

UNITED STATES GOVERNMENT

Memorandum

TO : FC551/Head, Flight Dynamics Officer Section

DATE: APR 19 1969

FROM : FC551/William M. Stoval, Jr.

SUBJECT: RTCC Differential Correction Process

Enclosed is a two-part explanation of the RTCC Differential Correction Program as it will be established for the Lunar Landing Mission.

The first section is a general explanation of the process and its various elements, with little emphasis on technical correctness. The second portion is a detailed examination of the process and includes thorough investigations of programs, software, etc.

As mentioned, the paper is intended to describe the LIM program, thus some of the procedures explained may not be implemented at this time.

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Enclosure

FC551:WMS:ewp



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INTRODUCTION

The RTCC Differential Correction (DC) process is basically an orbit determination program in which low-speed radar data is processed in order to establish orbited elements and continually improve our knowledge of the orbit. The Flight Dynamics Officer (FDO) in the performance of his mission assignment will depend heavily on the outputs from this program. The first portion of this report explains this complicated program in general terms.

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* SECTION I GENERAL DESCRIPTION

Essentially, the DC process takes low-speed radar inputs from remoted sites and uses these observations to compute solutions for vehicle position and velocity. As long as the orbit remains relatively unperturbed (no maneuvers, etc), these solutions will give better estimates of the orbital elements as more data is received. It is the responsibility of Data Select to keep this program working smoothly by outputting good solutions that may be made available for the Flight Dynamics Officer's use.

More specifically, the program uses an anchor or state vector which represents the present estimated orbit and computes from this vector several orbital parameters. These computed values are compared to the actual observed quantities. Then, utilizing these results, the program makes corrections to the state vector. The actual procedure is outlined as follows.

The program takes the state vector at some time (t_0) and integrates this vector to the beginning of a particular station pass (AOS). From this base vector, the program then predicts the vehicle flightpath through the pass and computes values of certain quantities based on that prediction. These quantities correspond to the observed quantities for that particular station (azimuth, elevation, and range; X and Y angles, range, Doppler). Then, as the station transmits the radar data to MCC, it is collected in batches, and these actual observations are compared to the computed values. The results are averaged and standard deviations (σ) are computed. Points (observations) not falling within a certain tolerance level (3σ) are eliminated from the comparison. The process is repeated several times until, finally, a curve is fitted through the data which compares fairly well with the predicted arc. The iterated fit will be somewhat different than the predicted curve however, and the reliability of the station data must be weighted with respect to the confidence held in the state vector. The decision as to how great an impact a particular solution is allowed to make on the ephemeris (state vector) is the responsibility of the Data Select.

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As more and more batches are processed, the confidence in the state vector will grow and the predicted and fitted curves will become more nearly identical. This increased reliability in the state vector is reflected by the covariance matrix, which is a summation of history data that is used as a weighting factor in the calculations.

The covariance matrix may best be thought of as a series of error ellipses which form a tube around the actual vehicle flightpath. After insertion, prior to the processing of any radar data, the tube is large due to our inaccuracies in estimating vehicle position. As data begins to be processed, however, the tube continually narrows as our knowledge of vehicle position becomes more accurate. Eventually the tube will become very small, encircling the flightpath in narrow bounds. Periods of limited coverage, orbital perturbations, or poor tracking data tend to loosen the tube however, causing our confidence in history data to lessen. Maneuvers, furthermore, with the resulting changes in the orbit, cause the tube to widen nearly to its post-insertion boundaries, causing the entire process to be repeated.

As each batch of collected data is processed and accepted (assuming good data), it is allowed to change the covariance matrix by some factor, thus, effecting our knowledge of the orbit. As more and more batches are accepted, the covariance strengthens, as does our confidence in the generated ephemeris. All stations, however, are not allowed to have equal impact on the covariance. Stations with a history of good data transmission and reliable observations are given more weight than those with marginal performance. Furthermore, in the real-time situation, data that seems somewhat poor may be accepted, but downweighted, in order that it might be allowed to reflect itself in the covariance, but not too strongly. The entire process is quite complicated but this discussion gives a good indication of the technique involved.

Since the solutions output by the program are a direct function of the quality of the observations being processed, maximum care is taken to prevent poor data from being processed. One important routine that

has been included for this specific purpose is the elimination of thrusting data from the batches. Since low-speed radar transmission is continuous, a station over which a maneuver is performed will necessarily include thrusting observations in the data stream. It is an inherent tendency of this data that thrusting observations will so adversely affect the solution as to make it totally (or nearly) useless. In order to prevent this obviously undesirable situation, the DC program has provided that all points falling within the defined maneuver ignition and cutoff times (MPT version) will be tagged "invalid". Data is broken into batches around the maneuver and thereby, assuming nominal execution, no thrusting data is included in the computations.

After the solution is obtained, the routine is ended with several important calculations. Once the solution vector is obtained, a new covariance matrix and state vector are computed. The state vector is then integrated to the next station AOS, while the covariance is propagated forward to this same time. After these computations are completed, the program is ready to repeat the cycle.

This (briefly) is the process involved in the DC program. The second portion of this paper will be devoted to a more detailed investigation of the program, the hardware and software, Data Select's MED and PBI capabilities, and a discussion of the options FDO may utilize in working with the program.

A DETAILED LOOK AT THE PROGRAM

Low-speed radar data flows from the sites to MCC via TTY at the rate of one sample per 6 seconds. Depending on station designation, the data will consist of several types of observations. C-Band stations transmit range, azimuth, and elevation (r,a,e) data, while S-Band (USB) stations transmit range, Doppler, and X and Y antenna angles (R, \dot{R} , X, Y). As the data arrives, it is stripped off the line and collected in the Low-Speed Input Processor. At this point, the RTCC DC process actually begins.

A. Pre-Orbit Determination (OD) Program

This program collects the incoming data frames and stores them according to the transmitting site and time tags. These frames (points) are collected in batches which may vary from 6 (minimum) to 80 (maximum) frames. Receipt of an end-of-transmission (EOT) signal by the program (either from the station or by manual insertion) will terminate collection of data for a particular batch. If the station transmits enough data frames to fill one batch, another is begun so that no frames will be lost.

This program performs other functions to aid the DC process. It will add 2π radians to all negative antenna angles (to prevent their signs from remaining negative, whereupon the data would be tagged invalid). It adds a 1 megacycle bias to Doppler observations (for the same reason), multiplies range and angle measurements by station granularity constants, adjusts observed angles for azimuth, local vertical, and local horizontal corrections, adds a range bias to C-Band data (for individual stations), and adjusts Doppler time tags to the middle of the count interval.

Another aspect of this process is batch ordering. As batches are filled from station observations, they are given an ID number, a station identification and other coding which

identifies the type and number of included observations. Upon receipt of the EOT, the batches are made available to the main program. Batches are sent to the convergence processor in time order (oldest first) unless manually instructed otherwise. The program can store 20 batches prior to entry into the processor and these batches may be divided among all vehicles.

As previously mentioned, this program makes corrections for station granularity constants, as prescribed premission. This process converts raw observations from counts to appropriate units (counts to radians, angles, range, etc). The calculations also include corrections from the venting model, which are determined from linear interpolation of the model. This table can be adjusted via MED if need be, when premission values are found to be different from the real-time situation. The model considers these venting forces (non-propulsive LH tank blowdown, LOX tank blowdown, and LH low level continuous vent from insertion to SEP/TLI) and all forces are assumed along the spacecraft roll axis.

Subsequent to batch formulation, conversion, and identification; they are ready for operation initiation by the convergence processor. In order for the process to be initiated, however, the state vector and covariance matrix must have been propagated forward to the time of the first valid data point in the batch under consideration. While vector propagation (integration) is fairly straightforward, covariance propagation is more complex and should be investigated.

B. Propagation Routine

Free flight propagation simply propagates the state error covariance matrix from some initial time (t_1) to another time (t_2) which will correspond to the time of the first valid data point in the batch to be processed. This routine also considers

uncertainties in μ and drag. Drag is considered only when the radius of the orbit is less than 1.1 earth radius ($h = 344$ n.mi.). The gravitational constant, μ , is always included in the routine and is utilized as a partial $\partial s / \partial \mu$ in analytic computation. Drag, while still considered as a partial ($\partial s / \partial D$), is a numerical solution and increases in importance as the vehicle nears reentry conditions.

Powered flight propagation is utilized when a maneuver occurs during the propagation time. This routine considers three major factors; these being the state vector, the navigation utilized, and the engine parameters. It considers each factor differently, but all partials are analytically computed (with the exception of engine parameters which are integrated with the powered flight integrator). The subroutine also considers factors such as platform misalignment, accelerometer deviations, uncertainties at ignition, et cetera.

Thus far, we have traced the program through batch collection, propagation and integration routines, and the other correction cycles used in the pre-orbit determination program. The next phase of the process is the dispatching of the batch to the convergence processor.

C. Convergence Processor

This processor is used to compute a correction to the initial estimate of vehicle position (state) and an updated covariance matrix. In effecting these calculations it utilizes an initial estimate of the state, the relative weight of the estimate (as reflected by the covariance matrix), a generated ephemeris covering the station pass, and the batch of observations previously collected. The processor will generate a table of residuals from the observations computed about the predicted flightpath for the pass. It also solves for bias elements if necessary. The processor is equipped to process batches

consisting of any of the following observation types:

1. Range (C-Band, USB, DSIF)
2. Azimuth and elevation angles (C-Band)
3. Right ascension and declination (DSIF)
4. X and Y antenna angles (30 ft USB)
5. X and Y antenna angles (85 ft USB)
6. Continuous count two- and three-way Doppler (USB and DSIF)

The vector used to generate the ephemeris may be any telemetry or DC vector from the usable vector table (UVT) or the vector evaluation table (VET). The processor has the capability to compute single batch solutions utilizing a prestored covariance matrix upon MED entry.

A general description of the routine utilized by the convergence processor would be:

1. It computes observation/local state partials
2. It computes residuals
3. The state transition matrix is computed
4. The state correction is computed.

After these calculations are concluded, the editing routine is called and the internal edit occurs. The general procedure for this process is to identify the time of the first observation in the batch and the code word that indicates the type of observation being considered. The theoretical observation is computed, (Y) , and the partial $(\partial y / \partial s)$ is calculated using the interpolated state vector from the ephemeris. This result is subtracted from the observed value and a residual obtained. A check is made to determine if a bias must be computed for that particular observation type and, if so, this is computed. After this check (calculation), the next observation in the batch is identified and processed in the same fashion. This cycle is repeated until the batch is cleared of all data frames. At this time, the correction to the state (ΔSN) and

the bias computation (Δb_n) are computed. The processor will compute one correction to the state each time it is called up.

The machine iterates to find residuals (since linear use of deviations is not accurate) until the convergence criteria is met, (that is, Q diverges), the convergence does not affect at least the eighth significant digit, or the maximum number of iterations is performed (10). If the criteria is met, a flag is set and iteration ceases. If not, (Q continues to converge), and after 10 iterations, another flag is set informing the processor of this condition. At that time, a new ephemeris is generated, based on the updated state, and the routine is called again, thus, beginning the iteration cycle again.

The convergence criterion is quite straightforward, in that Q , the computed quantity, is defined as:

$$Q = (\Delta S)^T \Gamma_o^{-1} (\Delta S) + \sum_{i=1}^n \sum_{j=1}^4 (\rho_o - \rho_c)_{ij} W_j (\rho_o - \rho_c)$$

where:

ΔS = Change to state vector

Γ_o = Initial covariance matrix

Γ_o^{-1} = Weighting matrix

i = Identification number of the observation being processed

j = A number defining the type of observation (Doppler, range, etc)

and the object of the iteration is to minimize Q . On inspection, it will be seen that for computed values, Q will follow a parabolic curve. Thus, as the iterations are performed, Q slowly converges toward the vertex of the curve until it reaches this point. On the next iteration, Q would diverge, violating the convergence criterion, causing the processor to return to the

previous computed value and designate that number as the best solution.

After the Q criterion is met (or 10 iterations are performed), the processor proceeds through the first edit loop and examines all points for $\pm 3\sigma$ values. Any points falling outside this criterion are eliminated from the computations (by negation). Then, with those points out of the solution, σ is redefined and P_0 is recomputed. Subsequently, iteration is begun again and the cycle is repeated. The processor has the capability to cycle through three edit loops (40 iterations). Processing is terminated when an edit loop entry fails to discover any points outside the 3σ limits, or all three loops are called. (This second situation is rare, as generally two loops will yield a good data batch.) If the full cycle fails to yield good solution values, the capability exists to manually edit the batch, eliminating obviously bad points, and repeating the entire process.

As was mentioned previously, the first step of the convergence processor's routine is the calculation of observations. These computations are complex and merit some discussion.

D. Computed Ground Radar Observations

The routine used to calculate these quantities will compute azimuth and elevation angles, X and Y antenna angles, range, Doppler, declination, hour angle, partials and station position (in topocentric coordinates). The position vectors for station and vehicle are calculated using an iterative technique which involves rotation through a precession-nutation matrix and a nearest Besselian year (NBY)/true-of-date change. Certain adjustments are made on angle observations, shifting them from the true system to topocentric system. Range equations (USB) are adjusted for comparison with observed

values, biased, and output in earth radii. Doppler computations involve a light time-delay routine and are biased as previously mentioned.

The precession-nutation matrix which the processor utilizes is complex and needs brief explanation. It might also be pointed out that libration; the moon's wobbling motion around its rotation axes, is handled in the same fashion.

Precession is the motion of the earth's X-axis (pointing to Aries) in the X-Y equatorial plane. Nutation is the wobble of the earth around the spin axis.

Both motions are cyclic functions (over a vast expanse of time) and thus, can be predicted for any given day. This capability of motion determination has produced several time/position-related axes systems. These systems (true-of-date, true equinox-of-date, nearest Besselian year (NBY), etc) are somewhat technical and need not be explained here. The various processors, however, utilize most of these systems, thus, requiring several rotations and transformations. Basically, however, both precession and nutation are corrected by means of a matrix which averages these motions to the nearest day. Libration is considerably more complicated and is considered only when predicting vehicle motion about the moon.

Proceeding in the discussion of ground computations, another factor that must be explained is the weighting matrix (Γ_0^{-1}). It is defined as the inverse of the covariance matrix and is used for all types of observations, but with varying degrees of weight. C-Band weights are determined premission and input to the processor where they can be adjusted manually by utilization of a PBI. USB weighting is similiar to C-Band for antenna angles but is very dissimiliar in range, which depends on biases, et cetera. Doppler weighting varies with count

time interval, as does Doppler quality. The shorter the interval, the less impact Doppler is allowed to have on the ephemeris. Two-way Doppler is weighted more heavily than three-way, thus having a greater impact on the ephemeris. In both cases, manual adjustment of the premission weights is possible in the real-time situation. State weights (covariance) can be altered by inputting a new diagonal into the matrix, or by selection of a prestored matrix.

With this being the final ground computation of major importance, one final portion of the DC needs to be discussed.

E. Editing

For observed data, editing simply removes singular wild points and/or groups of obviously incorrect points. Editing may be accomplished by any of three separate techniques. These are:

1. Automatic Edit (Interval)
2. Pre-Edit
3. Manual Edit

Automatic edit and pre-edit will be used only after batch-to-batch processing (where each batch is accepted or rejected on an individual basis). Automatic editing can be done after the convergence processor has computed a standard deviation (σ) about the mean of the residuals (for each observation type). At that time, any observations with residuals greater than 3σ are tagged invalid. This eliminates wild points and any sequences of thrusting of strongly biased data. After editing, another convergence sequence is initiated (if any points were removed based on the 3σ criterion).

In the pre-edit routine, residuals are compared to some fixed value for standard deviation (σ) as computed about the orbit (as defined by the state). This routine can be utilized to remove any bad points missed by the internal edit routine.

Manual edit is used to remove single points (or successive points) of obviously bad data (4σ or worse) by utilization of another MED, which causes points in a given time interval to be invalidated. This particular process can be utilized in the pre and post DC chain.

The role of the convergence processor in editing is simply to compute the state estimate and the updated covariance matrix in order that the standard deviation computations may be performed. The edit routine will then edit the observations based on residuals and standard deviations of the observations. It should be noted that the dynamically computed factors (such as biases, etc) are input in their corrected form for each loop, thus contributing to accuracy.

F. Summary

In order to summarize the past discussion and list some hardware utilized for the DC program, it seems easiest to break the entire program into three main programmed routines.

The first of these is the Propagation Control Routine which propagates the state vector and covariance matrix as described earlier. The subroutines utilized in this routine are:

1. Encke numerical integrator - which integrates the state vector over non-covered free flight intervals.
2. Free Flight Propagation Routine - which propagates the covariance through free flight.
3. Maneuver Propagation Routine - which propagates the covariance matrix through maneuvers.
4. Maneuver Prediction Program
5. Reentry Prediction and Propagation Routine
6. Mean Conic Partial's Routine

The second major aspect of the DC program is the DC Control Routine, which actually computes corrections to the state vector

and updates the covariance matrix. Its major subroutines are:

1. Encke Numerical Integrator - which generates the ephemeris over the entire data arc for residual computation.
2. Convergence Processor - which computes updata for the state vector and covariance matrix.
3. Edit Processor - which automatically edits data during the iteration process.
4. Speed-of-Light Delay Routine
5. Mean Conic Partial's Routine

The final main division is the Solution Control Routine which will send the DC results to the display processors, stores the updated state vector and covariance matrix, and processes MED's and PBI's.

This summary concludes the discussion of the DC program itself. There are other aspects of DC usage and control which are of concern to FDO and these must be examined.

G. Controls

The controls that Data Select does have over the program consist of two main types; MED's and PBI's. Together, they represent the various options available to Select when processing the data in the Manual Mode. These options, or most of them, are also of interest to FDO and must be listed here.

The MED's available give Select capability to:

1. Change station capabilities - used to determine generation of acquisition messages.
2. Insert late reporting station into the DC chain (pre-or post).
3. Change individual station characteristics.
4. Exclude/Include (option) - used for data in pre-and/or post-DC chain.
5. Multiply maneuver coefficients - used to multiply uncertainties by their coefficients.

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6. Change DC Edit coefficients - changes multiplier of σ from 3 to 4, 2, or 1.
7. Rechain - used to reprocess the DC batches in same time order as they were received.
8. Pre-edit - utilized to enter some nominal value of residuals
9. N1/N2 Edit - eliminates points on time basis from Station Residuals Plot.
10. Use "Starter" program - used to generate a starting vector for single station solutions on the first batch after insertion, an unconfirmed maneuver, et cetera ($\Gamma_0 = 0$).
11. Change minimum elevation angle - changes the minimum angle below which no points are accepted (nominally 3°).
12. Adjust minimum/maximum batch size - adjusts batch size between the 6 (min) and 80 (max) observation limits.
13. Use multipoint option - specifies the time interval between points to be saved for processing (always in multiples of 6 seconds).
14. Insert EOT signal - used to terminate observation collection (for a given batch).
15. Process Mode II/III low-speed data - causes low-speed radar data to be used for IP prediction and trajectory determination.
16. Use Vector Evaluation Table - causes specified vectors to be integrated to a common time and displayed on the VET.
17. Add C-Band range bias - per station
18. Alter the table of biases (USB) - can delete or change values in this table.
19. Initialize the Vector Residual Summary
20. Input covariance matrix
21. Eliminate angles - deletes X, Y or a, e angles from batches.

In addition to these MED's, Select also has several PBI's at his disposal for utilization during data processing. Those of interest to FDO are:

1. Auto/Manual - controls main mode of operation.
2. Accept/Reject - used for each solution.
3. Update/No Update - determines whether solution is used to update the UVT.
4. Force/Multistation
 - a. Forces one more iteration
 - b. Overrides use of SS, $K\alpha$, $K\rho$, or $K\Gamma$
5. SS1/SS2 - causes predetermined covariance matrix to be used for single station solution.
6. α_1/α_2 - causes station weights to be increased by multiplication from predetermined constants (3, 5).
7. $K\rho_1/K\rho_2$ - multiplies uncertainties due to μ and drag by 0 or 2.
8. $K\Gamma_S/K\Gamma_L$ - causes covariance to be multiplied by 5 or 10 (down-weighting the previous data).

One other manual control which may serve FDO is the option to inhibit acquisition messages from being transmitted. In this case, he may terminate all or some of the station acquisition messages for any period of time or retransmit those already sent.

Two non-nominal uses FDO may utilize the DC process for are presented in Mode II/III launch aborts and the reentry.

For reentry, the procedure is generally established premission. Approximately 30 minutes before entry interface (EI), Select will MED in instructions which cause processing to be shifted from the orbital to the reentry integrator. Simultaneously, the maximum batch size is set to 10 points, due to the breakdown of the drag model at the lower altitudes encountered in reentry. (Only by taking shorter, quick-look type solutions, can the program give good results.) Multistation solutions

are performed whenever possible, but all data is processed and single station solutions ($\Gamma_0 = 0$) are performed where necessary. In this fashion, FDO can utilize the most accurate estimate of the orbit to generate the ephemeris.

The other situation mentioned, Mode II/III aborts, necessitates that FDO use the DC, for lack of any other usable data, to try to determine the impact point (IP) and the trajectory of the vehicle. Assuming an unconfirmed maneuver, by utilizing a nominal postburn start vector and performing single station solutions on low-speed data, some estimate of vehicle position and trajectory may be obtained from the program.

One final explanation that must be given is the usage of the DC solution in updating the ephemeris. It will be the responsibility of Data Select to maintain the best DC vector in the Useable Vector Table (UVT) at all times. When FDO determines that he wants to update his trajectory with a DC vector, the UVT vector will be transferred to the ephemeris generator and used accordingly. (The UVT will also hold telemetry and high-speed radar L/O vectors).

Included as part of this report are the displays utilized by Data Select in the performance of his duties concerning DC processing. They should be relatively self-explanatory and are intended to give a better overall picture of the programs outputs.

VEHICLE ID OF VEHICLE

GMT TIME OF VECTOR COMPARISON
(UP TO 40 HOURS IN FUTURE
(OR PAST) BUT CANNOT GO
BACK THROUGH A MANEUVER)

GET

VECTORS FOR THIS TABLE MUST BE FROM:

- 1) USABLE VECTOR TABLE
- 2) EPHEMERIS VECTOR (ORBIT OF REENTRY)
- 3) ANY DC SOLUTION

 V INERTIAL VELOCITY (FPS) γ INERTIAL FLIGHT PATH ANGLE (DEG) ψ HEADING ANGLE (DEGREES)
 ϕ } GEOCENTRIC LATITUDE
 λ } & LONGITUDE (DEGREES)
 H HEIGHT ABOVE SPHERICAL EARTH (N.MI.) a SEMI-MAJOR AXIS (N.MI.) e ECCENTRICITY i INCLINATION (DEGREES) ω_P ARGUMENT OF PERIGEE (DEGREES) Ω RIGHT ASCENSION OF ASCENDING NODE (DEGREES) ν TRUE ANOMALY (DEGREES) U $r \cdot \hat{U}$ (RADIAL) (N.MI.) V $r \cdot \hat{V}$ (IN-PLANE) (N.MI.) W $r \cdot \hat{W}$ (OUT-OF-PLANE) (N.MI.) \dot{U} $v \cdot \hat{U}$ (FPS) \dot{V} $v \cdot \hat{V}$ (FPS) \dot{W} $v \cdot \hat{W}$ (FPS)

LEFT-HAND COLUMN QUANTITIES ARE DETERMINED FROM BASE VECTOR. OTHER THREE COLUMNS ARE COMPOSED OF SAME QUANTITIES BASED ON THREE OTHER VECTORS AND DIFFERENCED FROM THE BASE VECTOR QUANTITIES. ALL COMPONENTS ARE THE SAME EXCEPT IN U, V, W SYSTEMS WHERE POSITION COMPONENT DIFFERENCES ARE GIVEN IN YARDS.

WHERE: $\hat{U} = \frac{\bar{r}}{r}$; $\hat{V} = \frac{(\bar{r} \times \bar{v}) \times \bar{r}}{r^2}$; $\hat{W} = \frac{\bar{r} \times \bar{v}}{r^2}$

AM1471

VECTOR PANEL SUMMARY

1591 ○

CSM ANCHOR VECTOR ID

CURRENT GMT

LM ANCHOR VECTOR ID

GMT_{AV} VECTOR GMTGMT_{AV} VECTOR GMT

CSM VECTORS

LM VECTORS

<p>CMC ΔT INDICATES HOW OLD UVT VECTOR IS</p> <p>IF GMT OF VECTOR APPEARS HERE, VECTOR IS RETAINED IN EVALUATION TABLE</p> <p>UV</p> <p>EV</p> <p>T_H T_L</p>	<p>IU ΔT</p> <p>UV</p> <p>EV</p> <p>T_H } H - HIGH SPEED T_L } L - LOW SPEED</p>	<p>CMC ΔT</p> <p>UV</p> <p>EV</p> <p>T_H T_L</p>	<p>IU ΔT</p> <p>UV</p> <p>EV</p> <p>T_H T_L</p>
<p>LGC ΔT IF GMT OF VECTOR APPEARS HERE, VECTOR IS RETAINED IN THE USEABLE VECTOR TABLE</p> <p>UV</p> <p>EV</p> <p>T_H T_L</p>	<p>HIGH SPEED RADAR (C/O VECTOR)</p> <p>ΔT</p> <p>UV</p> <p>VECTOR AUTOMATICALLY TRANSFERRED TO UVT UPON RECEIPT</p>	<p>LGC ΔT</p> <p>UV</p> <p>EV</p> <p>T_H T_L</p>	<p>HIGH SPEED RADAR</p> <p>ΔT</p> <p>UV</p>
<p>AGS ΔT</p> <p>UV</p> <p>EV</p> <p>T_H } GIVES TIME OF MOST CURRENT VECTOR BEING RETAINED (IN GMT) T_L }</p>	<p>DC VECTORS</p> <p>ΔT</p> <p>UV GMT OF DC SOLUTION</p> <p>VECTOR TRANSFERRED TO UVT AFTER ACCEPT/UPDATE PBI'S UTILIZED</p> <p>LAST EXECUTED MANEUVER</p> <p>GMTUL GMT OF ULLAGE INITIATE</p> <p>GMTTO GMT OF TAIL-OFF TERMINATE</p> <p>(CMC MANEUVER)</p>	<p>AGS ΔT</p> <p>UV</p> <p>EV</p> <p>T_H T_L</p>	<p>DC VECTORS</p> <p>ΔT</p> <p>UV</p> <p>LAST EXECUTED MANEUVER</p> <p>GMTUL</p> <p>GMTTO</p> <p>(LEM MANEUVER)</p>

LM0271

CSM ORBIT DC SUM

1606

GET

GMT

AV	STA GMT	VECTOR ID AND TIME TAG OF BASE VECTOR FOR DC PROGRAM
----	------------	--

STA ID

PRE-DC CHAIN
(DATA NOT YET
PROCESSED)

A/R STA

POST-DC CHAIN
(DATA HAS BEEN
PROCESSED)

		R	R _R	A/X	E/Y
N		(YARDS)	(CYCLES)	(MILLI-RADIANS)	(MILLI-RADIANS)
ELP	REJ	ELLIPTIC EDIT ROUTINE	1) NUMBER OF POINTS REJECTED		
	RMS		2) RMS OF ALL ACCEPTED POINTS		
PRE	REJ	PRE-EDIT ROUTINE (α VALUES MED IN)	1) NUMBER OF POINTS REJECTED		
	RMS		2) RMS OF ALL ACCEPTED POINTS		
DC	REJ		1) NUMBER OF POINTS REJECTED		
	RMS		2) RMS OF ALL ACCEPTED POINTS		
	AVE		3) AVERAGE DEVIATION OF ACCEPTED POINTS		
		[XX.0]	[X.00]	[0.XX]	[0.XX]

STAC STATION BEING PROCESSED GMT GMT OF FIRST VALID DATA POINT

E_{MAX} MAXIMUM ELEVATION ED LPS (1→3) ITER (1→10) SS (1,2)PGM CTL ACCEPT/REJECT - DEPENDING UPON PROGRAM RECOMMENDATION α (1,2) K_T (1,2) K_p (1,2)

MAN CTL ACCEPT/REJECT/ACCEPT UPDATE DEPENDING ON SELECT DECISION FOM FIGURE OF MERIT (SHOULD BE LESS THAN FIFTY)

T TRACE # (0.XX-XX)

% FINAL T (INPUT TRACE / OUTPUT TRACE)

X
Y
Z
X
Y
ZOUTPUT VECTOR
AS CORRECTED
BY THIS DC
SOLUTIONDIFFERENCES BETWEEN OUTPUT
VECTOR AND INITIAL VECTOR IN:

- 1) EARTH RADII AND ER/HR
- 2) FEET AND FEET/SEC

MISHAP NO

SHOULD BE 0 (IF NOT, SOME
ERROR NUMBER WILL SHOW)

T ERROR

0.XX - XX

GMTPI GMT OF LAST MANEUVER

ΔV MANEUVER ΔV Δt_B BURN TIMEθ INITIAL PITCH ATTITUDE K_θψ INITIAL YAW ATTITUDE K_A K_M MANEUVER
UNCERTAINTIES
IN ATTITUDE,
ACCELEROMETER
BIASES, AND
THRUST LEVELS

CODE BURN ID

THESE QUANTITIES REFER TO DC SOLUTION:

V INERTIAL VELOCITY (FPS)

γ INERTIAL FLIGHT PATH ANGLE (DEGREES)

ψ INERTIAL AZIMUTH (DEGREES)

φ } GEOCENTRIC LATITUDE
λ } AND LONGITUDE (DEGREES)

h HEIGHT ABOVE SPHERICAL EARTH (N.M.I.)

KEPLERIAN PREDICTIONS FROM DC AND CHANGES
MADE TO EPHEMERISh_a HEIGHT OF APOGEE
(N.M.I.)Δh_ah_p HEIGHT OF PERIGEE
(N.M.I.)Δh_pi INCLINATION
(DEGREES)

Δi

a SEMI-MAJOR AXIS
(N.M.I.)

Δa

ε ECCENTRICITY

Δε

P PERIOD
(HR:MIN:SEC)

ΔP

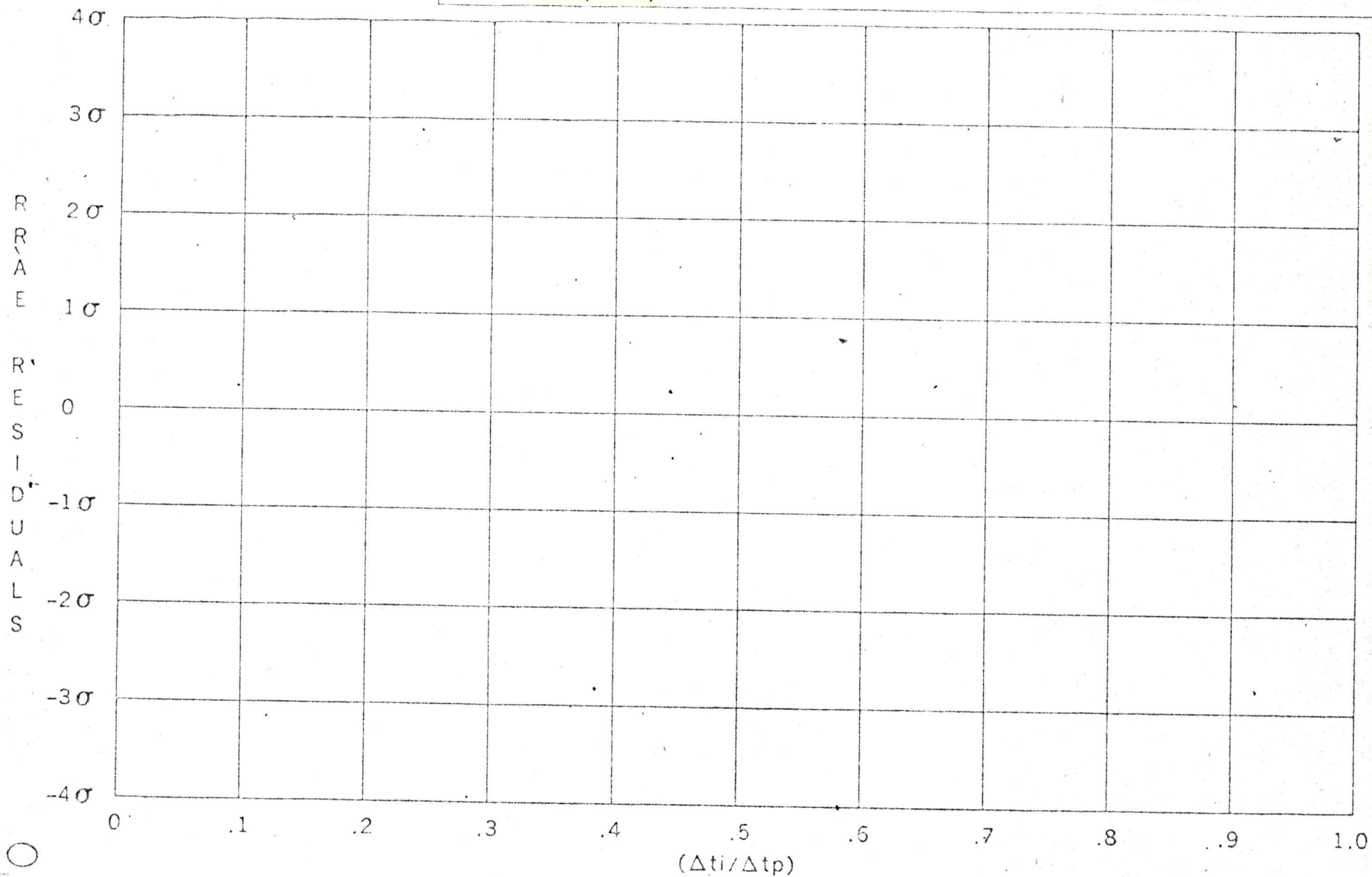
LM0158

CSM STATION RESIDUALS

1609 C

STA ACC LAST ACCEPTED DC
 GMT ACC GMT OF FIRST VALID POINT
 IN LAST ACCEPTED BATCH

STA ID OF STATION THAT IS
 BEING EXAMINED
 $\frac{\sigma}{\Delta R} \left[\begin{smallmatrix} \text{RMS} \\ \text{AVE} \end{smallmatrix} \right] \rightarrow \left(\begin{smallmatrix} \text{COMPUTED} \\ \text{ACTUAL} \\ \text{OBSERVED} \end{smallmatrix} \right) \frac{\sigma_{RR}}{\Delta RR}$
 GMT GMT OF FIRST VALID DATA
 POINT IN THIS BATCH
 $\frac{\sigma_{A/X}}{\Delta A/X}$
 $\frac{\Delta T_P}{\sigma_{E/Y}} \frac{\Delta E/Y}{\Delta E/Y}$ TOTAL AMOUNT OF
 TIME REPRESENTED
 BY THIS DATA



DOPPLER											
RMS _T (TOTAL) BATCH ID (20 STATION MAX)	ΔT	AVG _T (TOTAL) DOPPLER		RANGE		X ANGLE		Y ANGLE		BIAS (DOPPLER)	
		RMS	AVG	RMS	AVG	RMS (OR A)	AVG	RMS (OR E)	AVG		
NEWEST	INDICATES HOW OLD EACH BATCH IS WITH RESPECT TO THE CURRENT BATCH	RMS OF ALL ACCEPTED POINTS	AVERAGE DEVIATION OF ALL ACCEPTED POINTS							THIS COLUMN SHOWS INDI- VIDUAL BATCH VALUES FOR BIAS SOLUTION	
REJECTED STATIONS MAY BE EXCLUDED FROM THIS TABLE											
OLDEST											

RESIDUALS BASED ON

POST DC CHAIN

BATCH

ID

TWENTY
STATION
LIMIT

GMT BATCH

TIME

TIME OF
FIRST VALID
DATA POINT
IN EACH
BATCH

 ΔT_P

TOTAL PASS
TIME REPRE-
SENTED BY
EACH BATCH

E

MAX
ELEVATION OF
PASS

 N_D

TOTAL
NUMBER
OF
DOPPLER
POINTS

 N_R

TOTAL
NUMBER
OF
RANGE
POINTS

NUMBER OF REJECTED POINTS

 N_D
 N_R
 N_X

(COR A)

 N_Y

(COR E)

 α F

 Γ ρ S

0 = NOT USED
1 = USED FIRST
SETTING
2 = USED SECOND
SETTING

 α = $K\alpha$ OPTION

 Γ = $K\Gamma$ OPTION

 ρ = $K\rho$ OPTION

S = SINGLE STATION SOLUTION OPTION

F = FORCE OPTION FOR ANOTHER
ITERATION

LM0211

LOW-SPEED RADAR INPUT

1618 ○

CSM E MIN BATCH MIN BATCH MAX MULTIPOINT

S4B

NOMINALLY
3°NOMINALLY
6 POINTSNOMINALLY
80 POINTSSOME MULTIPLE OF
1 PT/6 SEC IF

OPTION IS UTILIZED - (INDICATES RTCC ACCEPTANCE RATE)

T	STATION	VEH	C-BAND			S-BAND		STANDARD	
:			N _{DC}	N _T	ID	N _{DOP}	N _{ANG}	RATE	TYPE MODE
* ASTERISK IN THIS COLUMN MEANS NO EOT SIGNAL HAS BEEN RECEIVED FOR THAT STATION	NEWEST	VEHICLE BEING TRACKED	NUMBER OF POINTS AVAIL- ABLE FOR DC (ABOVE 3°)	TOTAL NUMBER OF POINTS RECEIVED INCLUDING POINTS BELOW 3°	X ₁ , X ₂ ↓ WHERE X ₁ IN- DICATES VEHICLE AND X ₂ INDI- CATES BEACON ID	TOTAL NUMBER OF DOPPLER POINTS RECEIVED (VALID)	TOTAL NUMBER OF X, Y PAIRS RECEIVED (VALID)	ACTUAL RATE OF POINT INFLOW (SHOULD BE SAME AS MULTIPOINT INDICATOR)	*1-WAY 2-WAY 3-WAY (DOPPLER) *ONE WAY CANNOT BE PROCESSED
	OLDEST								