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APOLLO MISSION TECHNIQUES
C-PRIME LUNAR (ALTERNATE 1)
TRACKING DATA
SELECTION CONTROLLERS PROCEDURES

TECHNIQUES DESCRIPTION

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APOLLO SPACECRAFT PROGRAM OFFICE

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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APOLLO SPACECRAFT PROGRAM OFFICE
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Approved by Howard W. Tindall, Jr.

Howard W. Tindall, Jr., Chief
Apollo Data Priority Coordination

FOREWORD

This Tracking Data Selection Controllers Procedures Mission Techniques Document is one of seven documents describing the Apollo 8 mission. The others are:

- Saturn 5/Apollo Launch Aborts
- Earth Parking Orbit and Translunar Injection
- Translunar Midcourse Corrections and Lunar Orbit Insertion
- Lunar Orbit Activities
- Transearth Injection, Midcourse Corrections, and Entry
- Contingency Procedures

These documents contain the officially approved guidance and control sequence of events, the data flow, and real-time decision logic for the Apollo 8 lunar mission. The purpose of these documents is to insure compatibility of all related MSC and supporting contractor activities.

Data Priority Working Groups have been established under the direction of Chief, Apollo Data Priority Coordination, ASPO. These groups, which are comprised of representatives of MSC and support contractors, hold frequent meetings to coordinate their various associated activities and develop agreed upon mission techniques. TRW assists in the development of the techniques and documents them for ASPO. After formal review, a document such as this one is issued.

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TABLES

ILLUSTRATIONS

NOMENCLATURE

ACN	Ascension
ACRA	Atlantic continuous recovery area
ADRA	Atlantic discrete recovery area
AGS	abort guidance computer
A/H/O	abort/hold/orbit
ANG	Antigua
AOS	acquisition of signal
ASAP	as soon as possible
ASC	Ascension
A/X	azimuth/X angle
BAP	best adaptive path
BDA	Bermuda
CMC	command module computer
CRO	Carnarvon
CSM	command service module
CYI	Canary Island
D	doppler
DC	differential correction
DCU	digital control unit
DDD	digital display driver
DSC	dynamics standby computer
EOT	end of transmission
EPH	ephermeris
ESOS	events sequence override switch
EVT	evaluation vector table

NOMENCLATURE (Continued)

E/Y	elevation/Y angle
FDO	Flight Dynamics Officer
GBM	Grand Bahama Island
GDS	Goldstone
GMT	Greenwich mean time
GMTEI	GMT of entry interface
GMTRCNS	GMT to activate constraint table
GMTRI	GMT to start reentry integrator
GSFC	Goddard Space Flight Center
GWM	Guam
GYM	Guaymas
H	altitude
HAW	Hawaii
HS	high speed
HSK	Honeysuckle Creek
ID	identification
IMU	inertial measuring unit
IP	impact predictor
IPR	IP raw
IPS	IP smooth
IU	instrumentation unit on S-IVB
LGC	LM guidance computer
LM	lunar module
LO	lift-off
LOI	lunar orbit insertion

NOMENCLATURE (Continued)

LPO	lunar parking orbit
LTV	launch transfer vector
M&O	maintenance and operations
MAD	Madrid
MCC	midcourse correction
MCC-H	Mission Control Center - Houston
MED	manual entry device
MIL	Merritt Island
MOC	mission operational computer
MOCR	mission operations control room
MPT	mission plan table
MSFN	Manned Space Flight Network
MSK	manual selection keyboard
NAV	navigation
OD	orbit determination
ODP	orbit determination program
PBI	pushbutton indicator
PTC	passive thermal control
R	range
RFO	retrofire officer
RF	radio frequency
RMS	root mean square
RTCC	Real Time Computing Complex
SPS	service propulsion system
SS	single station

NOMENCLATURE (Continued)

S-IVB	Third stage booster
S-IVB CO	S-IVB cutoff
TBD	to be determined
TEI	transearth injection
TEX	Texas
TLI	translunar injection
TLM	telemetry
TPI	terminal phase initiation
TPF	terminal phase finalization
USB	unified S-band
UVT	usable vector table
V	velocity
ΔV	velocity increment

1. INTRODUCTION

This document contains detailed information and procedures concerning the Tracking Data Selection Controller's (Select) responsibility in the RTCC operations. Included in addition to the detailed procedures are the general responsibility, communication interfaces with other mission controllers, tracking site requirements, input and control of the real-time computers, and display identification and format. The Mission Control Center-Houston (MCC-H) definitions for the mission phases are:

a) Prelaunch I

b) Condition for launch

c) Launch

d) Abort (mode I, II, III)

e) Earth orbit insertion

f) Earth parking orbit

g) Translunar

h) Lunar orbit

i) Transearth

j) Reentry

2. GENERAL RESPONSIBILITIES

Data Select is responsible for the determination of the best state vector to be used for all trajectory control decisions and information. In addition, he shall advise other mission controllers of the state vector quality, as well as the quality of the data sources when possible or when so requested. General responsibilities for Data Select in the areas of processing high- and low-speed data, vector control, and site acquisition are discussed in the following sections.

2.1 LOW SPEED

a) Control and monitor the performance of the differential correction (DC) both vehicles in both the mission operational computer (MOC) and dynamics standby computer (DSC).

b) Insure that the ephemeris (EPH) stored in each of the ground computers agree and represent the best vectors available.

c) Advise Flight Dynamics Officer (FDO) as to the quality of each of the trajectories.

d) Confer with FDO and Track concerning future tracking data requirements.

2.2 HIGH SPEED

a) Monitor and evaluate the processing of all high-speed radar and telemetry trajectory data in both the MOC and DSC.

b) Evaluate the trajectory data processing and advise the FDO of the evaluation.

c) Evaluate the trajectory data sources and select the best source available.

d) Change sources upon request of FDO.

e) Evaluate the short-arc computations for each raw data source during hold phase and recommand to FDO the best source to use for transfer to low-speed orbit phase.

f) Determine and select the best telemetry and radar sources during a high-speed pass in both the MOC and DSC.

2.3 VECTOR CONTROL

a) Evaluate all telemetry vectors periodically and insure that the usable vector table (UVT) contains good, current vectors.

b) Update the ephemeris with the vector which FDO requests.

c) Perform vector comparisons for FDO's viewing upon his request.

2.4 ACQUISITION

a) Insure that each site receives its acquisition message.

b) Regenerate a site's acquisition message upon request.

c) Suppress or unsuppress all acquisition data upon request of FDO.

d) Eliminate C-band acquisition data when the CSM separates from the S-IVB following translunar injection (TLI).

e) Reinstate C-band contacts when so directed by FDO.

3. COMMUNICATION INTERFACES

The Data Select Controller interfaces and their functions are listed below.

a) Computer Supervisor is responsible for the overall real time computer complex (RTCC) operations.

b) Track is responsible for the receipt of tracking data from Goddard Space Flight Center (GSFC) input of the data to the real-time system.

c) Lemon One, located at the Cape, is responsible for the selection of the impact prediction (IP) data source.

d) FDO is responsible for all dynamic operations and decisions.

e) Goddard analyst is responsible for preliminary analysis of the tracking data received by Goddard.

f) Select Support is an advisor to Data Select and is responsible for cislunar and lunar tracking schedule planning.

4. TRACKING SITE CALIBRATION

The requirements for tracking site calibration are contained in this section. The range calibration consists of determining the site ranging delay. The frequency/time sychronization requirements are given for prelaunch as well as during the mission.

4.1 MSFN FREQUENCY/TIME SYNCHRONIZATION

4.1.1 Prelaunch

Within 1 month before launch perform frequency time synchronization on both frequency standards at all scheduled Manned Spaceflight Network (MSFN) unified S-band (USB) stations. Expected time synchronization is two parts in 10^{11}. Once the equipment is adjusted, do not readjust until the mission is completed.

In the time period between the equipment adjustment and launch, check the time and frequency synchronization weekly and report the time errors and frequency offsets to MCC-H. Also report any equipment anomalies that may affect either adjustment.

4.1.2 During Mission

Perform frequency/time checks (but no equipment adjustments) as part of the prepass station calibration procedures. Include the time errors and frequency offsets in the pretrack report sent to GSFC and MCC-H.

At the conclusion of each station pass, repeat the frequency/time checks as performed prepass, and include the time errors and frequency offsets in the posttrack report. Do not adjust the equipment to resynchronize either frequency or time.

4.2 RANGE CALIBRATIONS

Calibrate the site ranging delay within ±10 yards. (Do not change the site calibration adjustment during the mission unless equipment replacement is necessary. Report the ranging data delays applied to the data in the posttrack reports).

4.2.1 Transponder Delay

a) USB stations (except ships) will not correct for transponder delay.

b) Houston and Goddard computers will correct for transponder delays in USB (except ships).

4.2.2 Station Delay

a) Station delay must be measured in accordance with MSFN systems test ST-12.

b) This must be accomplished in accordance with the network readiness test schedule, but at least once permission and again any time an equipment change negates the calibration.

c) Delay must be measured within ±10 yards.

Note: ST-12 requires calibration within ±5 range units.

d) Station delay in octal range units as set into the MK. 1A range system will be reported to NST/USB and Houston/Track by TWX.

e) Any station delay changes during the mission will be reported to NST/USB and Houston/Track by voice, followed by a TWX confirmation.

5. TRACKING SITE SELECTION

This section presents the criteria for the selection of the MSFN tracking sites for cislunar and lunar phases. The criteria for the selection of MSFN sites is to establish the best station-to-station geometry for the purpose of orbit determination. The priority of the sites based on geometric separation, mission phase considerations, maneuver requirements, and wing-site evaluation are discussed along with the contingency situation due to a biased two-way site. Procedures for site selection are then presented.

Data Select, Select Support, and Track will plan the two-way site schedule and coordinate the schedule with FDO so that other Mission Operations Control Room (MOCR) flight controllers will be aware of the tracking plan.

5.1 PRIORITY TRACKING SITES

During the Apollo 8 mission, control will be maintained over which sites tracking data will be transmitted in real time. The criteria for this control is to establish the best station-to-station geometry for the purpose of orbit determination. Obviously, the highest priority is given to the 85-foot site in two-way lock. Second priority is given to the 30-foot site offering the greatest north/south separation from the two-way site. Third priority is assigned to the upcoming 85-foot site. Fourth and fifth priorities are assigned to 30-foot sites with the greatest east/west and north/south separations, respectively. The sixth priority is the wing site to be used for backup of the 85-foot site in two-way lock. This station selection priority is summarized in the following table.

Priority Number	Station/Criteria
1	85 ft
2	30 ft N/S*
3	85 ft E/W
4	30 ft E/W
5	30 ft N/S
6	Backup wing site of primary 85 ft

*N/S and E/W mean that the greatest north/south and east/west separation of sites, respectively, should be obtained.

To assist in the selection of the actual sites using this criteria, Table 1 presents the sites in descending order of preference with respect to north/south and east/west separation for each of the 85-foot sites. Sites listed on the same row are considered to offer equal geometric separation. As an example, if Goldstone (GDS) is the primary site (in two-way lock) and Ascension (ACN), Antigua (ANG), Bermuda (BDA), and Madrid (MAD) have the spacecraft (SC) in view, the priorities are:

1) GDS
2) ACN
3) MAD
4) ANG
5) BDA

Although data can be obtained for six sites (over the six teletype lines from GSFC), the data obtained from the first four sites using this selection procedure will be used for OD and data from the fifth for backup.

The exception to the above rules involves the TPQ-18 at CLQ for the period of time prior to actual undocking. It is expected that data from this site will greatly enhance the quality of the initial solutions and should be scheduled for tracking.

5.2 PRIMARY TRACKING SITES

5.2.1 Cislunar Phases

In addition to the 85-foot sites, selected 30-foot sites will be utilized for primary site tracking during the cislunar phases. The rationale behind this procedure is twofold:

1) Allows a data arc of primary site data which is sufficient to obtain a well determined orbit from two-way data only
2) Provides a means for recognition and recovery from a two-way biased site

The basic rule during cislunar free flight requires switching to a 30-foot site for two-way lock during the mid two-hour portion of an 85-foot site tracking period. The 30-foot site selected will be the site offering

Table 1. Site Preference Based on Geometric Separation

Two-way 85-Foot Site	Preference	North/South Separation	East/West Separation
MAD	1	HSK, CRO	GDS
	2	ACN	HSK
	3	GWM, ANG, HAW	GWM, HAW, CRO
	4	MIL, CYI, TEX, GYM, BDA, GDS	GYM, TEX, MIL, BDA, ANG, ACN, CYI
GDS	1	HSK, CRO	HSK, MAD
	2	ACN, GWM	CRO, GWM, ACN, CYI
	3	ANG, HAW	ANG, BDA, HAW, MIL
	4	CYI, MIL, MAD, TEX, GYM, BDA	TEX, GYM
HSK	1	MAD	MAD
	2	GDS	GDS
	3	BDA, GYM, TEX, MIL	ACN, CYI
	4	HAW, GWM	ANG, BDA, MIL, TEX, GYM
	5	ACN	HAW
	6	CYI	CRO, GWM
	7	CRO	

Notes: 1) Stations are listed in descending order of geometric preference for each 85-foot site.
2) Sites in same row are equal in preference.

the greatest north/south separation from the 85-foot site. This is the second priority site as described in the previous section. This switch will be made even though the 30-foot site may not have ranging capability.

5.2.2 Lunar Orbit

Normally, an 85-foot site will be the primary tracking site from SC emergence to occultation. A real-time decision to switch the primary site will be made in the event of orbit determination program (ODP) convergence problems. This situation is discussed in the Lunar Orbit Ranging Requirements section of this report.

5.3 CISLUNAR MANEUVER TRACKING

An 85-foot site should be in primary lock 1 hour prior to and 1 hour following a maneuver. One hour after the maneuver, a primary site switch is desired. This switch should be made to an 85-foot site, if possible, to obtain tracker geometry. Since the switch is to obtain geometry, the primary sites wing station should not be considered.

5.4 WING-SITE EVALUATION

In order to assure that the wing sites can provide full USB capability backup, they should be evaluated as soon as possible (ASAP). Handover from the primary site to the wing site should occur during the last 2 hours of the primary sites initial track period following the first midcourse correction (MCC). No attempt should be made to switch to a wing site prior to MCC-1 unless the primary site has problems. Three-way data from the wing sites will be evaluated when available during any mission phase.

5.5 BIASED TWO-WAY SITE

If at any time during the mission, a tracking site in the two-way doppler mode is determined to be sending biased data to MCC-H, handover to another site should be accomplished ASAP. If the range data is found to be biased, the site will be instructed to reacquire range. In some cases, this handover may be to a 30-foot site. The selection of the 30-foot site will be made in real time considering past performance of the sites, relative geometry, view periods, and operational considerations.

6. TRACKING SITE DATA REQUIREMENTS

The tracking site data requirements for ranging, data rates, and antenna angle control modes are given in this section. In addition to these data requirements, radio frequency (RF) doppler data is required from every site used to track the SC.

6.1 RANGING REQUIREMENTS

The ranging requirements for cislunar and lunar orbit mission phases are presented in this section. In cislunar free flight, range data is needed to obtain good spacecraft position solutions. In lunar orbit, the range data will be used with the starter program to obtain a crude start vector in the event orbit determination (OD) convergence problems are encountered with all the available vectors. As long as the command service module (CSM) high-gain antenna is visible and operable, ranging does not compromise the USB capability and desired ranging requirements can be realized. However, due to passive thermal control (PTC) in cislunar flight and SC attitudes required to accomplish the objectives in lunar orbit, the high-gain antenna will not always be visible. In addition, there is the possibility that although the high-gain antenna is visible, it may not be operable. In these cases, range acquisition and clock updated ranging, if required, must be accomplished using the omni-directional antennas. As seen from the expected USB capability presented in Table 2, ranging with the omni antenna can be accomplished to an 85-foot site but it is questionable when a 30-foot site is used. If ranging can be accomplished to the 30-foot site, no other USB capability may exist depending on the mission phase. Consequently, ranging requirements must consider either of the CSM antenna systems for lunar orbit and cislunar phases.

6.1.1 Lunar Orbit

In lunar orbit there is no urgency to obtain range data as long as the ODP is converging using the RF doppler data and no problems are suspected. In this nominal case, range data is not required if the high-gain antenna is not usable. As soon as possible after acquisition of signal (AOS) in each rev (if the high-gain antenna is usable), the ranging sequence* followed by clock updated ranging is desired for postflight analysis and as a check on the OD solution.

If problems are suspected or confirmed based on telemetry (TLM) or voice data, attempts will be continued at OD using doppler data only. (During these OD attempts, the MSFN will have voice capability even though the high-gain antenna is out.) If the ODP fails to converge within 10 minutes after AOS, range data becomes the highest priority in consideration of SC communications. These data will be obtained using the ranging sequence followed by 20 minutes of clock updated ranging. After this 26-minute period, tracking will be switched to another two-way site (possibly a 30-foot dish) and the 26-minute ranging period repeated. If the high-gain antenna is out or not available due to SC attitude, voice communication with the SC may not be possible during these two 26-minute periods. If the crew has an emergency during these 26-minute intervals and requires voice communications, the ranging can be stopped by the crew. This will require a restart of the 26-minute ranging period. In summary, ranging has number one priority during an emergency situation (whenever the OD process fails to converge) unless the crew overrides the ranging in real time.

6.1.2 Cislunar Free Flight

If the high-gain antenna is available during cislunar free flight, the ranging sequence followed by continuous clock updated ranging is required for each acquisition until the SC is within 17,000 miles of the moon. This applies to 30-foot sites as well as 85-foot sites. If the high-gain is not available, no ranging is required of the 30-foot sites; however, the range sequence followed by clock updated range is required for the 85-foot sites. (Note: At approximately 150,000 nautical miles, voice command and TLM may be lost due to range requirement.) If it is determined in real time that ranging with the 85-foot site interferes with other USB capability, the range requirement will be changed to consist of the ranging sequence followed by 20 minutes of clock updated range every hour rather than

*Ranging sequence consists of three independent range acquisitions spaced at least 90 seconds apart to be accomplished within a minimum period of time.

Table 2. Expected USB Capability*

	CSM Ant.	Site Ant.	Range, Up Voice & TLM**	Range & TLM	Range & Down Voice	Range
Lunar orbit	HG	85	Yes	Yes	Yes	Yes
Lunar orbit	HG	30	Yes	Yes	Yes	Yes
Lunar orbit	OMNI	85	Yes?	Yes	Yes	Yes
Lunar orbit	OMNI	30	No	No	No?	No?
TL/TE < 10^5 mi	HG	85	Yes	Yes	Yes	Yes
TL/TE < 10^5 mi	HG	30	Yes	Yes	Yes	Yes
TL/TE < 10^5 mi	OMNI	85	Yes	Yes	Yes	Yes
TL/TE < 10^5 mi	OMNI	30	No?	Yes?	Yes	Yes
TL/TE > 10^5 mi	HG	85	Yes	Yes	Yes	Yes
TL/TE > 10^5 mi	HG	30	Yes	Yes	Yes	Yes
TL/TE > 10^5 mi	OMNI	85	Yes?	Yes	Yes	Yes
TL/TE > 10^5 mi	OMNI	30	No	No?	No?	Yes?

*Television capability exist from CSM high-gain to 85-foot site only, does not interfere with ranging.

**Downlink voice exists when TLM capability exists, but the reverse is not necessarily true.

continous ranging as is required when no USB capability is impaired. The 20-minute interval does not have to be continuous, but 20 minutes total out of the hour is required. For example, as the SC rotates during PTC, the omni antennas will have to be switch in order to maintain coverage. While ranging is being accomplished, it is possible to drop a few cycles during the omni-antenna switch. If an anomaly is encountered in the range data after the switch, a single range reacquisition will be used followed by clock update ranging. When a sequence such as this occurs, the countdown will continue on the 20-minute per hour ranging requirement.

Within 17,000 miles from the moon, range data is not used for OD. The range data obtained will be used for postflight analysis, independent checks of the OD solution, and to obtain a start vector if required.

Data Select will in real time evaluate the clock updated ranging data. If it appears that a site locked up on a bad range acquisition after the ranging sequence, select will inform FDO and request a single range reacquisition.

6.2 DATA RATES

All tracking sites will use a data rate of one sample every 6 seconds. The actual data rates to be used in OD will be achived by Data Select's utilization of the multipoint option. The data rates for the various mission phase to be used in OD are discribed in the Detailed Procedures section.

6.3 USB ANTENNA ANGLE CONTROL MODES

The tracking sites have two means of controlling the antenna orientation angles, the program track and auto track modes. In the program track mode, the antenna angles are based on the vehicle ephemeris. In the auto track mode, the antenna orientation is controlled closed loop at the site.

Program track during the cislunar and lunar phases will simplify station operations during SC high-gain antenna operations. Frequent signal losses are expected, particularly during PTC, and program track will eliminate the need for angle reacquisition. The tracking sites will be in the program track mode during cislunar and lunar phases except for maneuvers or contingencies when the starter program may be required.

The auto track mode will be used for the following:

a) Earth orbit

b) From cutoff until cutoff plus 2 hours for all cislunar maneuvers greater than 50 feet per second ΔV

c) In lunar orbit following LOI-1, LOI-2, and TEI

d) Any contingency which may require the use of the start starter program

6.4 DATA EOT TAG

The end of transmission (EOT) terminates a batch of data. Due to activities such as PTC, it is not desirable to EOT a site data due to a loss of contact with the SC. The EOT flag is not to be used unless there is an obstruction between the SC and the tracking site. Use of this procedure will prevent the collection of numerous data batches containing fewer data points than desired.

7. MOC/DSC INPUT AND CONTROL

This section describes the input and control of the mission operational computer (MOC) or dynamics standby computer (DSC) provided to Data Select. These controls consist of input processing manual entry devices (MED's), differential correction (DC) logic control, and vector control panel.

7.1 INPUT PROCESSING MED's

The MED's provide Data Select with the capability to manually change inputs to the MOC or DSC in real time. The inputs consist of prestored data, real-time data, and tracking site acquisition data. The MED's provide the capability to do the following:

1) Control acquisition data.
2) Alter station characteristics.
3) Reject, reorder, and delete station data.
4) Adjust time tags.
5) Compensate for data biases.
6) Alter data weights.
7) Alter data rates.
8) Alter vehicle identification (ID).
9) Initiate reentry controls.
10) Alter state vector weights.

7.2 DC LOGIC CONTROL MODULE DESCRIPTION

Two groups of 18 pushbutton indicators (PBI's) are located on the Data Select Console for the purpose of exercising various controls on the differential control program. Listed below are the functions of these PBI's.

a) Control the procedure of the program in an automatic or manual mode.

b) Accept or reject a DC.

c) Place an accepted DC in the UVT.

d) Alter a current station data weight in a multistation solution.

e) Force another iteration on a set of data awaiting a decision.

7.3 VECTOR CONTROL PANEL

The vector control panel, shown in Figure 1, is used to select the vectors (up to four) to be compared via the vector comparison display. The controls allow the selection of vectors from the following sources:

a) Command module computer (CMC)

b) Instrumentation unit on S-IVB (IU)

c) High-speed (HS) radar

d) Differential correction (DC)

The vectors can be transferred to an evaluation slot, the usable vector slot, or the EPH update. The EPH update automatically generates the ephemeris for the CSM* as selected by the vector control panel. The EPH is the real-time trajectory used for trajectory control decisions and information. Other controls are provided to enter the vector in either or both computers as well as to clear the entry.

*Two-vehicle capability exists only through earth orbit phase for the Apollo 8 mission.

CMC	LGC*	AGS*	IU	HS RADAR	DC
CSM	LM* (OTHER)		HIGH SPEED	LOW SPEED	TO EVALUATION SLOT
TO USABLE VECTOR SLOT	TO EPHEMERIS UPDATE	CLEAR	MOC	DSC	BOTH

*NOT USED FOR APOLLO 8

Figure 1. Vector Control Panel Diagram

8. DETAILED PROCEDURES

This section contains the detailed procedures to be used by Data Select in the RTCC operations for the Apollo 8 mission. In general, Data Select is responsible for the monitoring and control of the DC as well as to insure that the ephemeris is based on the best vector available.

8.1 DATA RATES FOR OD

All tracking sites will use a data rate of one sample every 6 seconds. For cislunar and lunar orbit phases, where geometry does not change rapidly with time, it is expected that too much data in too short a time interval will hinder the data processing. Since RTCC is constrained to 30 batches of data containing 80 observations at most (per vehicle), the six tracking sites using a 1/6 sample rate will generate a 40- minute data arc. Shortly after TLI, this data arc is too short to accurately determine the SC trajectory. In order to obtain data arcs that are sufficient for OD, Data Select will exercise the multipoint option. This option has the effect of increasing the time between observations. Through the use of this option, the effective data rates shown in Table 3 will be used.

The intent of the 1/90 second data rate is to obtain data batches from 2 to 3 hours in length. If these batches tend to be longer than 3 hours due to PTC, the sample rate will be altered in real time.

8.2 DIFFERENTIAL CORRECTION PROCEDURES

The DC procedures to be used for earth orbit, cislunar flight, and lunar orbit are described in this section.

8.2.1 Earth Parking Orbit

As a station ends its transmission, a DC is performed. The purpose of the DC is to obtain the state vector that best fits the radar data in a weighted least squares sense. The following fundamental questions arise due to this DC:

a) Are the data valid?

b) Is an orbit change (or ephemeris update) required?

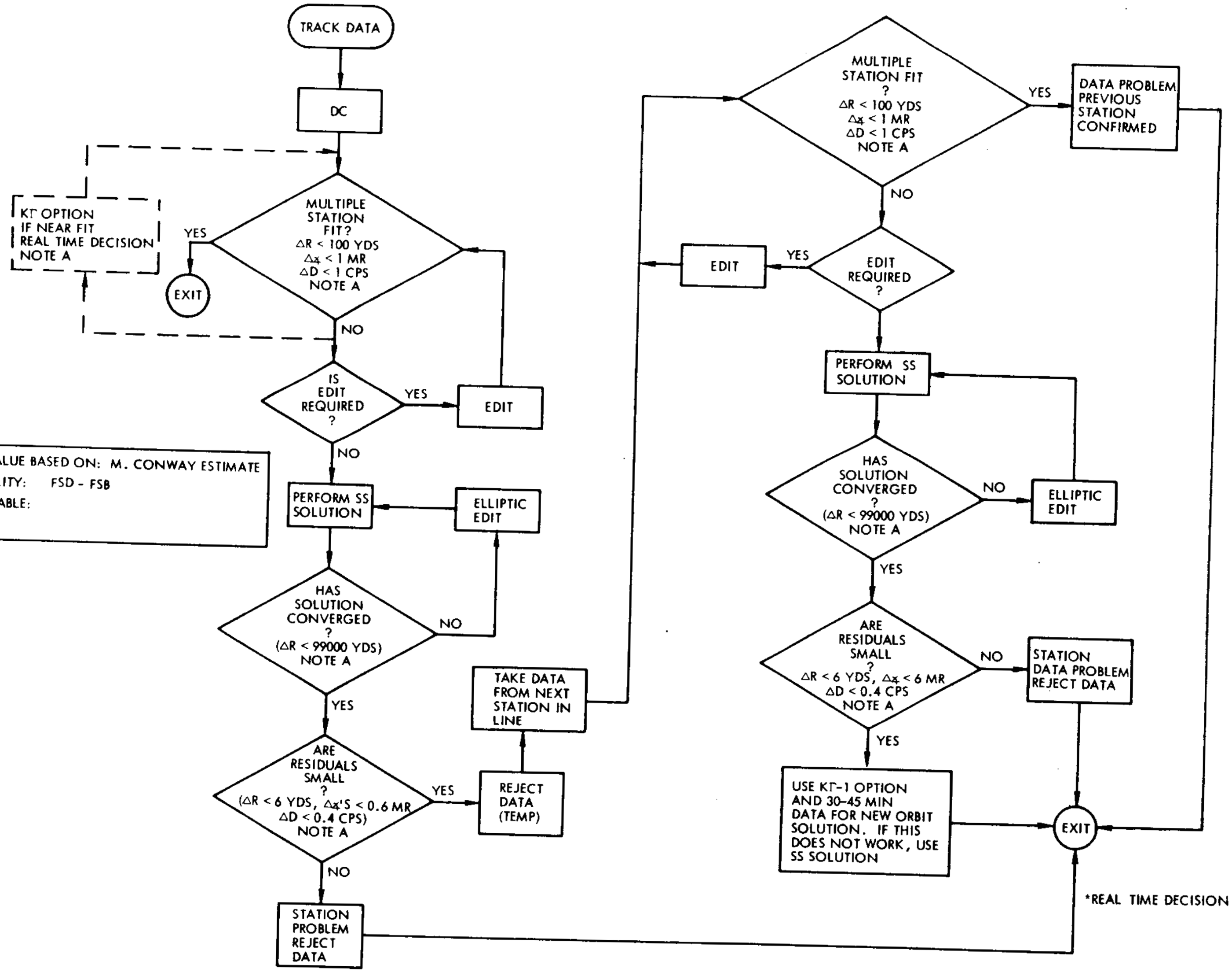
The logic flow to arrive at the answers is given in Figure 2.

Table 3. Effective Data Rates to be Used for OD

Mission Phase	Effective Data Rate*
Post-TLI to TLI + 45 min	1/6 sec
TLI + 45 min to TLI + 2 hr	1/18 sec
TLI + 2 hr to MCC-1	1/60 sec
Post-MCC-1 to Pre-LOI	1/90 sec
LOI-1, LOI-2 first 16 min after AOS	1/6 sec
Lunar orbit (other than LOI's)	1/18 sec**
TEI first 24 min after AOS	1/18 sec
Remaining TE	1/90 sec
EI-2 hr to EI-20 min	1/18 sec
EI-20 min to splash down	1/6 sec
MCC's	1/18 sec
Starting 2 min prior to IGN for a 10-min duration	1/6 sec
All other phases	1/6 sec

*Effective data rate is obtained using the multipoint option on the tracking sites 1/6 sec data rate.

**This data rate will decrease for off-nominal large period orbits.



NOTE A

CURRENT VALUE BASED ON: M. CONWAY ESTIMATE
RESPONSIBILITY: FSD - FSB
DATE AVAILABLE:
REFERENCE:

Figure 2. Earth Orbit Procedures Logic Flow

As the DC is performed, Data Select should monitor the DC Summary Display. If the residual root mean square (RMS) is small including the new station data, no action is required. Small residuals are generalized to include RMS values less than 100 yards in range, 1 milliradian in angles and 1 Hertz in doppler.

If the residuals are close to these values, Select can exercise the $K\rho$ option to alter the variances on drag and μ and the DC can be performed again. This can be repeated and may bring a marginal set of data in tolerance. Another situation that can exist is to have a good orbit established and with the inclusion of a new set of data, the residuals look good, but the state change is large (greater than 0.5 foot per second). In this case, the $K\alpha$ option can be used to downweight the latest data and thus reduce the state vector change. If the next station in line indicates a similar vector change, $K\alpha$ can be removed from the first station and the solution repeated with both of the later data batches.

If the residuals of the multistation (or batch) solution are not small with the addition of the last station's data, the latest data may require editing. The editing can be accomplished using MED entries, such as:

a) Preedit - deletes points with residuals greater than a specified value (used for biased data)

b) N1/N2 Edit - deletes data over specified time interval (used for biased data)

c) DC Edit Coefficients - deletes data with residual values larger than N sigma - N specified with the option call (used for noisy data).

After the edit, the DC can be tried again. If the residuals are small after editing, no further action is required. If the residuals are still large, a single station (SS) solution should be performed with the intent of determining if something is wrong with the latest data. The RMS values for an SS solution should be between 5 and 6 yards in range, 0.1 to 0.6 radians in angles, and less than 0.4 cycles per second in doppler. Larger residuals than these indicate that the data are not so high in quality as normal. If the residuals are extremely large even after an SS solution, the elliptic edit program will have to be called to force convergence for the SS solution. Even though the SS solution may be bad, the data should not necessarily be rejected. Rejection of data should be made with careful consideration given to the quality of the existing orbit.

Assuming the SS solution indicates small residuals, then one of several problems may be presenting itself: the covariance matrix indicates too great a weight on the vector; or the data is biased in some way (such as station location error). When two consecutive stations indicate large residuals, then in all probability a correction to the orbit is necessary. This condition may arise due to small attitude control maneuvers. When this case is recognized, the DC program should be repeated (SO3 MED) to a batch of data between 30 and 45 minutes old. Then the $K\Gamma$-1 option should be exercised to downweight the previous data and the stations in turn should again be DC'd. This procedure may have to be repeated several times if upon returning to the current batch of data, the residuals are still large. Select should resort to an SS solution only if this procedure does not work and two successive stations indicate the orbit should be changed.

8.2.2 Cislunar Flight

The DC procedures to be used for cislunar flight are to be determined.

8.2.3 Lunar Orbit

The DC procedures to be used in lunar orbit are to be determined.

8.3 POWERED FLIGHT SOURCE AND LAUNCH TRANSFER VECTOR

During the period from launch until escape tower jettison, FDO has directed Select to use a booster data source for display driving, if possible. The need for the booster source is due to the RTCC program handling of the escape tower ΔV. This ΔV is added to the state at the time of the mode I abort to determine the postabort state. Sources other than a booster source will contain this ΔV and result in the tower ΔV being added improperly. The FDO preferred source is impact predictor smooth (IPS) with the IU data as the alternate. If these booster sources are not available, then the order of the preferred sources is:

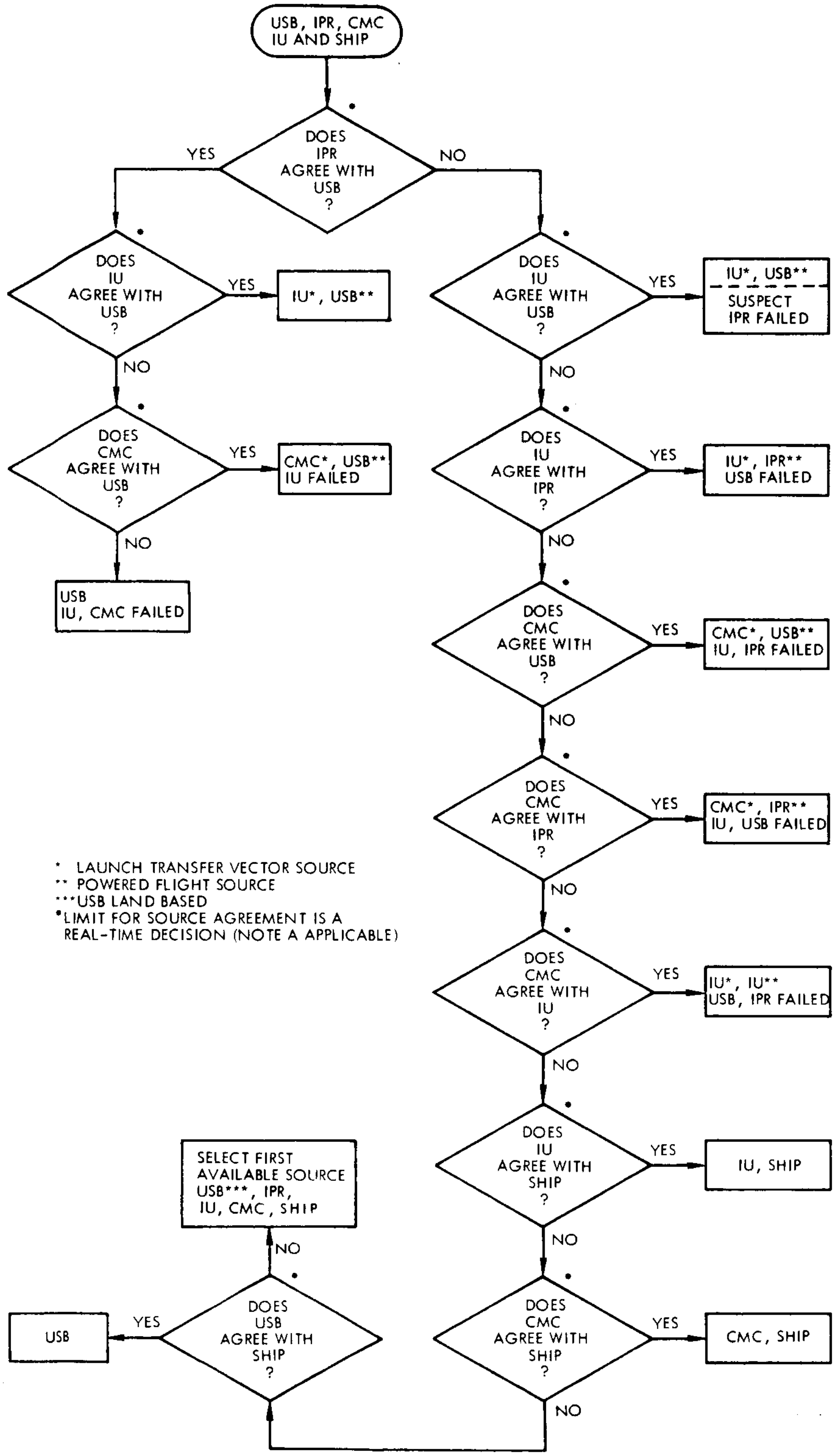


Figure 3. Logic for Selection of Launch Transfer Vector and Powered Flight Source

a) USB

b) CMC

These two are not booster sources, and the resulting error must be dealt with by FDO in real time.

The remainder of this section deals with the selection of the launch transfer vector and prime display driving source for powered flight from the time of escape tower jettison to insertion. The launch transfer vector is used to generate the ephemeris. The source selected for prime display driving will be the source deemed to be the most accurate. The data sources available during this phase are listed in the Table 4. In addition, the relative accuracy and reliability are indicated (the numeral 1 being associated with the better source). The relative reliability rating is used to validate the performance of sources in the event that no two sources agree and further information to base the decision on is not available.

Table 4. Relative Accuracy and Relative Reliability of Launch Data Sources

Source	Accuracy	Relative Reliability
IU	1	3
CMC	2	4
USB	3	1
IPR, IPS	4	2
Ship C-band	5	5

The data sources are evaluated by monitoring MSK 1613, MSK 1614, plotboard one, and plotboard four. The first three displays provide V, γ plots; the fourth display is latitude versus longitude for impact as well as the vehicles present position. These monitors are used to determine which of the various data sources are in agreement. The RTCC operational procedures for these comparisons are the following:

a) If three sources are plotting smooth, consecutive points and one curve differs from the other V, γ source plot, then that single data source is biased. Report to FDO that the source is biased.

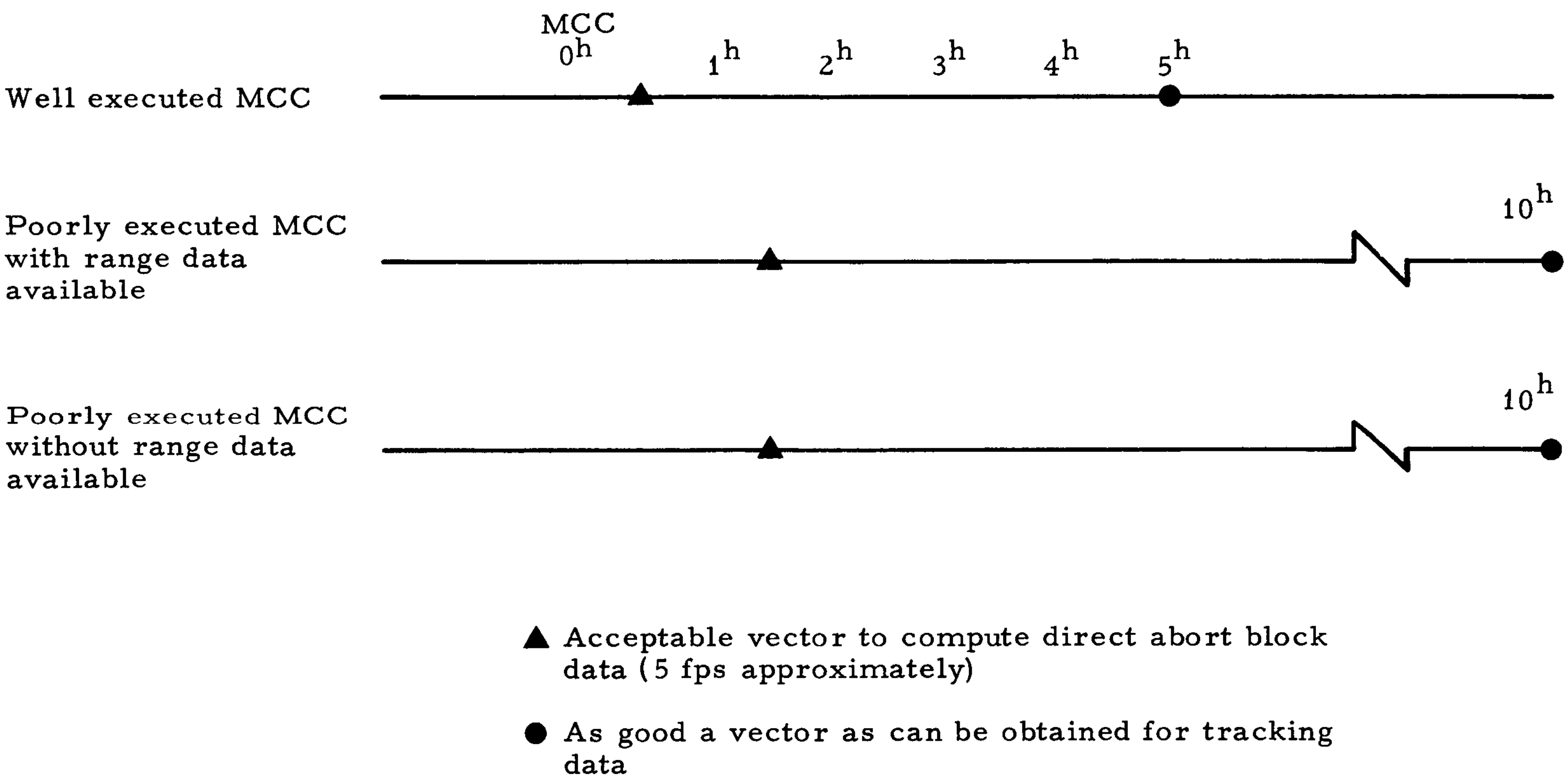
b) If any two sources agree, stay on one of these two sources.

c) If no two sources agree, there is no sure way to tell which, if any, source is correct. The selected source in this case should be that source with the greatest confidence factor since lift-off.

d) If noise appears on a source, inform FDO that the source is noisy. This source should be selected only if other sources are missing or biased.

Based on these procedures, the logical flow to select the launch transfer vector (LTV) and the powered flight source for the next mission phase are given in Figure 3. It should be noted that the selections are based on agreement between various sources. In general, the logic for the choice is to compare the sources thought to be most accurate to those thought to be most reliable. The desired selection is to use a TLM source for LTV and a radar source for powered flight. Before a TLM source is selected as the LTV, its out-of-plane components are checked to assure that it is a reasonable vector. This test is monitored by FDO. The flow chart of Figure 3 assumes this test has been passed by the selected TLM source. Assuming data are obtained from the IU, CMC, USB, and IPR, the first step is to see if the USB and IPR data agree. If these sources are in agreement, the USB will be used for powered flight. The IU data are then compared to the USB and if they agree, the IU is used for the LTV. In the event they do not agree, the CMC is compared to the USB. If these are in agreement, the CMC is used for the LTV. If they do not agree, the USB or IPR can be used for the LTV.

Table 5. Vector Availability Following MCC



Note: No unmodeled vents assumed.

For the case when the USB and IPR data do not agree, a so-called "tie" exists. In order to break the tie, the USB and IPR are alternately compared to the IU and CMC data in an attempt to establish two sources in agreement. If agreement is found in this sequence of tests, the TLM source is used for the LTV and the radar source for the powered flight. If the IU or CMC do not substantiate either radar source, the two TLM sources are checked. If they agree, the IU will be used for LTV, and either the CMC or IU can be used for powered flight. If the TLM does not agree, the ship radar is compared to the TLM sources. If agreement is found between a TLM source and the ship radar, the TLM is used for the LTV and ship radar for the powered flight source. If these do not agree, the final test is to compare USB versus ship. If the USB is validated, it will be used. (The ship and IPR data cannot be compared.) If no two sources are found to agree and further information is not available, then the first available source in the reliability list of Table 1 is selected.

In general, these sources should be in close agreement, and these procedures are for the unlikely cases.

8.4 INSERTION PROCEDURES

The logic flow for the insertion procedures is given in Figure 4. It is assumed that the LTV has been selected and the ephemeris has been generated from this vector. If a radar source was used to transfer to orbit phase, the ephemeris should be updated with the first DC solution. If an IU vector was used at orbit initiation to update the EPH, an a priori weight will be used for the first DC. If a TLM vector (CMC or IU) was used to update the ephemeris at orbit initiation, then each DC vector should be compared to the EPH vector to determine how well the radar data agrees with the TLM vector. After inclusion of Canary Island (CYI) data in the multistation DC solution, the TLM and DC vector should agree within 3, 000 feet and 10 feet per second. If the differences are greater, the EPH should be updated with the DC vector. If the differences are within these limits, no update should be performed. If the CYI solution is a single station solution, these limit should be 5, 000 feet and 30 feet per second.

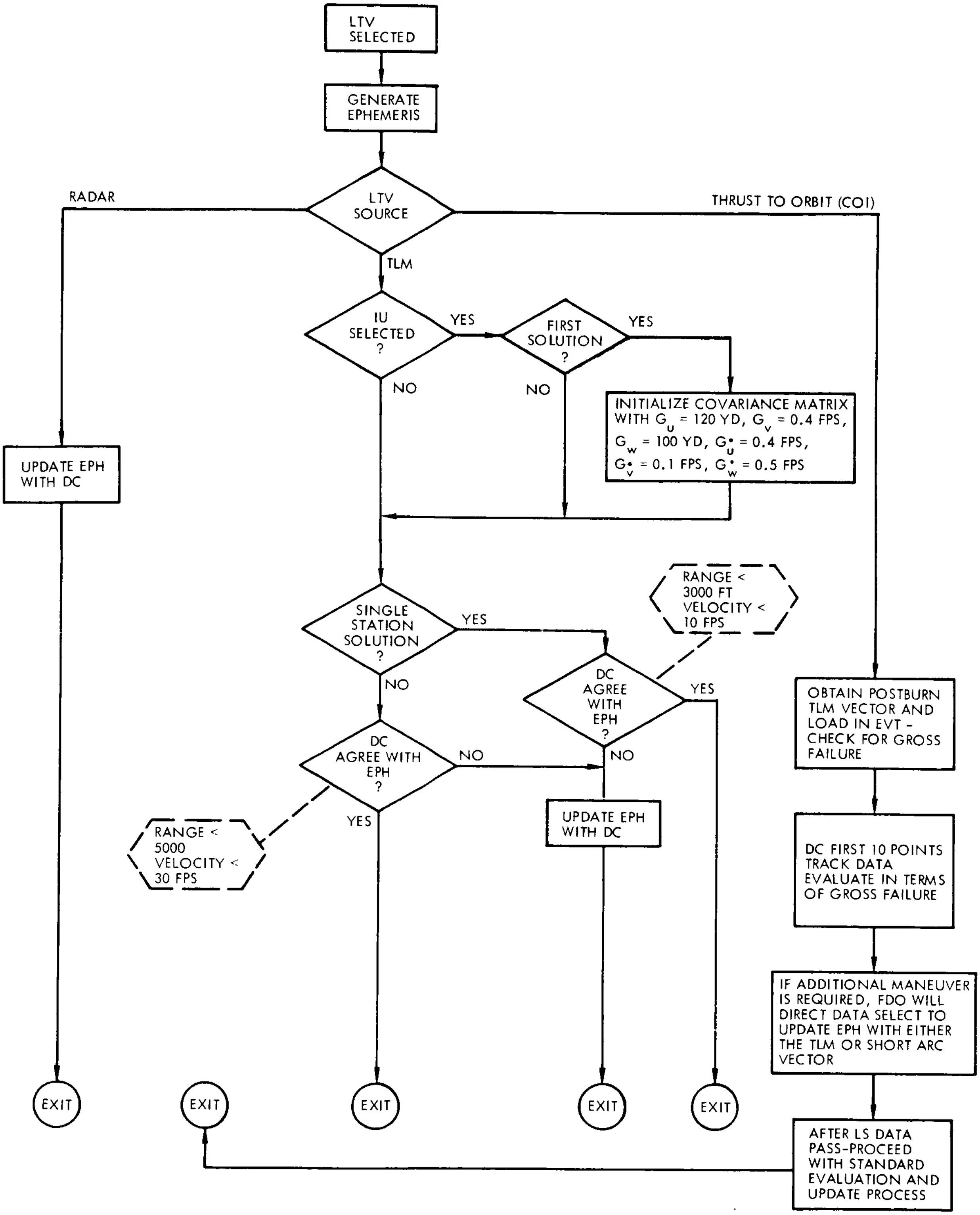


Figure 4. Insertion Procedures Logic Flow

In the event of a contingency insertion in which no CMC vector or radar track was obtained after the maneuver, then upon receipt of a TLM vector following orbit initiation, this vector should be loaded in the evaluation vector table (EVT). This vector should be checked only to assure that it is reasonable and no gross failures have occurred. With the receipt of 10 tracking data points after insertion, a DC should be performed and evaluated to determine that the solution is reasonable. If an additional maneuver is required, FDO will direct Select to update the ephemeris with either the TLM vector or the 10-point DC solution.

After completion of the low-speed data pass, normal procedures will be used by Select for evaluations and updates.

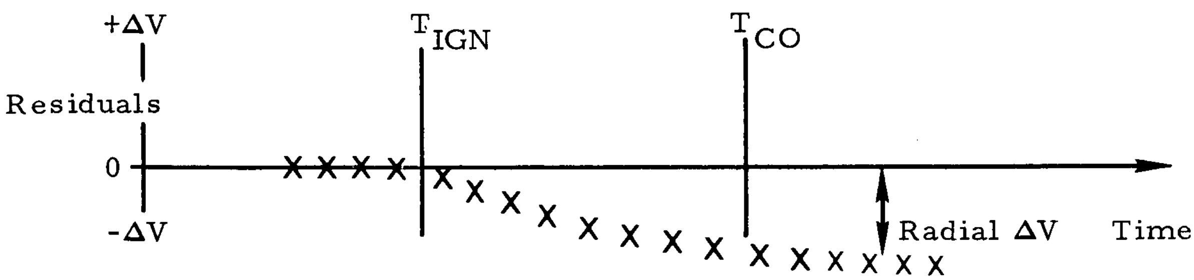
8.5 TLI PROCEDURES

During the TLI burn, Data Select will monitor the CMC and USB data (if available) in the high-speed mode to obtain a gross check on how well the maneuver is performed. At TLI cutoff, the CMC, EPH, and HS radar vectors will be displayed on the vector comparison display. FDO will recommend which vector to use. After an 8-minute postburn data arc is obtained, Select will perform an OD solution and place the resultant vector in the UVT. FDO will use this vector to run an initial best adaptive path (BAP).

At S-IVB/CSM separation, Select will recommend a vector. Normally this will be the DC vector. After separation, the minimum batch size will be set to 20 points to keep each data batch as large as possible without sacrificing information. Also, the minimum elevation will be set to 5 degrees. When the first data batch (postseparation) is obtained and processed, Select will give FDO the best vector (OD, EPH, or CMC) to be used for block data computation. At TLI + 3 hours Select will furnish FDO a vector for preliminary MCC_1 planning and computation. This vector will probably be the low-speed radar OD solution. At TLI + 4.5 hours the vector to finalize MCC_1 will be used to update the EPH. At TLI + 2 hours angles are no longer processed in the DC.

8.6 MCC MONITORING

Approximately 2 minutes prior to a MCC, Data Select will enter a one sample per 6-second mode and remain in this mode for 10 minutes. During this period, the residual display will be monitored to obtain a feel for how well the MCC is executed. A typical trend expected from the residual display is shown below. The display shows the change



in the radial velocity during the burn and the radial ΔV resulting from the burn. This information should be useful to FDO for burn confirmation.

8.7 MCC MANEUVER PROCEDURES

Two problems presented by maneuvers are the maintenance of the vehicle ephemeris and the selection of the proper weight to place on pre- and postburn data. Both these problems are related to the modeling of the burn in the mission plan table (MPT). The ephemeris problem is related to how well the MPT agrees with the burn in the deterministic sense, while the data weight is related to the burn model in the statistical sense. These problems are not independent; however, for the purposes of describing Data Select's Maneuver Procedures, they are presented separately.

8.7.1 MCC Maneuver Ephemeris Procedures

In general, the premaneuver ephemeris will be based on the best DC vector available prior to a maneuver. The maneuver ephemeris procedures, shown in Figure 5, are developed to perform the checks

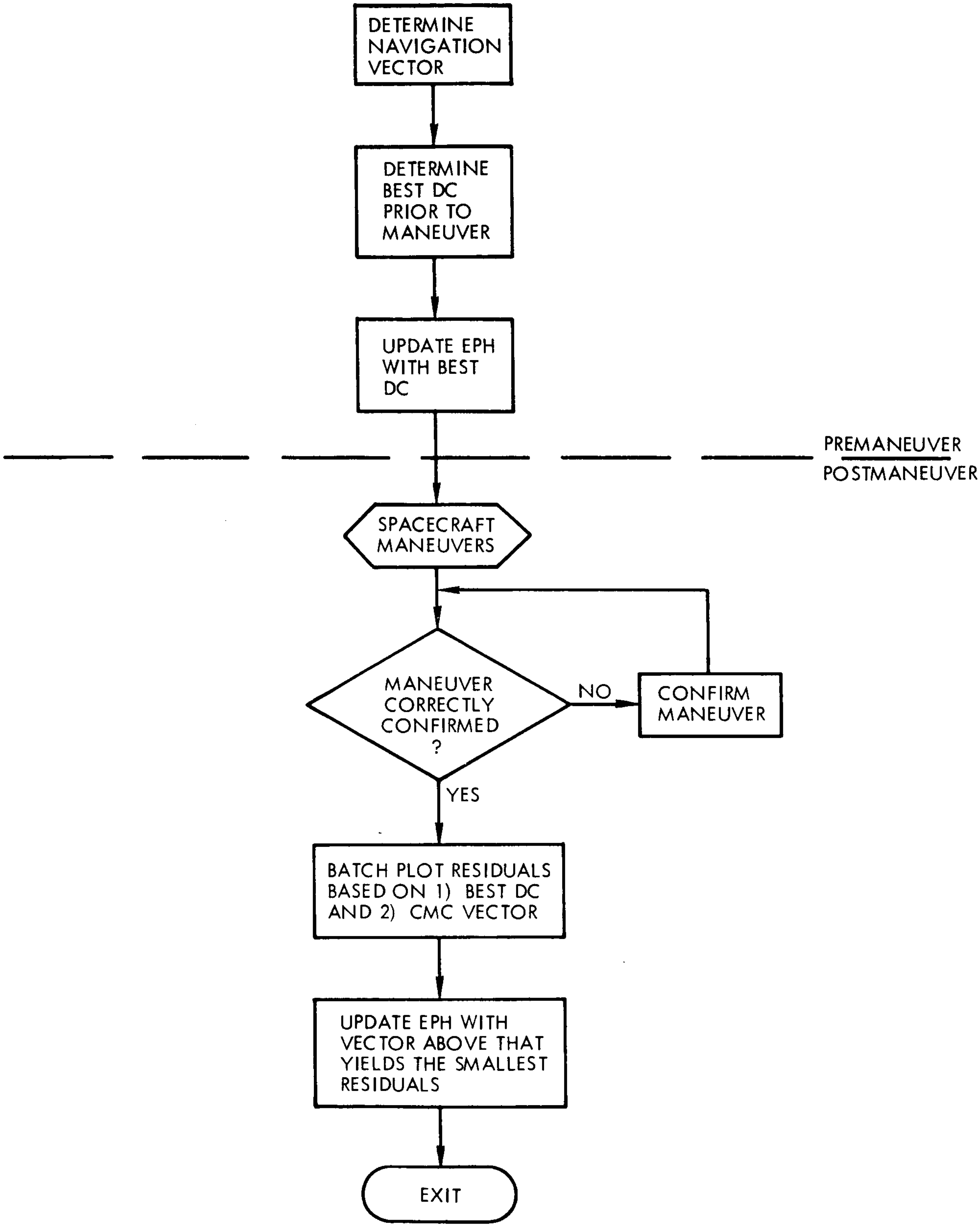


Figure 5. Maneuver EPH Procedure

needed to select the best postburn vector. Since FDO has agreed to confirm the maneuver as accurately as possible, the navigation (NAV) vector integrated through the maneuver, using the MPT, should agree with the CMC vector since the NAV vector was used to update the CMC prior to the burn. Provided the CMC is available and the maneuver is confirmed, these vectors will agree unless:

a) The TLM link is out or noisy.

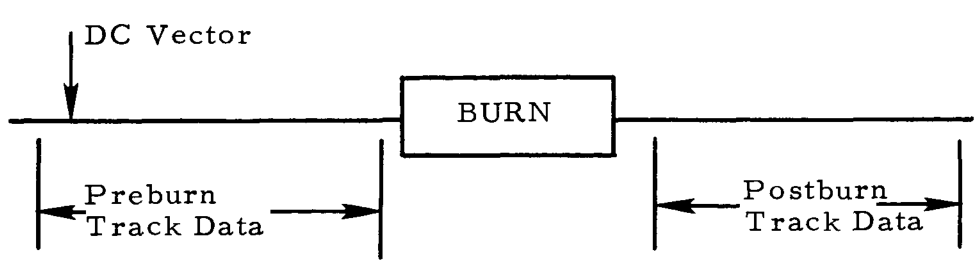
b) Major platform or computer failure occurs.

c) The time interval from the generation of the NAV vector to the time of the CMC vector is large enough that drag versus no-drag computations are significant.

It should be noted that undetected platform misalignments, drifts, or accelerometer errors will not result in disagreement of these vectors so long as the maneuvers are G&N controlled. This comparison does not confirm the IMU performance.

8.7.2 MCC Maneuver DC Procedures

The problems encountered with differential corrections through a maneuver are due to the uncertainty in the actual burn. Schematically, the problem is illustrated by the following sketch. Prior to the burn, the track data have been used to obtain a state vector. If the burn were not present, or if it were precisely known, the problem would be similiar to fitting through an arc of data continuing in region in which there was data



dropout. In this case both arcs of data would receive equal weights. This is the situation for small maneuver uncertainties. If the burn is unknown (or unconfirmed), the postburn data must be used to determine the state of the spacecraft. In this case the burn uncertainty is large and results in downweighting of the preburn data. The effect of the burn (or maneuver) uncertainty is to alter the weight placed on pre- and postburn data.

Since the quality of a fit through a burn is altered by the maneuver uncertainty, it is necessary to vary these uncertainties in the real-time solutions. This is performed by Data Select. His determination of proper maneuver uncertainties is made by halving or doubling of the maneuver uncertainties over a data arc and observing the quality of the fit of pre- and postburn data. The judgement of the quality is based on the magnitude of residuals, the trend of the residuals, the corrections to the state vector, knowledge of the involved stations performance, station geometry, etc. The logic used by Data Select is illustrated in the maneuver DC procedures flow chart (Figure 6). The procedures consist of taking new batches of postburn data as they are received and performing DC's using different values of maneuver uncertainties for each fit. The purpose is to find the best values for the maneuver covariance. If the pre-and postburn data cannot be fit using the allowable covariance (maximum and minimum values specified), postburn multistation solutions will be used to update the ephemeris.

An estimate of the time required to obtain a vector acceptable for computation of direct abort block data and to obtain a vector of quality suitable for maneuver targeting is given in Table 5. The three cases consider the execution of the MCC. The execution of the burn is assessed in real time by FDO through the burn confirmation procedures. The cases with and without range data do not differ if no unmodeled venting occurs. If unmodeled vents do occur, range data will offer considerable advantage in obtaining good position solutions.

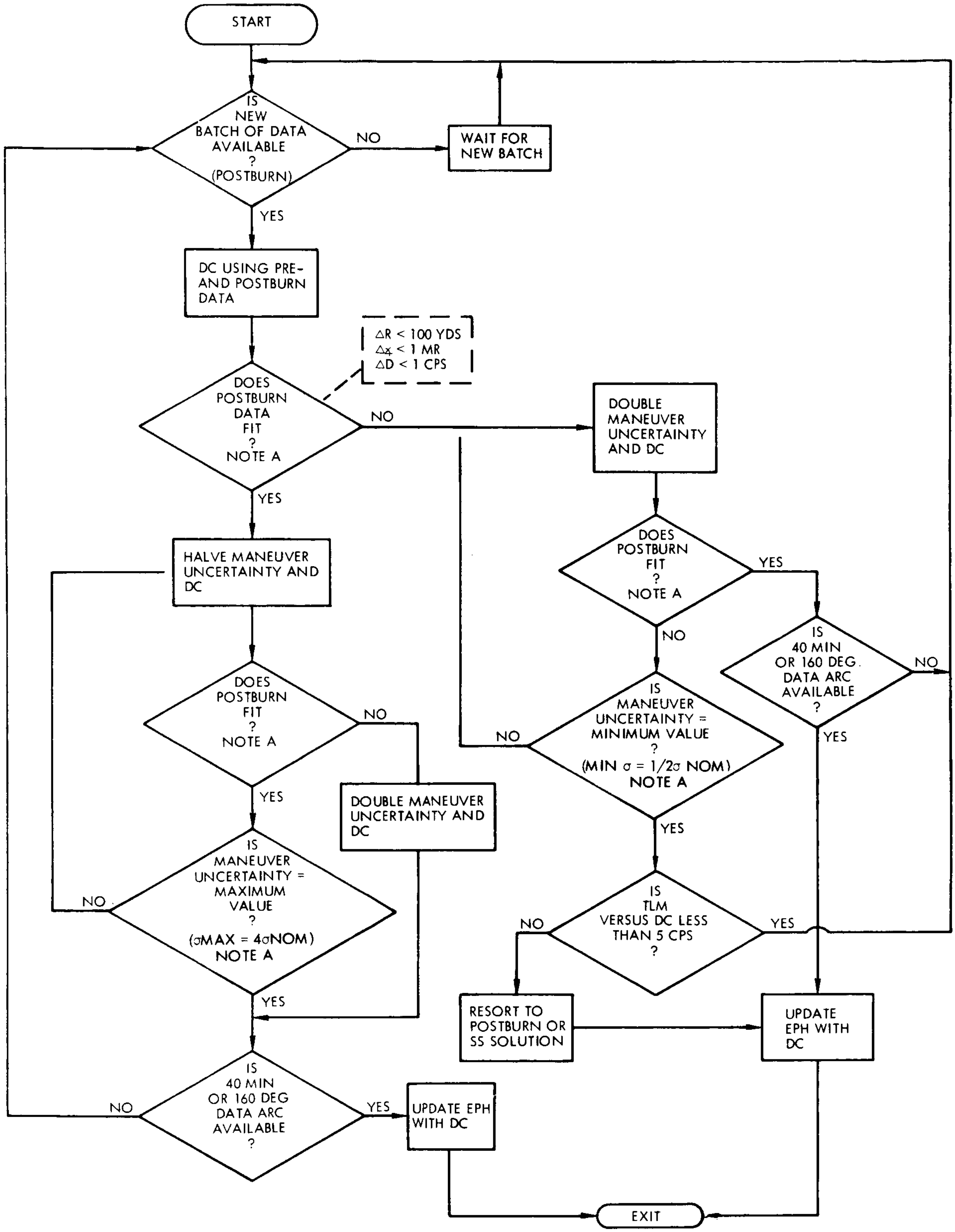


Figure 6. Maneuver DC Procedures

8.8 LPO PROCEDURES

The first solution following LOI-1 and LOI-2 is a short-arc solution which should be available 20 minutes after AOS provided no convergence problems are encountered. This short-arc solution will be used for status confirmation. That is, the solution will give reasonably confident values for perilune and apolune altitudes. Obviously, these parameters are very important after a large burn. The final solution will be a superbatch solution on a data arc acquired from acquisition of signal from (AOS) to loss of signal (LOS). This vector will be of sufficient quality for maneuver planning. The availability of these vectors for the various types of burn confirmations is given in Table 6.

The logic flow for the lunar orbit OD solutions is given in Figure 7. The use of the TLM vector following the burn assumes FDO has confirmed that the MPT and actual burn agree as close as possible. This confirmation considers crew inputs, guidance and navigation (G& N) performance, as known, and any other pertinent information available.

8.9 TEI PROCEDURES

About 40 minutes after AOS following TEI, a vector adequate to confirm status will be given FDO. One and one-half hour after TEI, Select will furnish FDO a vector suitable for maneuver planning.

8.10 REENTRY PREPARATION AND REENTRY

FDO will provide the updated tracking ship position prior to reentry. Tracking coverage for the reentry phase may be determined from the deorbit predicted site acquisition display (MSK349). Table 7 summarizes the entry preparation.

During the reentry phase, Select should monitor the CSM DC Summary display and the entry mode III digital displays. TLM vectors are not processed by Select during reentry. About 1 minute after the entry

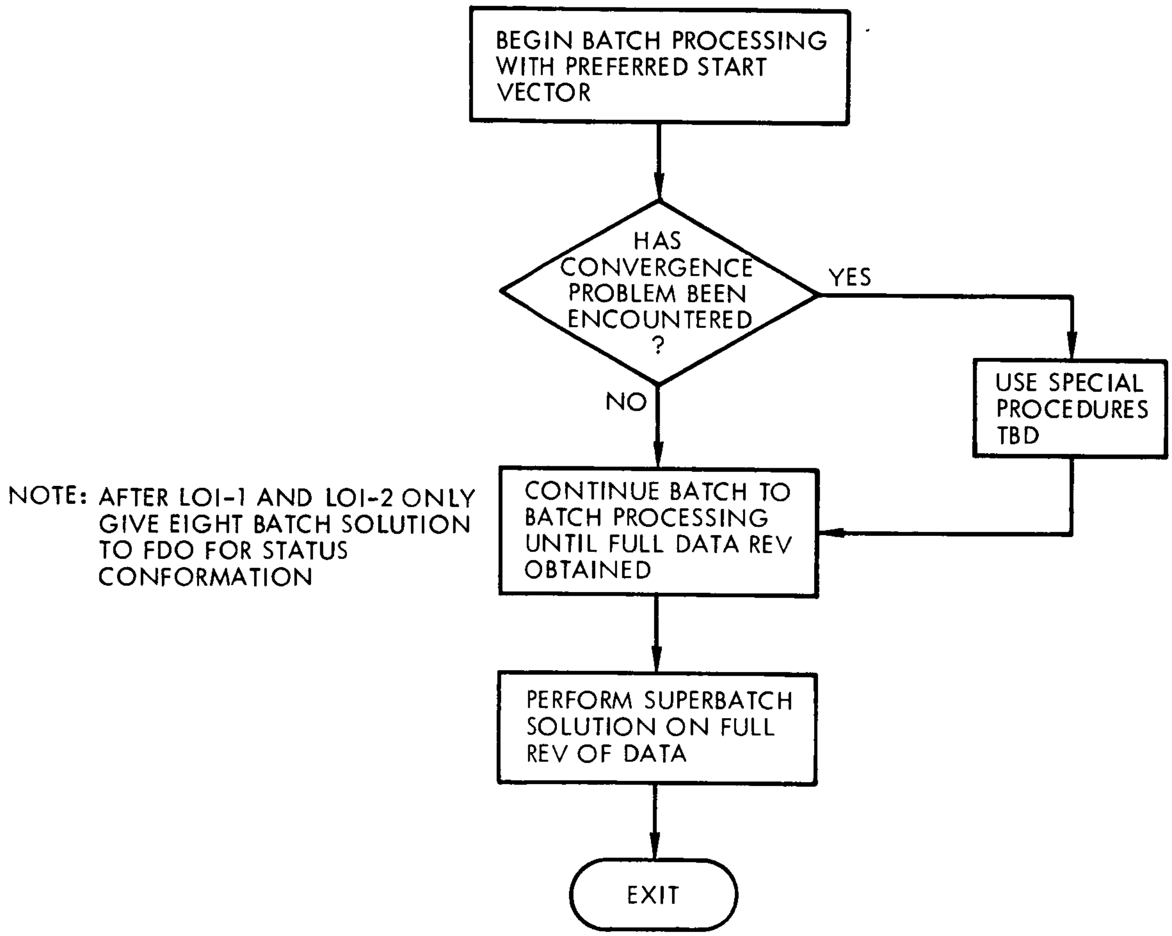


Figure 7. Logic Flow for LPO Procedure

Table 6. Lunar Orbit Vector Solution Availability after LOI

LOI	MSFN AOS	8	16	20	24	32	40	Time (min)
(TM vector agrees) Good burn report	▨			●				full rev ▲
(No TM vector) No idea in LPO				● (if conv)				full rev ▲ (if conv)
LOI-1 abort burned chart (basically like TEI but without good start vector) also applicable for manual takeover TEI							(36 min) ●	(1.5 hr) ▲
Butterfly cutoff							●	(1.5 hr) ▲

● Answer is not for maneuver planning but to confirm status ($h_A - h_p$ good solution)

▲ Good for maneuver planning

interface (GMTEI), the maximum batch size should be set to 10 points as opposed to the normal maximum batch size of 80. As the data are received, multistation solutions should be performed as long as possible and single station solutions performed on each set of data that does not fit with the multistation solution. The ephemeris should be updated with each accepted DC vector. After each update, the entry mode III digitals should be hardcopied. Particular attention should be paid to either the impact points or bank angles (for guided targets), since these quantities are the only parameters available to determine how good or bad the vector is. The logic flow diagram for the reentry phase is given in Figure 8.

8.11 LAUNCH ABORTS

The following procedure is used by Data Select for mode I aborts using the launch escape system and mode II aborts using a full-lift entry into the Atlantic continous recovery area (ACRA).

a) Monitor RFO I/II abort digitals (MSK331, mode 1/2 abort phase (MSK1615) and the digital display drivers (DDD's) for each source.

b) Compare V versus H plots for all data sources.

c) Keep FDO informed of the quality of each source.

d) Select the best source based on past history information or depending on agreement with other sources.

e) Reason for recommending to FDO to transfer to low-speed processing:

    1) Questionable quality of high-speed data

    2) Missing high-speed data or data dropout

f) Upon phase initiation, set the maximum batch size to 10 for the CSM (use MED S27) and proceed with reentry procedures.

The procedure for the mode III aborts involving a service propulsion system (SPS) retroburn and subsequent half-lift entry into the Atlantic discrete recovery area (ADRA) is a modification of the reentry procedure.

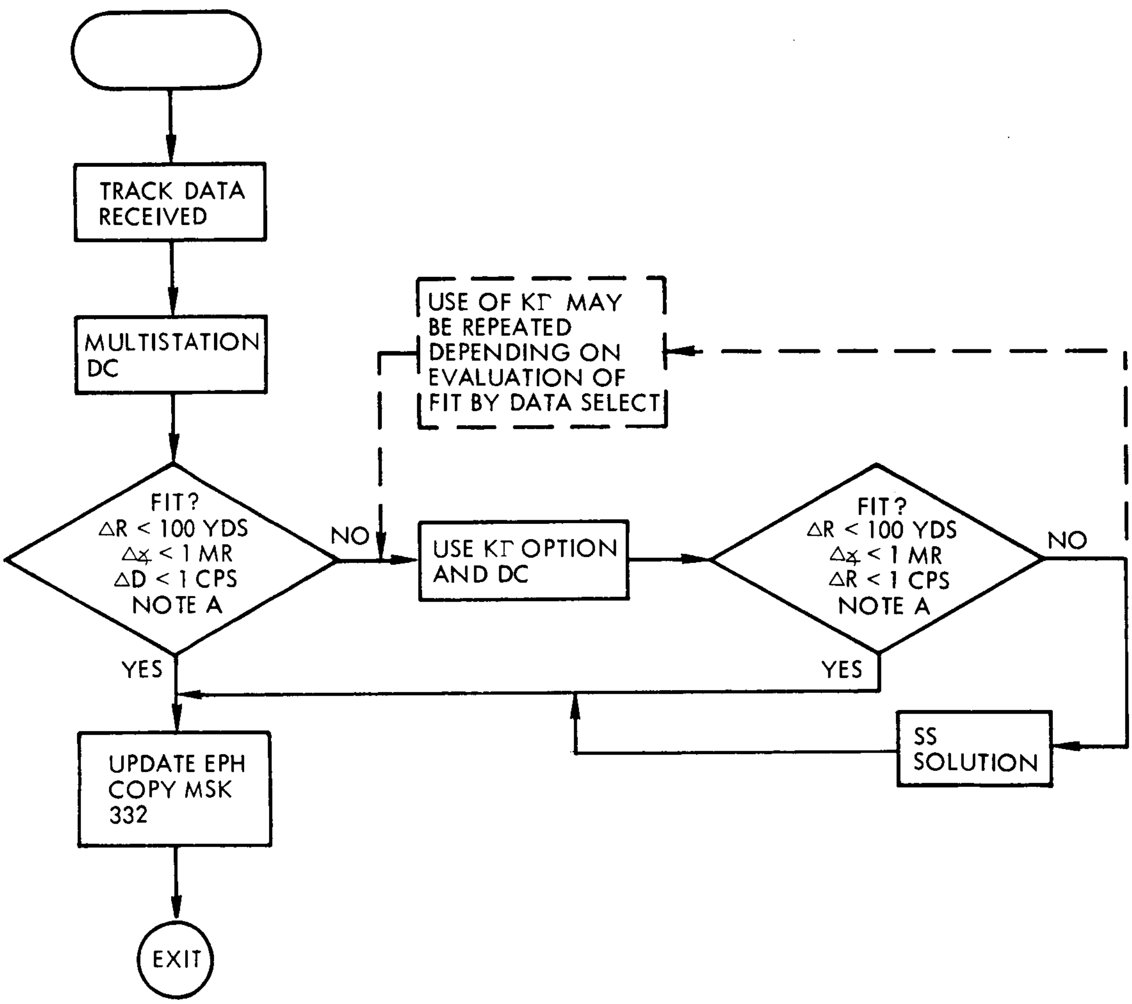


Figure 8. Reentry Logic Flow

Table 7. Entry Preparation

Time	Action
EI - 2 hr	1/18-sec data rate Min batch = 6 points Unsuppress use of Δ's in DC
EI - 20 min	1/6-sec data rate $\epsilon_{min} = 3^{o}$
EI + 1 min	Max batch = 10 points

APPENDIX

The procedure to validate the MSFN/RTCC orbit solution prior to LOI by comparison to an independent source is as yet undefined.