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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-327

December 31, 1969

RTCC REQUIREMENTS
FOR MISSION H-3:
LOI TARGETING

Lunar Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

MSC INTERNAL NOTE NO. 69-FM-327

PROJECT APOLLO

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By Robert F. Wiley
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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HOUSTON, TEXAS

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RTCC REQUIREMENTS FOR MISSION M-3: LOI TARGETING

By Robert F. Wiley

1.0 SUMMARY AND INTRODUCTION

Because of experience gained from previous lunar missions, the LOI targeting logic should be updated. Several things which are now being done preflight or in real time through use of graphs should be automated. In addition, the emphasis has changed from automatic computation of solutions for a range of azimuths at the landing site to computation of solutions to achieve a specified orbit at some point past LOI.

The present LOI targeting logic computes several types of maneuvers (which are referred to as solutions to the LOI problem or just as solutions in this internal note) corresponding to a range of azimuths at the landing site, propagates in only a circular orbit, propagates with the AEG, rotates the LOI ellipse in the minimum LOI ΔV direction only, and depends on some preflight data for certain calculations. Experience has shown that it is undesirable to change azimuth, that both possible lunar orbit rotations are necessary to set up the maneuver to the second lunar orbit, that propagation in a high ellipse (e.g., the one that would be used for a DPS LOI) must be considered, that the integrator should be used to predict the lunar orbit plane (when an RTCC integrator is developed that can do this), and that as much preflight data as possible should be eliminated.

The same philosophy that was used for the present program is used in the updated program. This philosophy consists of three things. First, the functions now known are programmed, but enough information is computed and displayed and enough degrees of freedom to the problem are specified as inputs to permit the accomplishment of other functions, even though it may require much real-time effort. Second, the problem of the sensitive node between the hyperbola and the lunar orbit caused by very small plane differences is solved in the same manner. Third, because it is impossible to obtain all of the desired end conditions of the LOI burn in some cases (e.g., if the nodal altitude is less than the desired lunar orbit perilune altitude, the desired lunar orbit perilune cannot be obtained), certain end conditions are relaxed one at a time to give various solutions.

2.0 LOI SOLUTIONS

Some terminology must be defined. A positive solution is one whose perilune is rotated ahead (i.e., in the direction of motion); a negative solution is one whose perilune is rotated behind (i.e., opposite to the direction of motion). Eight solutions are computed and all attempt to obtain the same azimuth at the landing site. There are four solution types, each with a positive-negative solution. The four types are as follows.

a. Plane solutions: obtain the desired azimuth at the landing site giving up the lunar orbit perilune altitude if necessary.

b. Coplanar solutions: obtain the desired lunar orbit shape in the plane of the approach hyperbola with a pre-hyperbolic perilune impulsive point for the positive solution and a post-hyperbolic impulsive point for the negative solution.

c. Minimum δ solutions: obtain the desired lunar orbit shape and minimize the wedge angle between the actual and desired lunar orbit within an input maximum allowable δV .

d. Intersection solutions: obtain the desired azimuth at the landing site and adjust the first lunar orbit perilune altitude to obtain an intersection with a desired lunar orbit at some point past LOI.

For the intersection solutions, the amount that perilune of the first lunar orbit may be above or below the second at perilune of the first is specified by a WEP. The angle between the node and perilune of the first lunar orbit is minimized. With the lunar orbit perilune altitude equal to the nodal altitude, if the perilune altitude is less than the altitude of the second LPO minus the δh bias, no further computations are done.

Note that this logic is like the one-azimuth logic of the old program with intersection and positive-negative solutions added and with a more sophisticated method of lunar orbit propagation.

3.0 DISCUSSION OF THE LOGIC

The LOI-1 maneuver is targeted based on the following assumed trajectory profile to the landing site. All plane change is accomplished with the first burn. A second burn adjusts the inplane orbital elements such that a specified orbit occurs at the landing site. It is not always possible to meet all desired end conditions, and thus the various solutions mentioned previously are computed.

The time at the landing site is estimated from the two initial parking orbits (LPO-1 and LPO-2) and the number of revs in each. Because plane perturbations are dependent on the orientation of the orbit relative to the moon, a true anomaly at which to transfer from the hyperbola to the first LPO is entered. (This input affects only the estimated time at the landing site.) Two-body equations are used; therefore, the error in time estimate will be caused by the perturbations of the lunar orbit perilune position in inertial space.

The backward integration from the landing site is done with the integrator to obtain the inplane elements of LPO-2 used to compute intersection solutions and the plane used to determine the node between the hyperbola and LPO-1.

A maximum allowable LOI ΔV for both positive and negative solutions is entered ($\Delta V_{\text{max}+}$ and $\Delta V_{\text{max}-}$) to calculate minimum θ solutions. Unlike the old program, solutions will be computed here even if ΔV is less than ΔV_{max} .

The logic is divided into two major parts after the orbit has been backed up from the landing site and the coplanar solutions have been calculated. On one path, the LPO-1 plane and hyperbola plane are within some specified small angle of each other; on the other path, they are farther apart.

To compute solutions for small plane changes, the capability is provided to compute intersection solutions in the minimum θ solutions' planes. This capability is used when the planes of the minimum θ solutions are so close to the desired lunar orbit plane that the difference is negligible.

The nodal altitude and true anomaly for the v_{ax} and v_{an} lunar orbits are computed. The θ at the LIS to give a node at hyperbolic perilune is computed. However, no solutions are computed for these azimuths.

The flow charts at the end of this internal note give the detailed computations discussed above. There is a functional flow chart, followed by detailed flow charts.

4.0 MED INPUTS

LOI targeting will require an initialization MED to enter the quantities that normally would not change. These quantities are as follows.

a. The lunar orbit parameters at the landing site except for azimuth: ϕ , λ , R of surface, h_a , h_p , angle of perilune from the site, l_{00} (l_{00} is negative if the site is postperilune).

b. Number of revs in the first and second lunar orbits, revs 1 and revs 2. Revs 1 may have a fractional part.

c. True anomaly for transferring from the hyperbola to LPO-1, α_1

d. Altitude constraint of the intersection solutions, Δh_{bias} . Δh_{bias} is negative if LPO-2 is to be below the LPO-1 perilune. The Δh_{bias} and α_1 should revert to zero.

e. A flag to specify if plane of minimum δ nodes should be used to compute intersection solutions. This should revert to plane solutions.

The computational MED should have the following information.

a. Apolune and perilune altitudes of the first LPO

b. A maximum allowable ΔV for the positive solutions and a maximum allowable ΔV for the negative solutions

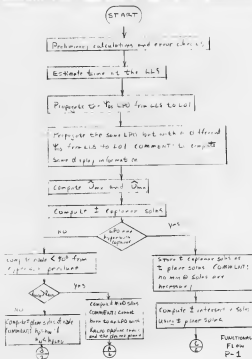
c. The maximum, desired, and minimum azimuths at the landing site

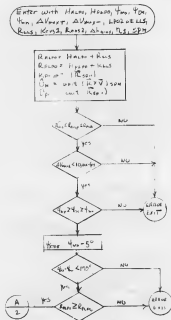
5.0 FLOW CHART NOTATION

LLS	lunar landing site
ψ_{max} , ψ_{ds} , ψ_{min}	maximum, desired, and minimum azimuths at the LLS
LPO	lunar parking orbit
h_{ALPO} , h_{PLPO}	apolune and perilune altitudes of the first LPO
ΔV_{max+}	the maximum allowable LOI ΔV for the + solution
ΔV_{max-}	the maximum allowable LOI ΔV for the - solution
revs 1, revs 2	revs in the first and second LPO's

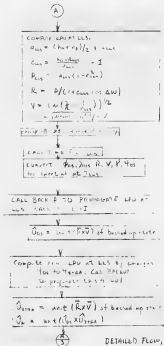
Δh_{bias}	difference between the perilune of the first LPO and the position on the second LPO
τ_1	true anomaly at which to get on the first LPO. Used only for V_{LIS} estimate
SPH	hyperbolic perilune state vector
\hat{U}_H	unit angular momentum vector to SPH
\hat{U}_{pc}	unit position vector to hyperbolic perilune
$\hat{U}_{ax}, \hat{U}_{ds}, \hat{U}_{mn}$	unit angular momentum vectors to the V_{ax}, V_{ds}, V_{mn} orbits backed up to LOI, including propagation in the first LPO
\hat{v}_H	unit vector, value redefined several times in the program
\hat{U}_H	unit ($\hat{U}_{DS} \times \hat{U}_{ATRA}$)
\hat{U}_{ATRA}	unit angular momentum vector to the LPO at the LIS made from $\psi_{ax} = 5^\circ$ backed up to LOI
ΔV_1	ΔV 's for + and - solutions
a_H, e_H	a, e of the hyperbola at perilune
\hat{U}_s	unit normal to the solution plane
\hat{U}_{pl}	unit inertial vector to the LIS LPO perilune at LOI-2 time
\hat{U}_L	projection of \hat{U}_{pl} in the \hat{U}_s + or - planes
$\eta_{ax}, \eta_{ds}, \eta_{mn}$	true anomalies of the V_{ax}, V_{ds}, V_{mn} nodes
φ_{pcyn}	computed φ at LIS to have node at hyperbolic perilune
+	denotes the positive solution
-	denotes the negative solution

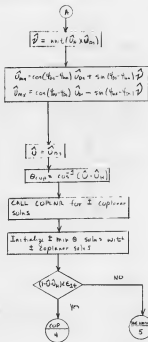
6.0 FLOW CHARTS FOR LOT TARGETING PROCESSOR





DETAILED FLOW, P-1

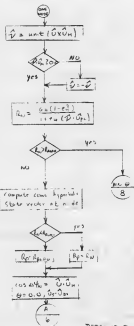




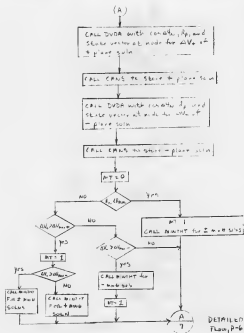
DETAILED FLOW, P-3

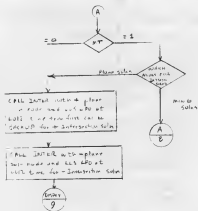


DETAILED FLOW, P-4

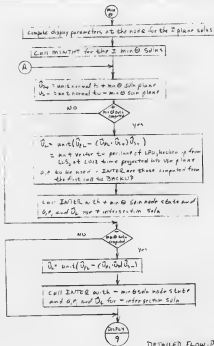


DETAILED FLOW, P-5

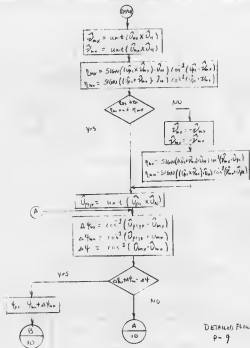


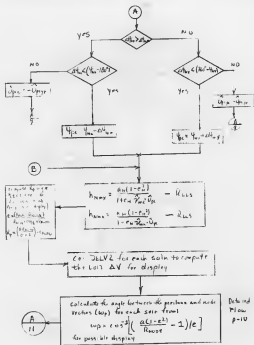


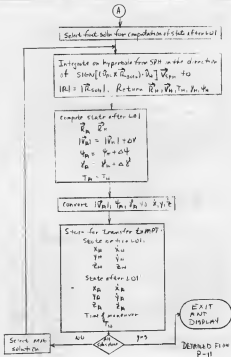
DETAILED FLOW, P-7



DETAILED FLOW, P-8



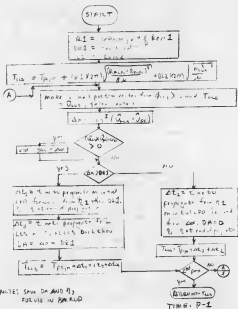




SUBROUTINE TIME

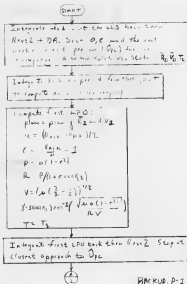
PURPOSE - TO ESTIMATE THE TIME OF TRAVEL

FUNCTION - TO ESTIMATE AND ADD THE EMPLOYEE'S TIME OF TRAVEL TO THE SUBROUTINE



Subroutine BACKUP

Purpose: To do step 4 in method 2 of the 4th
 thru 7th steps of the 2nd thru 4th paragraphs
 in an approximation to the real CPU time
 for the 1960s.



A

Compute quantities for use in computing
intersection solutions

R_{21} = optical radius of lens bounding frame

R_{22} = pinhole

U_{21} = pinhole width + air table bounding frame

R_{23} = optical radius of lens backed up to hole

R_{24} = pinhole

U_{23} = pinhole width

$$\Delta h_0 = R_{21} - R_{22}$$

$$\Delta h_p = R_{23} - R_{24}$$

$$\Delta u_p = \text{Sign}(U_{21} \times U_{23}) \cdot (R_{21} \times R_{23}) \cos^{-1}(U_{21} \cdot U_{23})$$

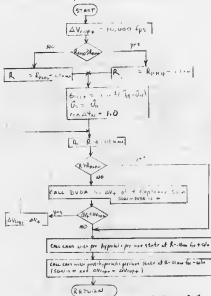
END OF SECTION

BACKUP

p-2

SUBROUTINE CODENR

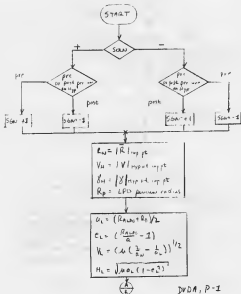
PURPOSE: to compute & explain solns, per page

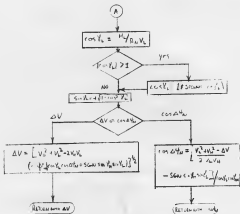


CODENR, P-1

SUBROUTINE DVDA

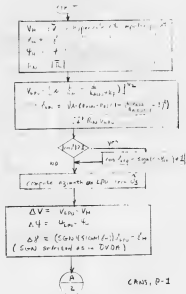
PURPOSE: to compute a maneuver ΔV in the case of
 the allowable plane change with a given ΔV

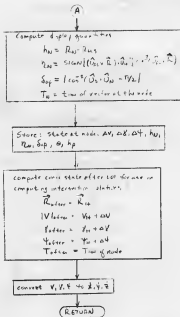




SUBROUTINE CANS

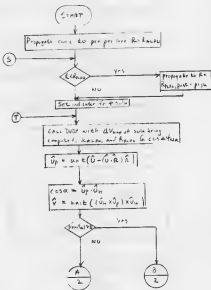
PURPOSE to make ΔV , $\Delta \phi$ at of the station and other display quantities for the station





CAND
p-2

SUBROUTINE MINTHT

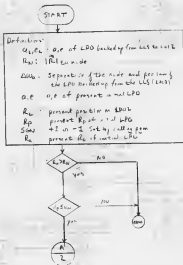
PURPOSE: to compute θ and θ - minimum @ value

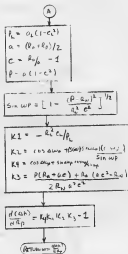
MINTHT, P-1

SUBROUTINE DHDR

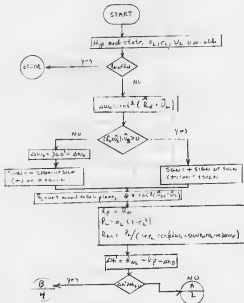
PURPOSE: To compute $d\Delta h/d\Delta p$ where Δh is the difference between a position in the second LPO and R_p of the first LPO.

COMMENT: Used in computing interstation solns

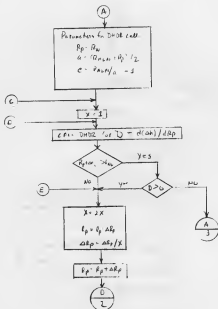




SUBROUTINE INTER

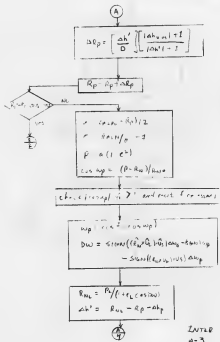
Purpose: to compute t or - intersection solns

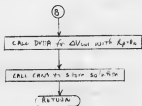
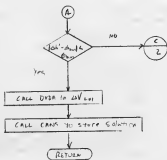
INTER, P. 1



IAC: e

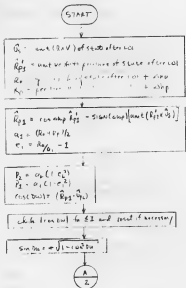
p-2

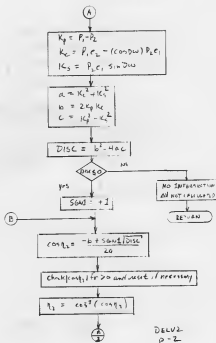


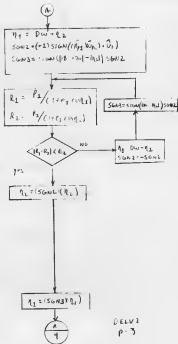


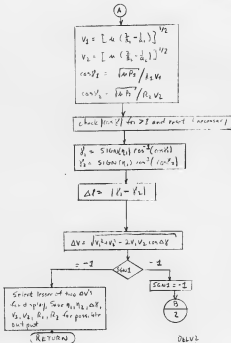
INT 10
p-4

SUBROUTINE DELV2

PURPOSE: To compute the ΔV for the maneuver after LofDELV2
P-2







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1. Type of Document

Technical Note

2. Identification

69-706-327

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Division Mission planning and analysis
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4. Title or Subject

RPOC REQUIREMENTS FOR MISSION N-3: LOI TACKLING

Date of Paper

December 31, 1969

5. Author(s)

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Memorandum

TO : See list below

DATE: Dec. 22, 1969

FROM : FMS/Chief, Lunar Mission Analysis Branch

69-FM54-320

SUBJECT: RTCC requirements for Mission M-3: LOI targeting

The enclosed WSC Internal Note No. 69-FM-327 contains detailed RTCC requirements for the LOI targeting processor for Mission M-3.

The major changes incorporated in this new targeting logic are:

1. Deletion of the automatic computation of the range of azimuths at the landing site solutions.
2. Addition of "intersection solutions", to insure intersection between the first and second lunar parking orbits.
3. Rotation of the LOI-1 ellipse, both forward and backward.
4. Incorporation of the RTCC integrator in a more sophisticated approach to the propagation of the lunar parking orbits.

Ronald L. Berry
Ronald L. Berry

APPROVED BY:

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

The Flight Software Branch concurs with the above recommendations.

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

Enclosure

cc: (See attached list)



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