \right]$$

$$\theta = 2 \tan^{-1} \left[ \sqrt{\frac{1+e_n}{1-e_n}} \tan \left( \frac{E}{2} \right) \right]$$

$$L_n = E - e \sin E \quad , \quad g_n = U_B - \theta$$

1/3



1

COMPUTE ANGULAR DISTANCE VEHICLE  
IS AWAY FROM THE POINT OF  
CLOSEST APPROACH

$$\theta = \cos^{-1} [\hat{r}_p \cdot \hat{r}_L]$$

TO DETERMINE THE SIGN ON  $\theta$ ,

$$\vec{h}_D = \hat{r}_L \times \hat{r}_p, \quad \hat{h}_D = \frac{\vec{h}_D}{|\vec{h}_D|}$$

OBTAIN THE SIGN ON THE Z  
COMPONENT OF  $\hat{h}_D$  AND  $\hat{r}_L$

$$s_1 = \frac{h_{Dz}}{|h_{Dz}|} \quad s_2 = \frac{r_{Lz}}{|r_{Lz}|}$$

SO THAT

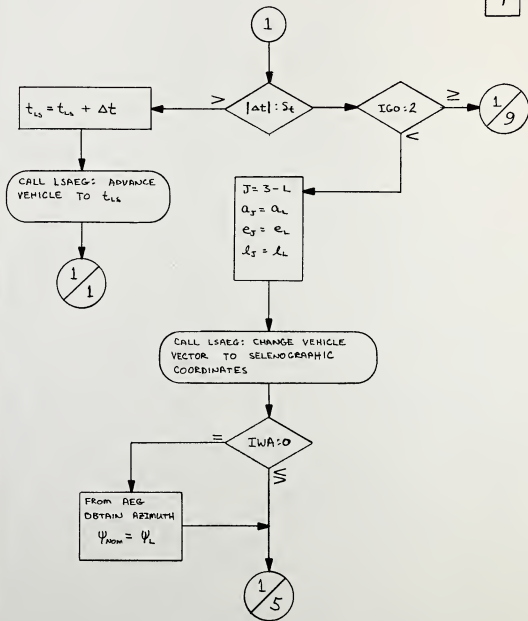
$$\theta = \theta \left[ \frac{s_1}{s_2} \right]$$

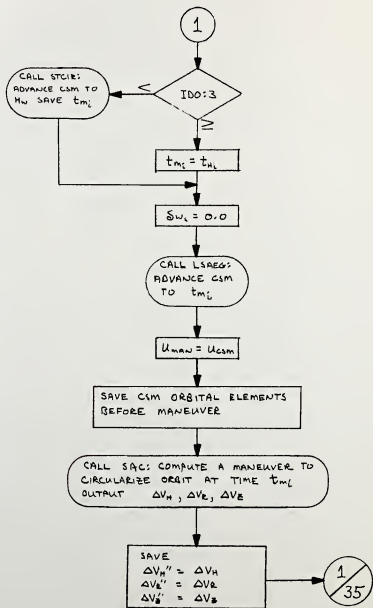
NOW COMPUTE  $\Delta t$

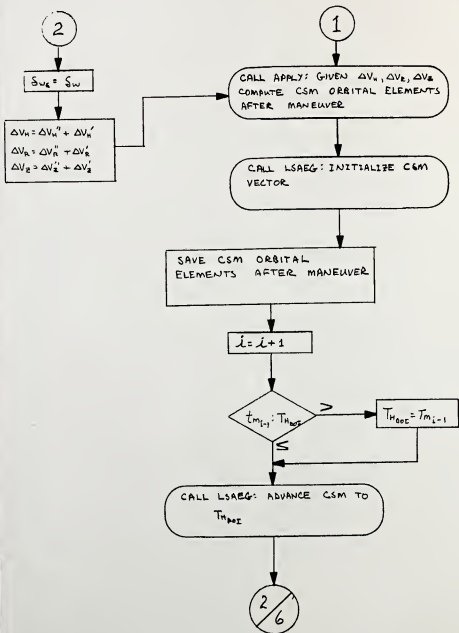
$$\Delta t = \frac{\theta}{\eta_L}$$

1

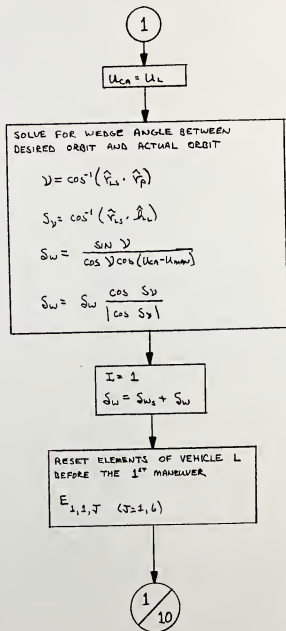
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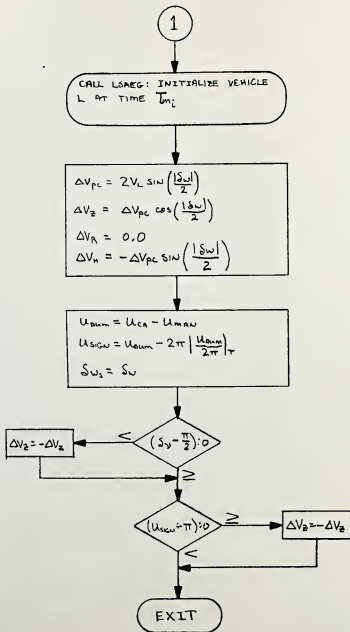












Change 1, dated July 15, 1968

(additional page)