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Orbital Mission Analysis Branch

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PROJECT APOLLO

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The purpose of this internal note is to describe the logic used to compute the lift-off time required for the early rendezvous profile to be used on Apollo 14 (Mission H-3). For the early rendezvous profile, the lift-off time desired is that lift-off time which corresponds to the following conditions.

a. Results in nominal offsets at terminal phase initiation (TPI)

b. Constant delta time from insertion to TPI

c. Constant radial velocity at insertion

These conditions can be met by varying the time of lift-off and the forward velocity at insertion. The lift-off time and delta forward velocity are found by using an iteration scheme that consists of an insertion vector predictor (subroutine ENSERT, ref. 1) and a two-impulse conic fit solution (ref. 2) to nominal offsets at TPI, with the initial impulse performed at insertion and TPI performed at a specific delta time from insertion.

The initial guess at the lift-off time is computed by finding the time at which the target passes over the landing site longitude after some specified threshold time and then biasing this time by the nominal insertion phase angle, time of powered flight, and the difference in the input delta time from insertion to TPI and the nominal delta time from insertion to TPI.

The iteration consists of varying the lift-off time as a function of the radial velocity of the initial impulse maneuver. A linear interpolation is used, and the lift-off time is varied until the radial velocity of the first maneuver is zero or within some tolerance.

When this tolerance is met, the forward velocity V_X of the initial impulse is added to the nominal insertion forward velocity to produce new insertion targeting.

With the new lift-off time and insertion targeting, an insertion vector is generated and the early rendezvous is computed. The insertion perilune is compared to some specified minimum to insure that the insertion orbit designed with the computed lift-off time and insertion velocity is safe.

Enclosed in the appendix are the required input, display quantities, and flow charts for the early rendezvous profile.

APPENDIX

LOGIC FOR THE EARLY RENDEZVOUS PROFILE

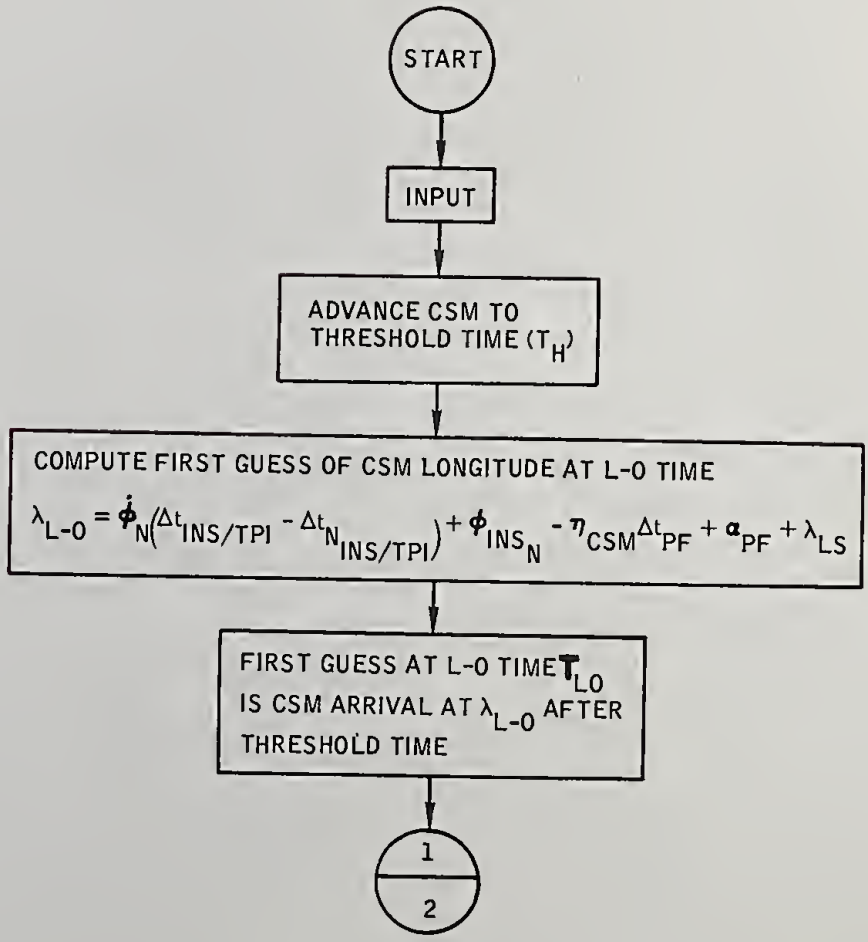
APPENDIX - LOGIC FOR THE EARLY RENDEZVOUS PROFILE

INPUT

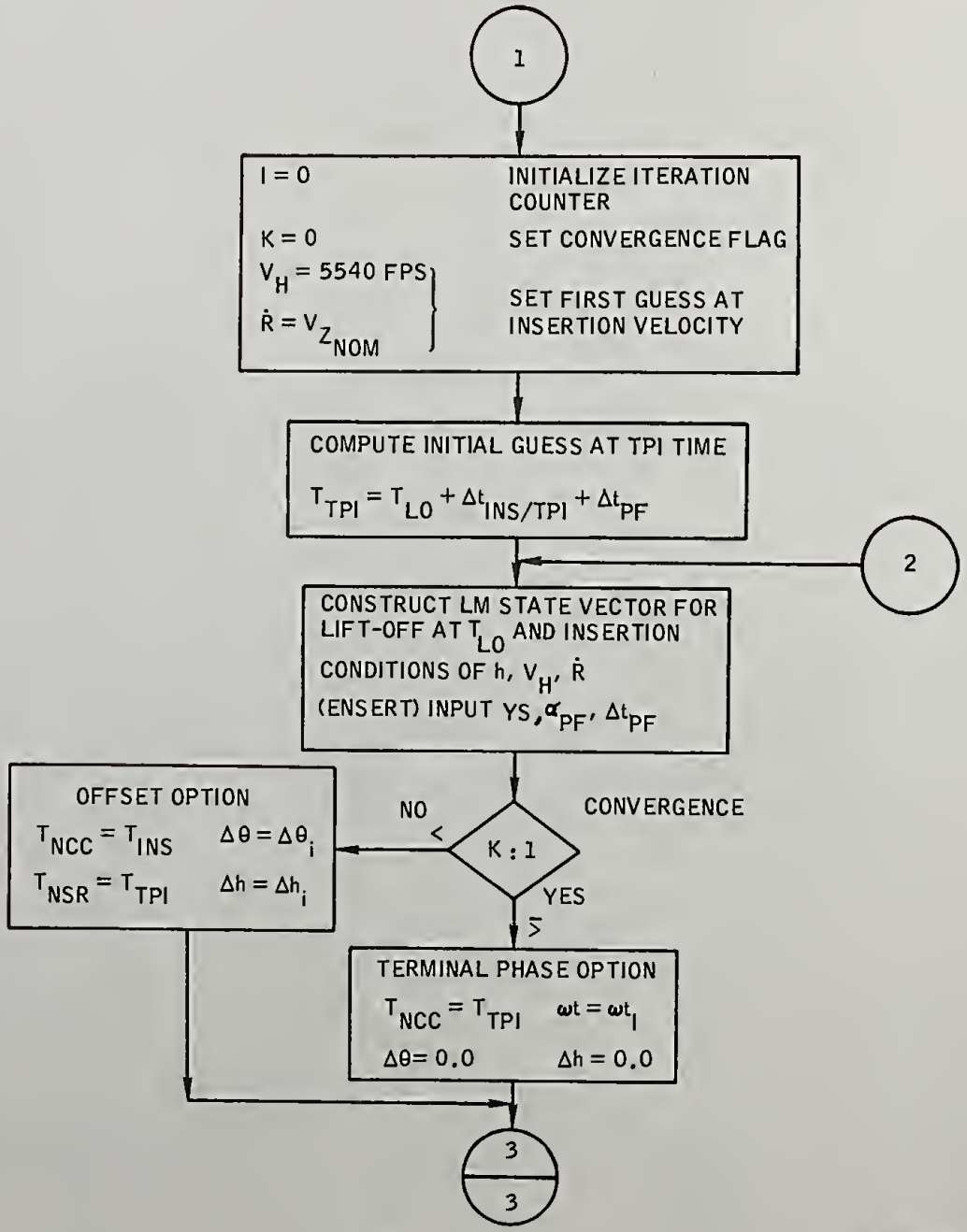
1. CSM state vector and time
2. Threshold time T_{HH})
3. Landing site radius, longitude, latitude (R_{LS}, λ_{LS}, ϕ_{LS})
4. Powered flight arc α_{PF}
5. Powered flight time Δt_{PF}
6. Insertion altitude h
7. Desired radial velocity at insertion $V_{Z\ nom}$
8. TPI phase offset $\Delta\theta$
9. TPI height offset Δh
10. Time between insertion and TPI $\Delta t_{ins/TPI}$
11. Nominal time between insertion and TPI $\Delta t_{n\ ins/TPI}$
12. Minimum insertion perilune $h_{p\ min}$
13. Yaw steer limit YS
14. Nominal phase rate between insertion and TPI $\dot{\phi}_N$
15. Nominal phase angle at insertion $\phi_{ins\ n}$
16. CSM mean motion η_{CSM}

DISPLAY QUANTITIES

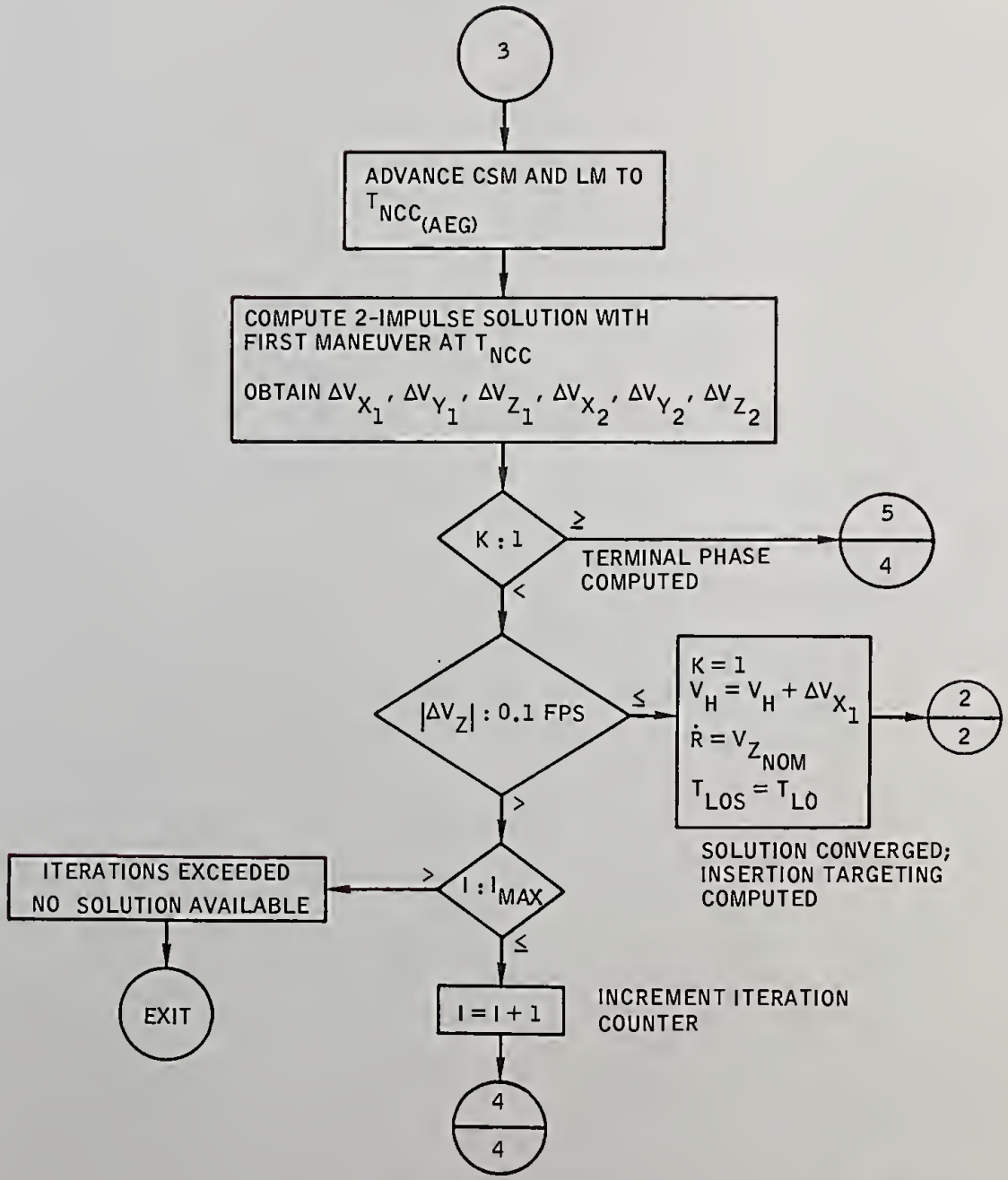
1. Powered flight arc and time
2. TPI phase and height offsets
3. Landing site coordinates
4. Threshold time
5. Time between insertion and TPI
6. Recommended lift-off time
7. TPI time
8. Horizontal insertion velocity
9. Radial insertion velocity
10. TPF time
11. ΔV_X, ΔV_Y, ΔV_Z at TPI
12. ΔV_X, ΔV_Y, ΔV_Z at TPF



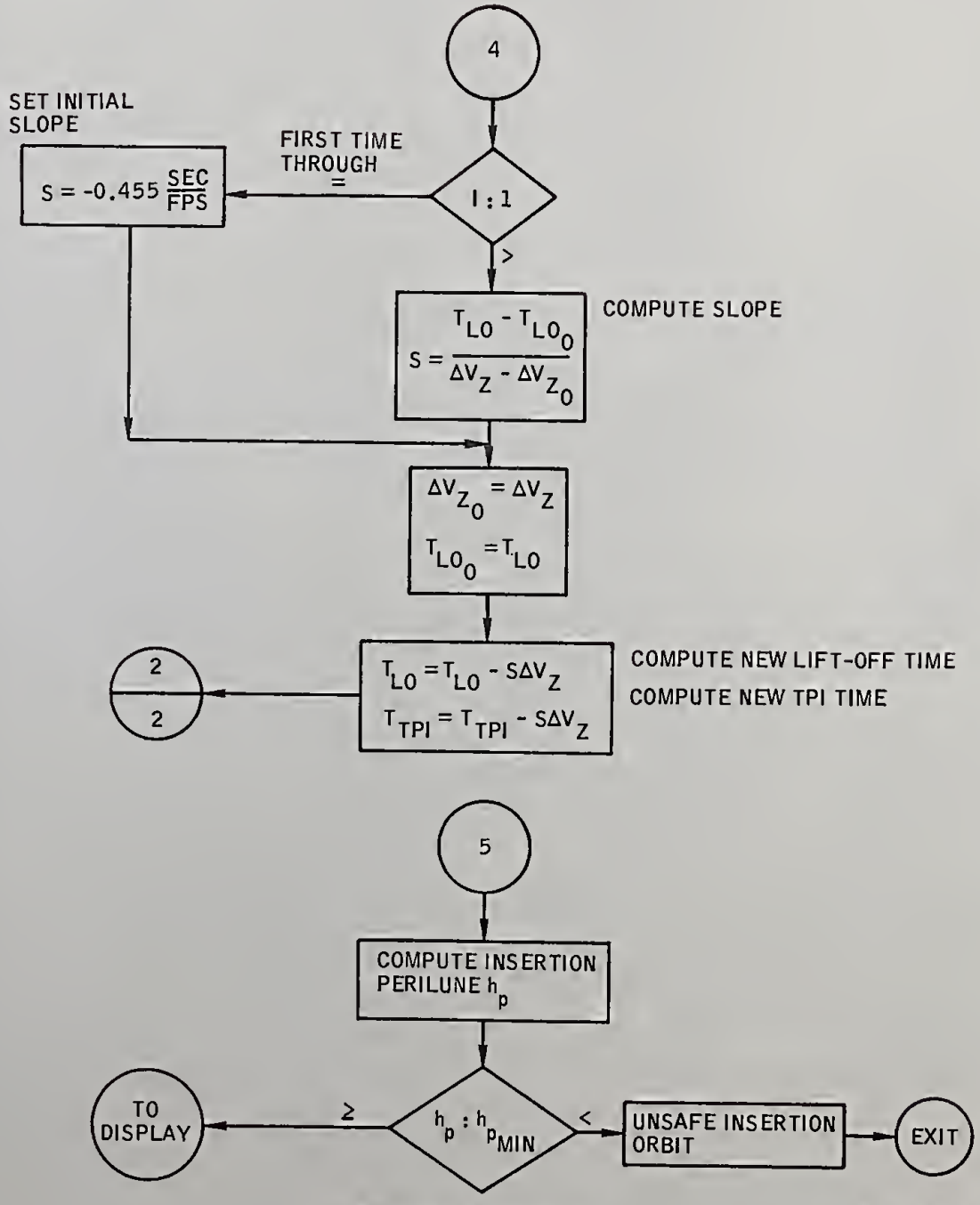
Flow chart 1.- Early rendezvous lift-off processor.



Flow chart 1.- Continued.



Flow chart 1.- Continued.



Flow chart 1.- Concluded.

REFERENCES

1. McDonough, R. K.; and Sullivan, W. A.: Logic and Equations for the Real-Time Computation of AS-207/208 Insertion Elements and Specialized Orbital Maneuvers. MSC IN 66-FM-116, Oct. 9, 1966.

2. Alexander, J. D.: Two-Impulse Rendezvous Technique Incorporating Earth Perturbation and Drag. MSC IN 65-FM=27, July 19, 1965.