NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 68-FM-67

March 8, 1968

LOGIC AND EQUATIONS FOR THE REAL-TIME COMPUTATION OF THE LM LAUNCH TARGETING AND DISPLAY

By Jerome W. Kahanek,
Orbital Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

UNITED STATES GOVERNMENT

Memorandum

TO : See list below

DATE: 13 MAR. 1968

68-FM61-79

FROM : FM/Mission Planning and Analysis Division

SUBJECT: Transmittal of detailed programming requirements

The enclosed MSC Internal Note No. 68-FM-67 presents detailed requirements for the real-time computer program to be employed in support of the Apollo missions beginning with the G Mission (CSM 107/LM-6).

Edgar C. Lineberry, Chief
Orbital Mission Analysis Branch

John P. Mayer
Chief, Mission Planning
and Analysis Division

The Flight Software Branch concurs with the above recommendation.

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

Enclosure

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cc:
See attached list

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13 MAR 1968

See list below

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FM/Mission Planning and Analysis Division

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Original Signed By
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Edgar C. Lineberry, Chief
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Original signed by
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John P. Mayer
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PROJECT APOLLO

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By Jerome W. Kahanek
Orbital Mission Analysis Branch

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LOGIC AND EQUATIONS FOR THE REAL-TIME COMPUTATION OF THE LM LAUNCH TARGETING AND DISPLAY

By Jerome W. Kahanek

SUMMARY AND INTRODUCTION

This internal note presents the logic and equations for the lunar module (LM) launch targeting processor (LLTP). The LM launch targeting display will be a part of the lunar rendezvous plan table (LRPT) and will be used by the flight controllers to verify the LM onboard targeting computations.

LM LAUNCH TARGETING PROCESSOR

The LLTP computes the following targeting parameters. The symbols are the same as those that will be used on the LRPT.

wedge $\measuredangle$	The wedge angle existing between the CSM orbit plane and the plane resulting from inserting the LM parallel to the CSM plane (assuming no yaw steering), deg.
ΔR	Cross-range distance from the launch site to the CSM orbital plane that will normally steered be out during the ascent maneuver, n. mi.
$\Delta Y\measuredangle$	Wedge angle remaining between LM and CSM orbital planes at LM insertion, deg. This value is nominally zero unless input Y_S is less than parallel launch wedge angle.
Yd	Desired insertion cross-range distance measured from the CSM orbital plane, n. mi.
AZ_P	Launch azimuth for plane parallel launch, deg (measured clockwise from north).

The following quantities are the inputs necessary to compute the targeting parameters.

	CSM state vector and time
ϕ_{LS}, λ_{LS}	LM selenographic latitude and longitude on the lunar surface, deg
GMTLO	Desired or actual Greenwich mean time of lift-off.
Y_S	Wedge angle to be taken out by yaw steering during LM ascent, if the input value of Y_S < the parallel launch wedge ∄, then the wedge angle at insertion will be greater than zero.
t_{PF}	LM nominal powered flight time, sec
P_{FA}	LM nominal powered flight arc, deg

COMPUTATION OF WEDGE ANGLE, CROSS-RANGE DISTANCE, AND PARALLEL AZIMUTH

The LM launch targeting processor uses subroutine ENSERT to generate a LM insertion vector. Wedge angles are computed from the selenographic orbital elements of the CSM and LM at insertion, using the following equation:

$$\delta_w = \tan^{-1} [\cos i_C \cos i_L + \sin i_L \sin i_C \cos (h_L - h_C)]$$

where

i_C - inclination of target orbit (CSM)

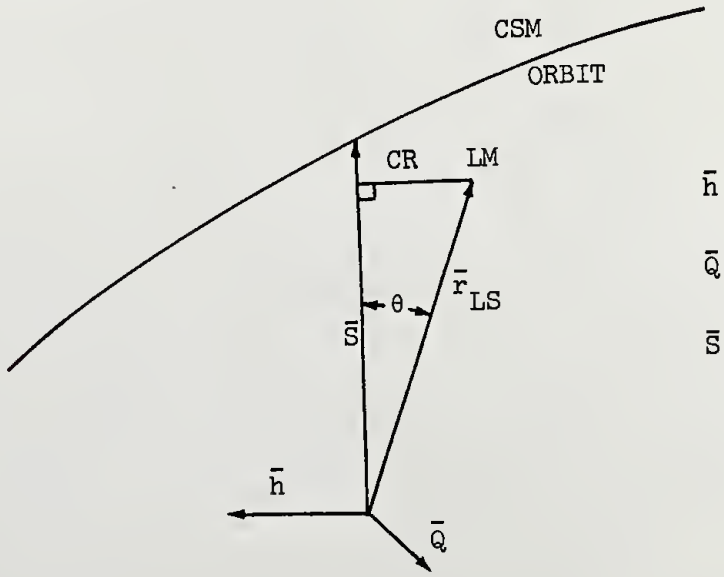
i_L - inclination of LM orbit

h_C - ascending node of target orbit

h_L - ascending node of LM orbit

Cross-range distance is the distance from the launch site or insertion point to a perpendicular intersection of the CSM orbit. It is measured by finding the angle between the LM vector and the projection of the LM vector in the plane of the CSM orbit. This projection is found by creating

a coordinate system referenced to the CSM orbital plane and the LM position by:



$$\bar{h} = \text{unit } (\bar{r}_C \times \bar{V}_C)$$

$$\bar{Q} = \text{unit } (\bar{r}_{LS} \times \bar{h})$$

$$\bar{S} = \bar{h} \times \bar{Q}$$

where $\bar{S}$ is along the projection of the LM vector at the closest approach in the CSM orbit. Cross-range distance is then computed by

$$CR = \text{cross-range} = |\bar{r}_{LS}| \sin \theta$$

where $$\theta = \cos^{-1}\left[\bar{S} \cdot \bar{r}_{LS}\right].$$

The parallel launch azimuth is computed from the following equation.

$$AZ_P = \tan^{-1}\left[-\frac{\cos i_C \cos \phi_{LS} + \sin i_C \sin \phi^* \sin \phi_{LS}}{\sin i_C \cos \phi^*}\right]$$

where

i_C - selenographic inclination of the target orbit (CSM)

ϕ_{LS} - selenographic latitude of launch site

ϕ^* - angular distance measured along the equator between the launch site and the target descending node at lift-off time.

The launch azimuth is computed and displayed for ground information only since the LM onboard system does not use or display an azimuth.

The LLTP (see flow chart 1) uses subroutines LATLON and ENSERT (ref. 1) and LSAEG (ref. 2) in its computations. LATLON computes an inertial landing site vector and ENSERT computes the LM insertion vector. LSAEG is used for vehicle ephemeris prediction.

SYMBOLS FOR LLTP FLOW CHART

Input Constants

π	3.141592...
ω_m	moon rotation rate

Input Variables

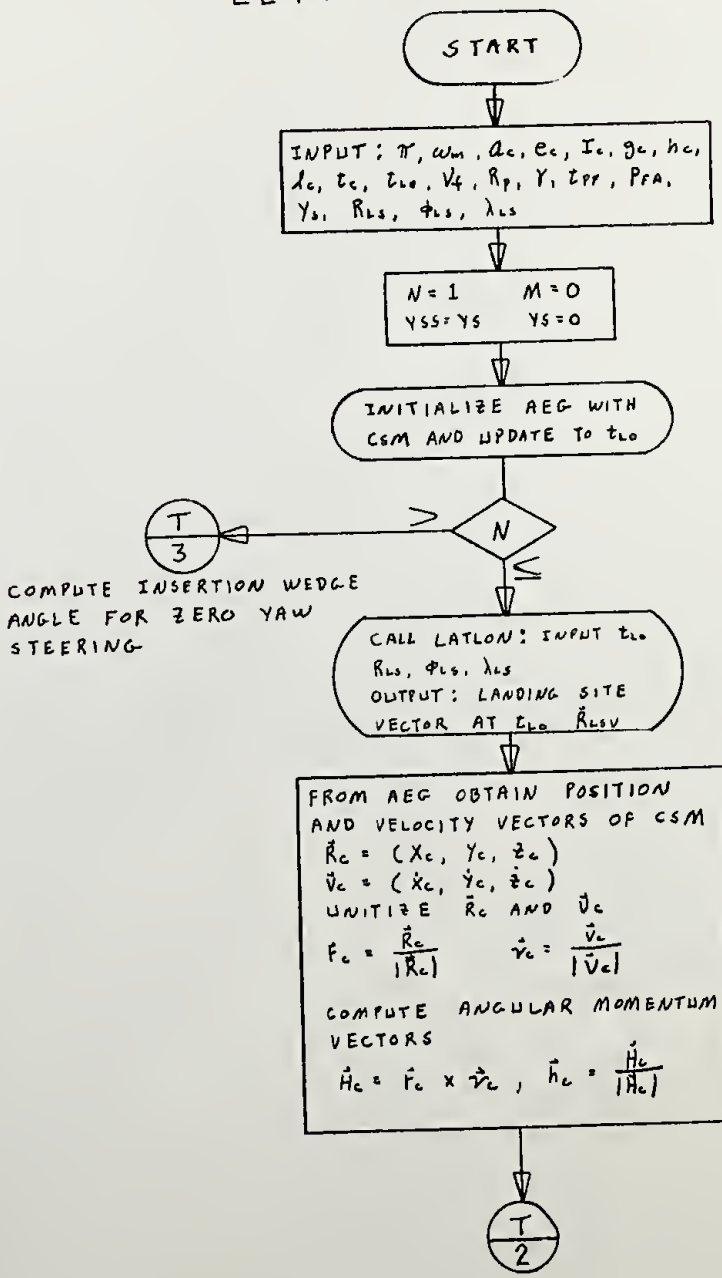
a_c	semimajor axis of CSM orbit
e_c	eccentricity of CSM orbit
I_c	inclination of CSM orbit
g_c	argument of pericynthion of CSM orbit
h_c	selenocentric node of CSM orbit
ℓ_c	mean anomaly of CSM orbit
t_c	time of CSM orbital elements
t_{lo}	lift-off time
V_f	LM insertion velocity, fps
R_p	LM insertion radius, ft
γ	LM flight-path angle at insertion, deg
t_{PF}	LM nominal powered flight time, sec
P_{FA}	LM nominal powered flight arc, deg
Y_S	yaw steering capability, deg
R_{LS}	radius of the landing site, ft

ϕ_{LS}	selenographic latitude of the landing site, deg
λ_{LS}	selenographic longitude of the landing site, deg

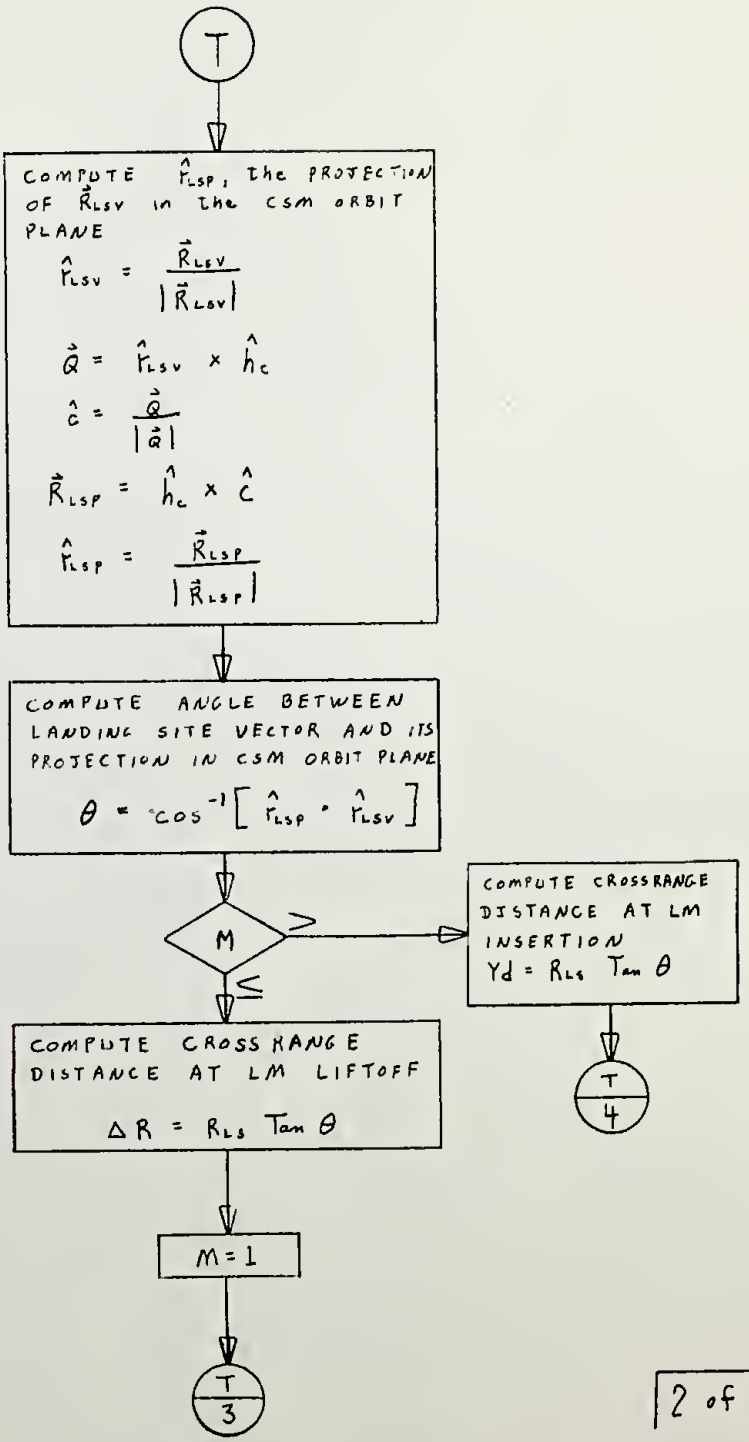
Output Variables

δ_{wo}	wedge angle for zero yaw steering, deg
ΔR	cross-range distance at lift-off, ft
δ_{w}	wedge angle with yaw steering, deg
Y_{d}	cross-range distance at insertion, ft
AZ_{P}	parallel launch azimuth, deg

LLTP FLOW CHART



Flow chart 1.- LLTP logic.



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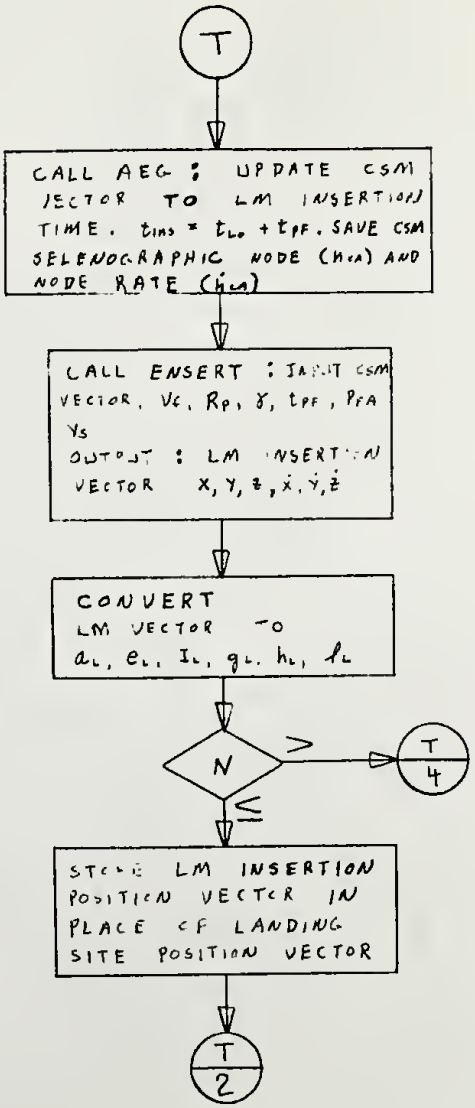
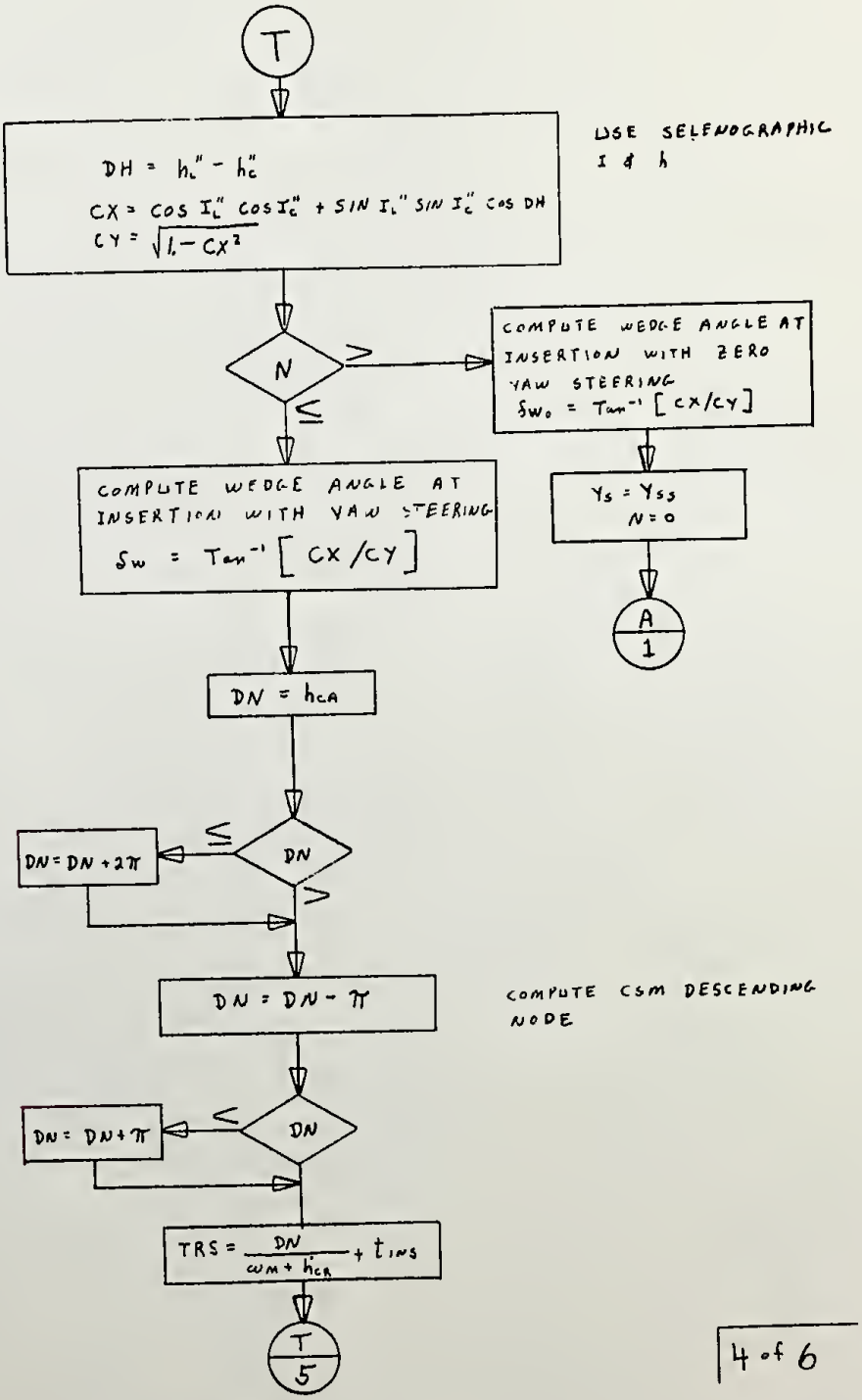
Flow chart 1.- LLTP logic - continued.



Flow chart 1.- LLTP logic - continued.



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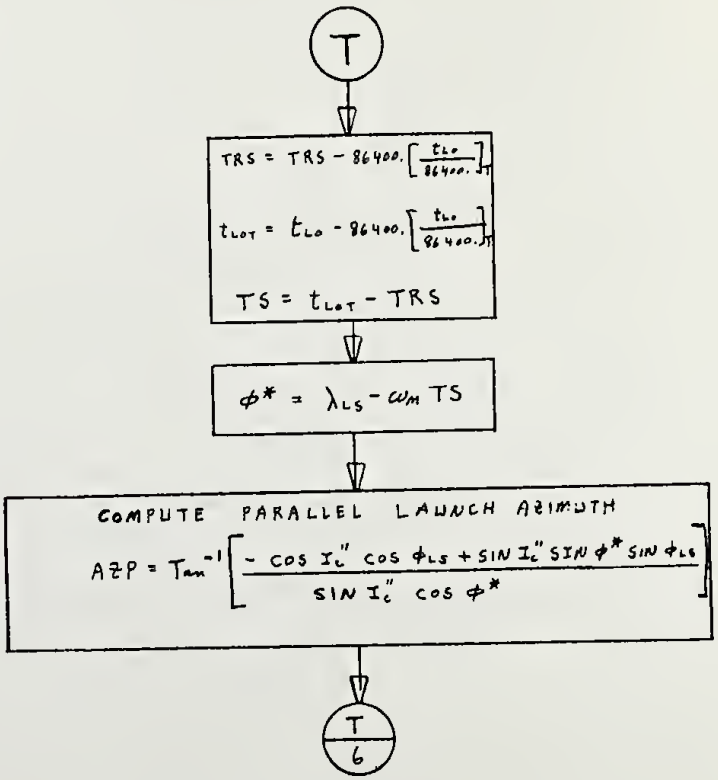
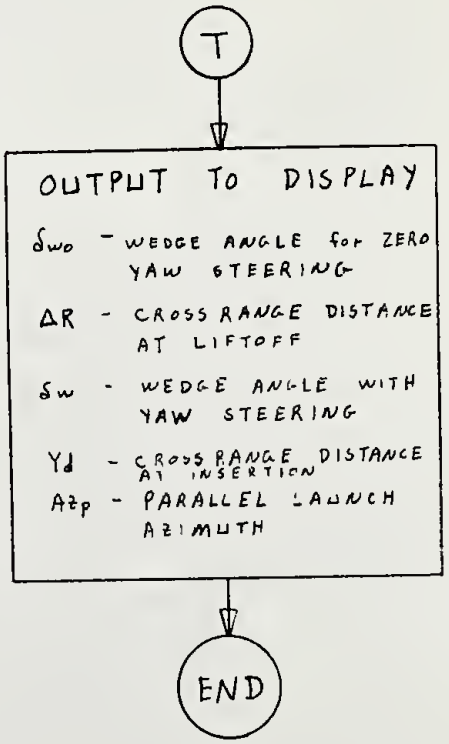
Flow chart 1.- LLTP logic - continued.



Flow chart 1.- LLTP logic - continued.



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Flow chart 1.- LLTP logic - concluded.

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1. Sullivan, W. A.: Logic and Equations for the Computations of Lunar Module Launch Window and Recommended Lift-Off Time. MSC Internal Note 68-FM-5, January 5, 1968.

2. Ingram, D. S.; and Nickerson, K. G.: Generalized Lunar Satellite Analytic Ephemeris Generator (GLSAEG). TRW Report 3842-H003-R0-000, June 15, 1966.