MSC-03763

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 70-FM-198

December 22, 1970

SKYLAB LAUNCH WINDOW PROCESSOR

Program Development Branch
MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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SKYLAB PROGRAM

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By Jerome W. Kahanek
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HOUSTON, TEXAS

Approved: for Robert R. Rydberg
John P. Mayer, Acting Chief
Program Development Branch

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

SKYLAB LAUNCH WINDOW PROCESSOR

By Jerome W. Kahanek

1.0 SUMMARY AND INTRODUCTION

The Skylab launch window is the overlay of two separate windows: the plane window and the phase window. The plane window is centered on the lift-off time, which will provide an inplane launch with minimum payload loss by the booster. This minimum payload loss lift-off time does not coincide with the analytical inplane lift-off time but occurs some time earlier. The reason for this is that the booster does not begin steering toward the desired launch plane immediately. Therefore, if lift-off occurs at the analytical point, the booster will be drifting out of plane because of the rotational velocity of the earth; and, when steering starts, the out-of-plane movement will have to be steered out. If the booster lifts off before the analytical inplane lift-off point, then the earth's rotational velocity component that the booster has during the early part of launch before steering actually will be moving the booster toward the final desired plane. This results in a lower payload loss caused by steering into the desired launch orbit. The plane window opens and closes when the booster fuel necessary to get in plane is 700 pounds.

2.0 DISCUSSION

Subroutine LWT is used to find the analytical inplane lift-off time. This time is adjusted by an input value to determine the optimum launch lift-off time. The opening and closing of the plane window corresponding to fuel cost of 700 pounds is computed from this optimum lift-off time by adding and subtracting an input delta time. The delta times to find the optimum and 700-pound opening and closing will be determined before the mission.

The phasing window for Skylab is a function of the delta velocities of the NC1 and NCC maneuvers. The nominal Skylab rendezvous sequence is composed of four maneuvers plus terminal phase. These four maneuvers are NC1, NC2, NCC, and NSR. The phase window opening for a given M rendezvous number is defined as the lift-off time that corresponds to an NCC maneuver of 30 fps. The closing of the phase window is defined as the lift-off time corresponding to an NC1 maneuver of 30 fps. Because the phase window is a direct function of the maneuver plan, it is necessary to simulate or compute the maneuver plan for different lift-off times to find the lift-off time corresponding to the opening and closing of the phase window.

The Skylab rendezvous plan is computed using the DKI processor by means of the four-maneuver special route. To compute the lift-off time for the opening and closing of the phase window, the DKI must be called twice, for two lift-off times, to give two sets of data. These data are used to define a slope of lift-off time as a function of maneuver delta velocity. Using this slope, a linear extrapolation is used to estimate the lift-off for the opening and closing of the phase window.

The first guess at the lift-off time for the launch window is computed by first finding the inplane lift-off time using subroutine LWT. This time can be biased by an input value ΔTb to give a lift-off time to be used as the starting point to find the lift-off time corresponding to zero phase angle at insertion using subroutine GMTLOS. This zero phase angle at insertion lift-off time is then biased by an input value "BIAS" in subroutine RLOT to give the lift-off time corresponding to a desired phase angle at insertion for the planned rendezvous. After computing the Skylab rendezvous plan for this lift-off time, the lift-off time is increased by 1 minute and a new plan is generated. These two plans are then used in the linear extrapolation to determine the opening and closing of the phase window. After generation of the insertion vector in subroutine RLOT, the separation maneuver is applied to the vector at some input delta time from insertion before the DKI plan is computed.

If the phase window for more than two rendezvous numbers (M-lines) are to be computed, the launch window processor (flow chart 1) will compute only the phase windows for the first and last rendezvous numbers specified. The intermediate M-lines will be determined by linear extrapolation for display purposes. If an intermediate M-line is chosen for the rendezvous plan, the launch window should be rerun using this M-line as the first or only M-line desired.

3.0 DESCRIPTION OF SUBROUTINES USED BY SKYLAB LAUNCH WINDOW PROCESSOR

3.1 LWT

Purpose: To find the analytical inplane northerly or southerly launch time (flow chart 2)

Input: Target vector and time; λ_{LS}, launch site longitude; ϕ_{LS}, launch site latitude; NS, flag for north or south launch; DAY, day of launch; ΔTb, time bias to be added to inplane launch time

Output: TIP, time of inplane launch plus ΔTb

3.2 RLOT

Purpose: Compute insertion elements at insertion for input lift-off time or to find lift-off time corresponding to a desired phase angle or time bias past zero phase angle at insertion (flow chart 3)

Input: Target vector and time; λ_{LS}, ϕ_{LS}, R_{LS} - landing site radius; TLO, lift-off time; I is a flag, use to input TLO or compute a TLO; BIAS, delta time to bias lift-off for zero insertion phase angle; TPF, PFA, VF, γ, RINS, YS

Output: Vectors at insertion, time of insertion

3.3 GMTLOS

Purpose: Compute lift-off time corresponding to zero phase angle at insertion (flow chart 4)

Input: Target vector and time; TLO, lift-off time to start searching from; RINS, VF, γ, TPF, PFA, λ_{LS}, ϕ_{LS}, R_{LS}, MV - maneuvering vehicle

Output: TLO, lift-off time for zero phase at insertion

4.0 DEFINITIONS OF INPUT FOR THE SKYLAB LAUNCH WINDOW PROCESSOR

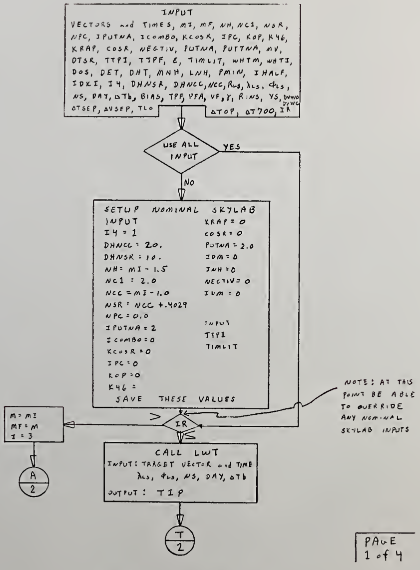
BIAS	time bias added to lift-off time corresponding to zero phase angle at insertion
COSR	phase angle desired at TPI (if input)
DAY	day of launch; 0 = day of time reference
DET	time tolerance

DHNCC	delta height desired at NCC
DHNSR	delta height desired at TPI
DHT	delta height tolerance
DOS	phase angle tolerance
DTSR	minimum delta time required between NSR and TPI
DVWO, DVWC	delta velocity for phase window opening and closing
ICOMBO	central flag to force the phase adjustment maneuver to set up a common node 90° from NC1
IDKI	flag used in subroutine TIMA to identify DKI run
IHALF	counter line or period option
	= 0 counter line option
	= 1 period option
IPC	vehicle number for plane change
IPUTNA	flag that determines how the maneuver line is defined or computed
IR	flag
	= 0 compute launch window
	= 1 compute DKI plan for input lift-off time TLO for display on launch window display
I4	flag for Skylab four-maneuver route
	= 0 regular DKI
	= 1 Skylab rendezvous route
KCOSR	control flag for phase angle at TPI
KOP	optimize maneuver line control flag
KRAP	control for initial phase angle wrapping
K46	control flag for TPI time computation

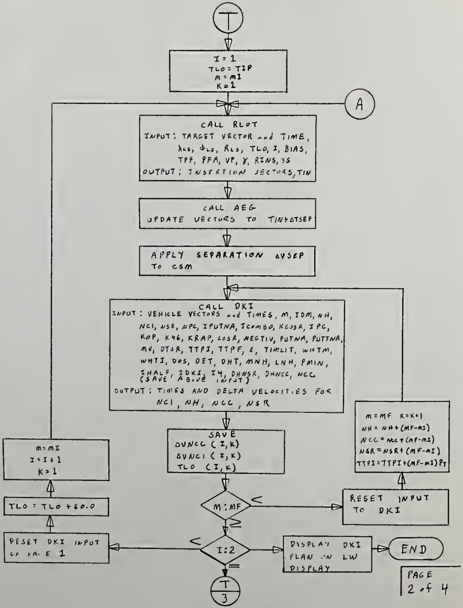
LNH	flag to relocate NH if minimum height is violated
	= 0 no
	= 1 yes
MF	final M-line or rendezvous number
MI	initial M-line or rendezvous number
MNH	flag to determine where to place NH in multiple plans
	= 0 same point
	= 1 relative to NSR
MV	maneuvering vehicle
NCC	maneuver line point for the NCC Skylab maneuver
NC1	maneuver line point for the NC1 Skylab maneuver
NEGTIV	flag that determines whether initial phase angle is negative or positive
NH	maneuver line point for the NC2 Skylab maneuver
NPC	maneuver line for the plane change maneuver
NS	flag for northerly or southerly launch opportunity
NSR	maneuver line point for the NSR Skylab maneuver
PFA	powered flight arc
PMIN	minimum height allowed in DKI plan
PUTNA	value of the initial maneuver line
PUTTNA	time of initial maneuver line
RINS	insertion radius
R_{LS}	launch site radius
TIMLIT	delta time of lighting condition for TPI

TLO	lift-off time
TPF	time of powered flight
TTPF	time of TPF
TTPI	time of TPI
VF	insertion velocity
WHTI	weight of target vehicle
WHTM	weight of maneuvering vehicle
YS	yaw steering capability
γ	flight-path angle
ΔTb	time bias added to inplane launch time to give first guess at lift-off
ΔTOP	delta time from optimum inplane launch time to analytical inplane launch time
ΔTSEP	delta time from insertion to separation
ΔT700	delta time from optimum inplane launch time to 700-pound opening and closing
ΔVSEP	delta velocity of separation
ε	elevation angle
λ_{LS}	longitude of launch site
ϕ_{LS}	latitude of launch site

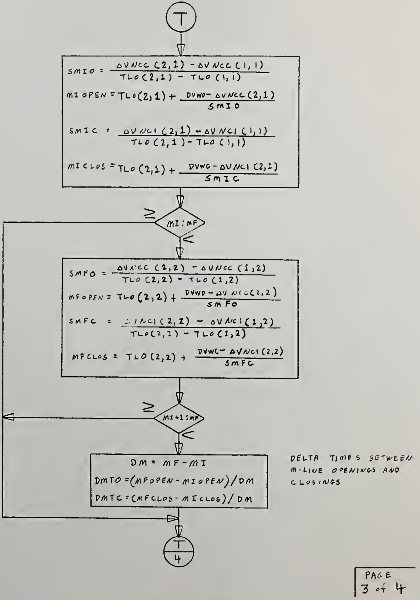
LAUNCH WINDOW PROGRAM



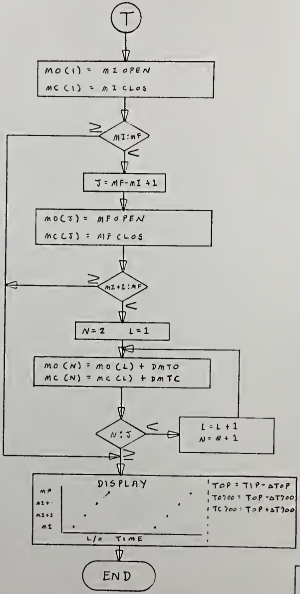
Flow chart 1.- Launch window program.



Flow chart 1. - Continued.



Flow chart 1.- Continued.



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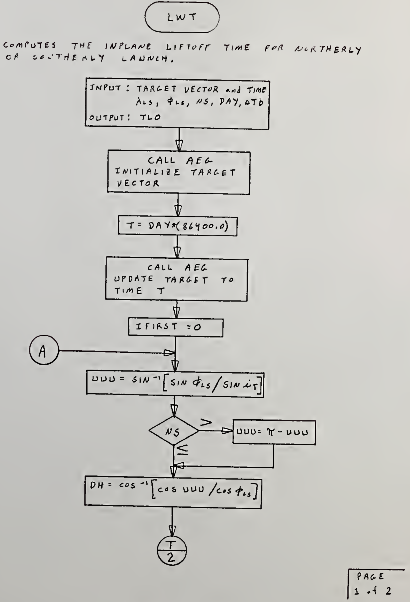
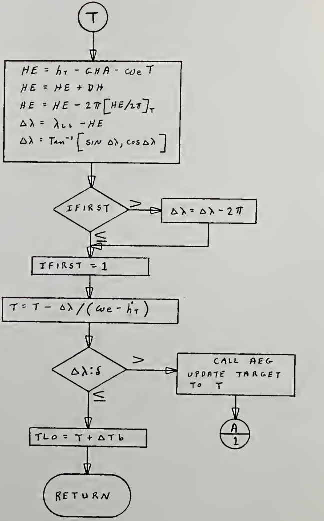
Flow chart 1.- Concluded.



Flow chart 2. - LWT.



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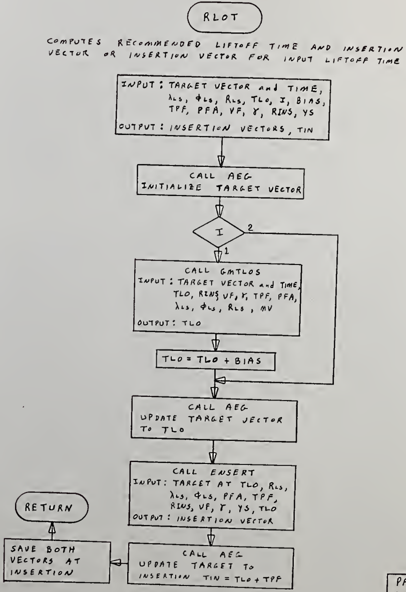

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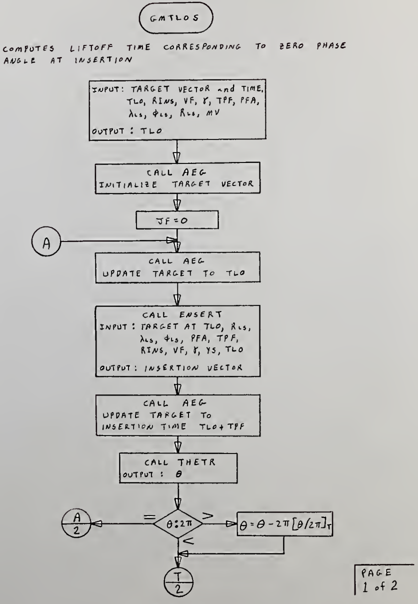
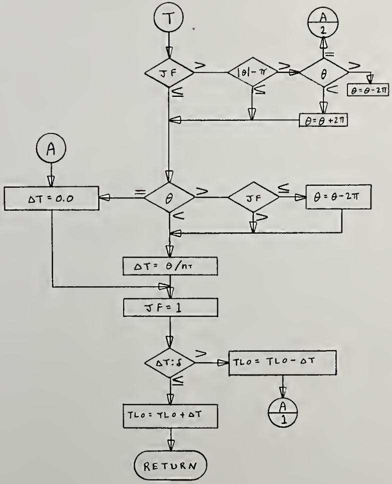
Flow chart 3.- RLOT.



Flow chart 4.- GMTLOS.



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NASA — MSC

Flow chart 4.- Concluded.

CHANGE SHEET

FOR

MSC INTERNAL NOTE 70-FM-198 (MSC-03763) DATED DECEMBER 22, 1970

SKYLAB LAUNCH WINDOW PROCESSOR

By Jerome W. Kahanek

Change 1

August 15, 1972

Elric N. McHenry, Acting Chief
Software Development Branch

John P. Mayer, Chief
Mission Planning and Analysis Division

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

After the attached enclosures, which are replacements and additions, have been inserted, insert this CHANGE SHEET between the cover and the title pages and write on cover, "CHANGE 1 inserted".

1. Replace pages.

Change History for 70-FM-198

Change no.	Date	Description
1	8/15/72	The following changes have been made. Page — Change 6 — Input definition changes 7 — Flow chart change 8 — Flow chart change 10 — Flow chart change 11 — Flow chart change 12 — Flow chart change 13 — Flow chart change 14 — Flow chart change NOTE: The detailed flow charts have been replaced in full.

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	= 1 yes
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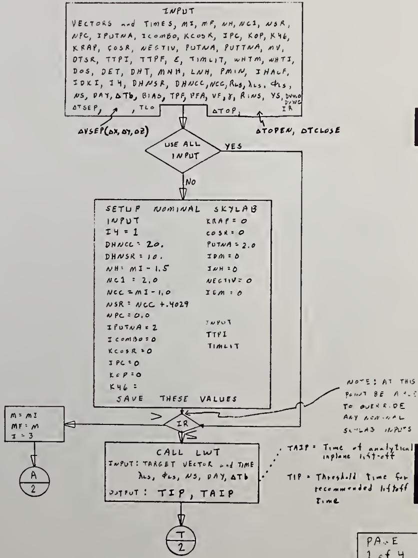
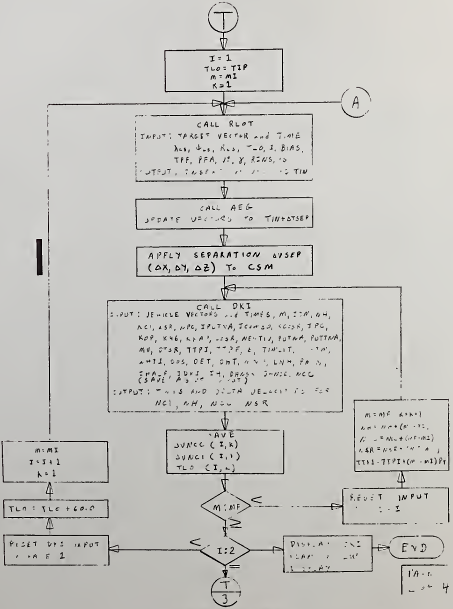
ΔTb	time bias added to inplane launch time to give first guess at lift-off
ΔTOP	delta time from optimum inplane launch time to analytical inplane launch time
ΔTSEP	delta time from insertion to separation
ΔTOPEN	delta time from optimum inplane launch time to opening of window (depends on fuel reserves allowed for steering)
ΔTCLOSE	delta time from optimum inplane launch time to closing of window (depends on fuel reserves allowed for steering)
ΔVSEP (ΔX, ΔY, ΔZ)	delta velocity components of separation maneuver
ε	elevation angle
λ_{LS}	longitude of launch site
ϕ	latitude of launch site

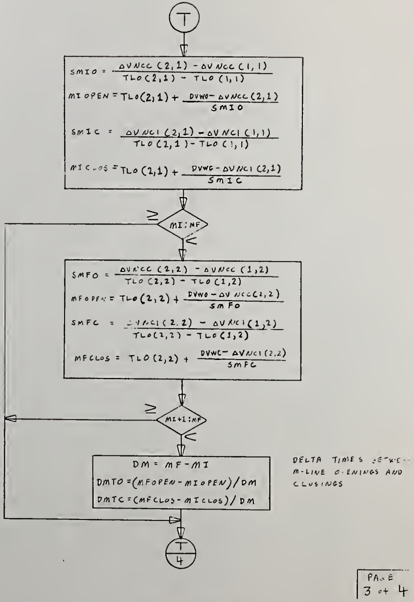


Flow chart 1. - Launch window program.

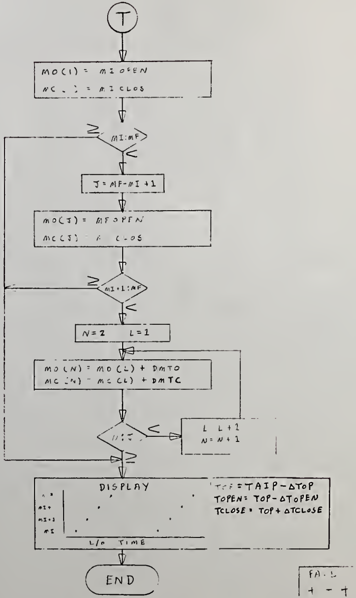
Change 1, August 15, 1972



Flow chart 1.- Continued.



Flow chart 1.- Continued.

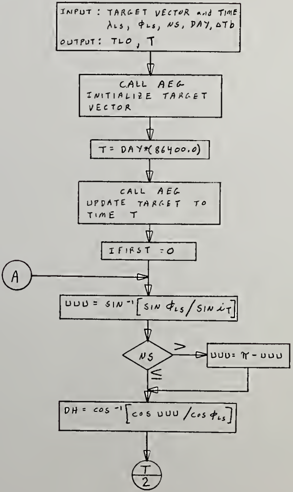


Flow chart 1.- Concluded.

Change 1, August 15, 1972

LWT

COMPUTES THE INPLANE LIFTOFF TIME FOR NORTHERLY OR SOUTHERLY LAUNCH.



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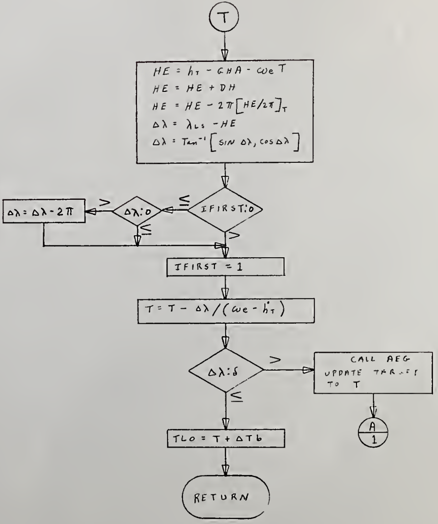
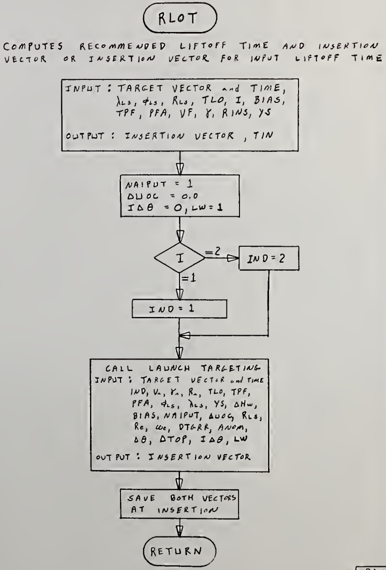
Flow chart 2.- LWT.



Flow chart 2. - Concluded.

Change 1, August 15, 1972



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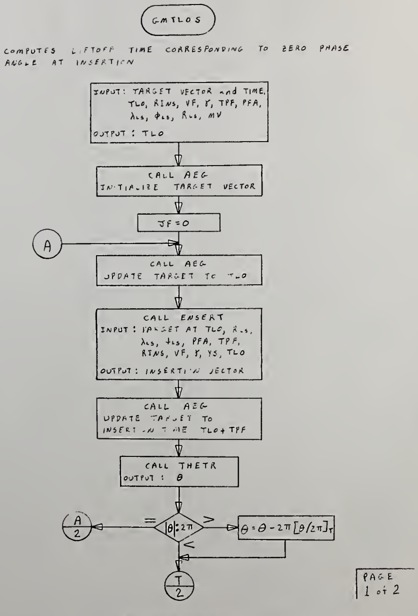
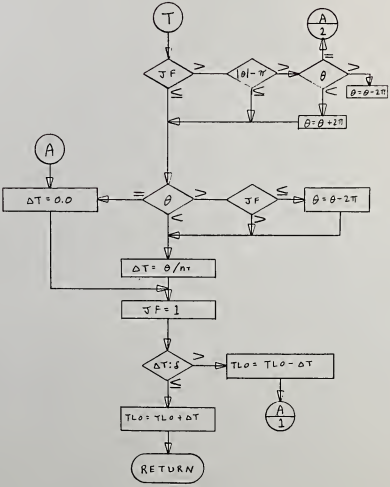
Flow chart 3.- RLOT.



Flow chart 4.- GMTLOS.



Flow chart 4.- Concluded.