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HOUSTON ASTRONAUTICS DIVISION

SPACE SHUTTLE ENGINEERING AND OPERATIONS SUPPORT

DESIGN NOTE NO. 1.4-3-15

RENDEZVOUS RADAR REQUIREMENTS ANALYSIS FOR MISSION 3B

MISSION PLANNING, MISSION ANALYSIS AND SOFTWARE FORMULATION

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1.0 SUMMARY

This note presents data verifying the compatibility of currently proposed rendezvous radar measurement accuracies with Mission 3B rendezvous requirements. In addition, data presented indicate a potential for increasing the acceptable time lag between termination of thrusting and availability of accurate measurement data. Additional investigation is recommended to define any acceptable time lag above the current proposed value. Finally, Mission 3B rendezvous performance is shown to be sensitive to variations in the relative downrange position dispersions at insertion. It is therefore recommended that insertion relative state dispersions used in studies of 3B rendezvous be reviewed when results of 3B ascent dispersion studies are available.

2.0 INTRODUCTION

Due to the nature of Mission 3B, the rendezvous capability is only minimally dependent on onboard navigated state information. Per the Reference A groundrules and guidelines which govern the proposed rendezvous technique, the braking maneuvers, the line-of-sight (LOS) rate control maneuvers, and the LOS attitude correction maneuvers are to all be performed manually using data directly from the rendezvous radar. Previous rendezvous evaluations for Mission 3B have used perfect navigation for performing the terminal control maneuvers. This study was initiated to verify the compatibility of the currently proposed rendezvous radar specifications and the Mission 3B rendezvous requirements by using data directly from a rendezvous radar math model for support of the 3B terminal control maneuvers. The study was conducted during this time period to provide data in a time frame compatible with the rendezvous radar request for proposal scheduled for November 1975.

Data is presented for evaluation of the proposed rendezvous radar specifications in terms of Mission 3B rendezvous performance characteristics. In addition, data is presented for the evaluation of rendezvous performance impacts associated with Orbiter/target relative downrange position dispersions at insertion.

3.0 DISCUSSION

The subsections to follow present briefly the major guidelines and assumptions, the simulation description, and the general study approach.

3.1 Guidelines and Assumptions

The major guidelines and assumptions governing the study are as follows:

(a) The maximum time between Orbiter insertion and stationkeeping should be less than twenty-five minutes.

(b) Rendezvous radar data is available six minutes after Orbiter insertion and terminal control maneuvers are allowed immediately thereafter.

(c) The nominal rendezvous profile and the braking gates employed are those defined for the baseline reference mission 3B (Reference A).

(d) The Reaction Control System (RCS) is used for all maneuvers with braking and LOS rate control maneuvers made component by component. (A single component LOS rate control maneuver may occur with a braking maneuver provided the LOS control algorithm has scheduled it to occur at the beginning of the braking maneuver.)

(e) The braking maneuvers are performed with the ±Z-axis RCS thrusters using an acceleration level of 1.0 ft/sec^2.

(f) The Orbiter X-axis is nominally pointed in the plane of the Orbiter and the target and a ±X-axis acceleration level of 0.5 ft/sec^2 is used for inplane LOS rate control maneuvers. A ±Y-axis acceleration level of 1.0 ft/sec^2 is used for out-of-plane LOS rate control maneuvers.

(g) The rendezvous radar provides range, range rate, angles (shaft and trunnion), and angle rates data out to a range of 10. n.mi.

(h) The terminal control maneuvers are performed using data directly from the rendezvous radar.

(i) The rendezvous radar look angle uncertainty associated with initial target acquisition is not addressed herein.

3.2 Simulation Description

The dispersion analysis data presented within this note were generated via sixty cycle Monte Carlo runs that are initialized at Orbiter insertion and continue through the terminal control braking maneuvers. A brief description of major modeling and evaluational considerations follows.

Orbiter Systems Models

Per the guidelines and assumptions, all maneuvers are performed with the RCS. The RCS propulsion model was configured so as to provide constant acceleration levels and propellant flow rates on a per axis basis. This model was selected to aid parametric evaluations in terms of available acceleration levels should they be desired. The model did not include RCS nozzle cant angle effects. Attitude corrections are performed instantaneously with propellant requirements based on a maneuver rate of 0.5 deg/sec. and the assumption that the pitch and yaw corrections would be performed sequentially. Propellant requirements for attitude hold are computed using propellant weight per time where the particular value is based on vernier control, a ±0.1 degree deadband, and the Orbiter in approximately a 100 n.mi. orbit with the Y-axis pointed out-of-plane. It should be noted that the propellant usage rate for attitude hold is that for a non-thrusting Orbiter and because there are considerable periods of thrusting the attitude hold propellant is biased low. The specific data used for this study is presented in Table I.

TABLE I - PROPULSION MODEL CHARACTERISTICS

CHARACTERISTIC	VALUE	REFERENCE
TRANSLATION MANEUVERS		
Acceleration -ft/sec^2/Propellant Flow Rate -lbs/sec		
±X-Axis (3 Jets Effective)	0.5/9.09*	B
±Y-Axis (6 Jets Effective)	1.0/18.18*	B
±Z-Axis (6 Jets Effective)	1.0/18.18*	B
ATTITUDE MANEUVERS		
Propellant Requirements - lbs (For a vehicle rate of 0.5°/sec)	26.6	C
ATTITUDE HOLD		
Propellant -lbs/hr (for vernier control and a ±0.1° deadband)	2.27	C

* Propellant flow rates are for three and six jets respectively. The acceleration is approximately that for the Mission 3B vehicle weight and the available thrust from the number of jets indicated.

The terminal control maneuvers are to be performed manually using data directly from the rendezvous radar. The measurement data provided by the rendezvous radar model includes range, range rate, shaft and trunnion angles, and shaft and trunnion angle rates. For purposes of this study and convenience, the angle and angle rate data are modeled as measurements of the Orbiter +Z-axis with respect to the Orbiter-to-target line-of-sight. The measurement accuracies used as a reference for this study are those which are currently being proposed for inclusion in the radar procurement specification. The proposed accuracy specifications are presented in Table II.

TABLE II - RENDEZVOUS SENSOR MEASUREMENT ACCURACIES *

PARAMETER	NOISE SIGMA	BIAS SIGMA	UNITS
Range > 29860 ft.	99.5	26.2	ft
< 29860 ft.	.0033R or 32.8 (whichever is greater)	26.2	ft
Range Rate	.328	.328	ft/sec
Angles (Shaft & Trunnion)	.191	1.0	deg
Angle Rates (Shaft & Trunnion)	.1604	.1604	deg/min

* Data obtained from J. W. Griffin of the Tracking and Communications Development Division

The radar model employed for this study provides measurement data having an accuracy which depends on input bias error and noise error standard deviations. The resulting accuracy is independent of whether or not the vehicle is undergoing coasting or accelerated flight.

The proposed terminal control technique and the scope of this study were such that no other areas of systems modeling were considered.

Trajectory Dispersion Considerations

The trajectory dispersion data used for this study is primarily that associated with the 3B rendezvous dispersion analysis presented in Reference A. The specific dispersion standard deviations associated with the Orbiter insertion state and the knowledge of the payload position and velocity are presented in Table III along with the resulting relative state dispersion standard deviations.

TABLE III - ORBITER/TARGET ACTUAL STATE DISPERSIONS AT INSERTION

STATE PARAMETER	ORBITER(1σ)	TARGET(1σ)	RELATIVE(1σ)*
Down Range Position(ft)	1575.	3000.	3397.
Out-of-Plane Position (ft)	3085.	200.	3092.
Radial Position (ft)	1560.	400.	1609.
Down Range Velocity (ft/sec)	3.37	0.2	4.61
Out-of-Plane Velocity (ft/sec)	7.45	0.2	7.46
Radial Velocity (ft/sec)	4.75	3.4	4.19

* Relative state dispersion standard deviations are target centered relative rotating curvilinear.

The nominal 3B rendezvous trajectory used for this study is that presented in Reference A. The trajectory dispersions for the Monte Carlo runs were obtained by dispersing the nominal insertion relative state using the relative state dispersion covariance matrix presented in Table IV.

Terminal Control Algorithm

Terminal control is initiated at insertion plus six minutes. The subsequent maneuvers for braking, line-of-sight rate control and line-of-sight attitude corrections are performed using data directly from the rendezvous radar.

The braking maneuvers are performed according to the range/range rate gate schedule presented in Table V using the current measured range and range rate from the rendezvous radar. Ideally the braking ΔV is applied along the line-of-sight to the target. However, in general, the Orbiter braking axis (assumed to be +Z) will not lie exactly along the line-of-sight due to the non-zero line-of-sight rates and errors in aligning the +Z axis with the LOS to the target. Braking maneuvers are performed independently of the attitude and, consequently, will in general have components normal to the line-of-sight.

TABLE IV - ORBITER/TARGET RELATIVE STATE COVARIANCE MATRIX AT INSERTION *

X	Y	Z	$\dot{X}$	$\dot{Y}$	$\dot{Z}$
11541545.00000000	594610.25000000	-87519.34375000	5441.42749023	137.22616959	-172.99908066
594610.25000000	2590473.09375000	530720.86718750	5639.01617432	5824.90252686	1362.30749512
-87519.34375000	530720.86718750	9558195.00000000	91.02346802	1617.58309937	22859.40893555
5441.42749023	5639.01617432	91.02346802	21.24398088	8.78575933	.27651531
137.22616959	5824.90252686	1617.58309937	8.78575933	17.55065298	4.03495198
-172.99908066	1362.30749512	22859.40893555	.27651531	4.03495198	55.62539721

\- REFERENCE RELATIVE STATE AT INSERTION *

X = 40776.8 ft., Y = -56817.8 ft., Z = -1.8 ft.

$\dot{X}$ = -109.9 ft/sec., $\dot{Y}$ = 56.35 ft/sec., $\dot{Z}$ = .057 ft/sec.

* The data is target centered relative rotating curvilinear with +X trailing, +Y above, and +Z in the direction of the angular momentum vector.

TABLE V - ASSUMED BRAKING GATES FOR MISSION 3B RENDEZVOUS

RANGE (ft)	MIN. RANGE RATE (ft/sec)	MAX. RANGE RATE (ft/sec)
40855.	75.0	85.0
36365.	70.0	80.0
32135.	65.0	75.0
28160.	60.0	70.0
24455.	55.0	65.0
21010.	50.0	60.0
17830.	50.0	55.0
14910.	45.0	50.0
12255.	40.0	45.0
9860.	35.0	40.0
7730.	30.0	35.0
5860.	29.0	30.0
4255.	24.0	25.0
2910.	19.0	20.0
1830.	14.0	15.0
1010.	9.0	10.0
455.	4.0	5.0
160.	0.1	1.0

The attitude model employed performs an attitude correction after initial target acquisition (at insertion plus six minutes) to align the +Z-axis along the line-of-sight as defined by the rendezvous radar angle measurements. Inertial attitude hold is then commenced. The +Z-axis is allowed to drift without correction until angle measurements indicate that it exceeds a specified deadband (taken to be 3.0 degrees for this study). Attitude propellant usage is continuously updated while in inertial attitude hold and deltas are applied for the attitude corrections as they occur.

Line-of-sight rate control is performed using the angle rate measurements. When a measured rate exceeds the input limit (taken to be 1.0 degree/minute for this study) thrusting begins to null the rate. For this study the line-of-sight rate corrections were only made to ninety percent of the initial rate. The line-of-sight rate control maneuvers are considered such that the inplane and out-of-plane rates must be controlled sequentially with the higher rate given priority.

- Following each translation maneuver a constraint is imposed which prohibits the execution of any subsequent maneuver within a delta time from thrust termination. This constraint was included to allow evaluation of the time lag requirement associated with the rendezvous radar accuracy following RCS maneuvers (for the proposed rendezvous radar 2.0 seconds is specified). All translation maneuvers are performed using a delta time of 1.0 second to account for inaccuracies introduced by the manual "powered flight guidance" which will be performed by the crew.

Terminal control ends when the final braking gate has been satisfied (successful rendezvous) or when an opening condition exists which cannot be reversed with a minimal maneuver (unsuccessful rendezvous) or the line-of-sight rates cannot be controlled (unsuccessful rendezvous).

3.3 Study Approach

The approach taken to verify the proposed measurement data accuracies for compatibility with Mission 3B was to first verify the adequacy for a successful rendezvous and to then determine the performance impacts resulting from improved or degraded accuracy. The improved or degraded accuracy cases involve changes in bias or noise error sigmas for each of the measurement parameters independently. Data generated is not intended for redefinition of the proposed accuracies but rather for background information on the performance aspects of improved or degraded measurements.

In addition to measurement accuracy investigation, it was desired to investigate the performance impacts associated with a post maneuver time lag for accurate rendezvous radar data above the currently proposed 2.0 seconds. For these investigations, all translation maneuvers are constrained such that following thrust termination the specified time lag must elapse prior to execution of the next maneuver. Here it should be noted that the radar measurement accuracies are not degraded during the periods of thrusting which would occur if the time lag is of real world concern. In addition, no consideration was given to maneuver execution prior to passage of the total time lag (i.e., to subsequent maneuver execution with degraded measurement accuracies). However, the approach taken should be adequate to identify the magnitude of the performance impacts associated with an increased time lag.

The last area of investigation is concerned with defining the rendezvous performance impacts associated with variations in the relative downrange position dispersion sigma at insertion. Two runs were made for comparison with the reference Monte Carlo run. For the first run, the relative state dispersion covariance matrix was modified so as to reflect a downrange variance of four times the original value and for the second run the matrix was modified to reflect a downrange variance of nine times the original value. The associated matrix modifications were made such that the original correlations were preserved.

4.0 RESULTS

The parameters used to measure the rendezvous performance are the total translational maneuver ΔV, the delta time from insertion to stationkeeping, the thruster duty time (percent of thruster on-time measured from time of initial thrust), the total attitude propellant (after acquisition of the target by the rendezvous sensor), and the rendezvous success status. The rendezvous performance data for the proposed rendezvous sensor accuracies (presented in Table II) were obtained with a 60 cycle Monte Carlo run where relative state trajectory dispersions were generated using the covariance matrix presented previously in Table IV. All rendezvous were successful and the resulting performance data are presented in Table VI.

TABLE VI - MISSION 3B RENDEZVOUS PERFORMANCE FOR CURRENTLY PROPOSED MEASUREMENT ACCURACIES

PARAMETER	UNITS	MEAN	SIGMA	MEAN+3SIGMA
Translation ΔV	fps.	107.2	23.36	177.3
Delta Time To Stationkeeping	min.	21.6	0.85	24.1
Thruster Duty Time	%	13.2	3.85	24.7
Attitude Propellant*	lbs.	733.7	118.11	1088.0

* See Section 3.0 for a discussion of propellant usage considerations.

Various runs were made in which the rendezvous radar measurement accuracies (bias and noise) were varied individually for each measurement parameter from a 25% improved accuracy to a 50% degraded accuracy. Results from these runs show only minor changes over that for the reference accuracies. For example, Table VII presents changes in the rendezvous performance parameters for the 50% degraded accuracy runs as compared to the reference accuracy run.

Each rendezvous associated with the degraded accuracy was successful and, as is seen by the resulting deltas to the performance parameters, only minimal impact occurs. The only significant changes are the translation ΔV increases (mean +3 sigma) of up to 6.6 fps and the attitude propellant increases (mean +3 sigma) of up to 145.1 lbs. Note that the data should not be construed to indicate that a relaxing of the rendezvous radar accuracy requirements is possible since the degraded accuracy could seriously degrade the performance of the rendezvous navigation for onboard state updates. The performance data for improved accuracy is not presented for discussion as there was no significant improvement in performance. The data is presented in Appendix A in graphical form for background information.

Two runs were made in which the post maneuver delay was increased from the currently proposed 2.0 second value. The first run used a 10.0 second delay and the second a 15.0 second delay. Every case of the 10.0 second delay run ended in a successful rendezvous, however, more than half the cases of the 15.0 second run were unsuccessful. The failure in every instance was due to loss of LOS rate control. This loss of control existed to some extent in both axes,

TABLE VII - MISSION 3B RENDEZVOUS PERFORMANCE DELTAS (MEAN +3 SIGMA) FOR 50% DEGRADED MEASUREMENT ACCURACIES

DEGRADED MEASUREMENT	δ(MEAN +3 SIGMA) TO PARAMETER REFERENCE VALUE			
	TRANSLATION ΔV (fps.)	δT TO STATIONKEEPING (min.)	DUTY TIME (%)	ATT. PROPELLANT (lbs.)
Range Bias	2.90	0.05	0.19	16.20
Range Noise	1.70	0.16	0.20	-2.10
Range Rate Bias	3.00	0.18	0.44	17.40
Range Rate Noise	5.30	0.13	0.51	67.10
Angles Bias	5.30	0.11	0.73	109.10
Angles Noise	3.40	0.10	0.23	29.90
Angle Rates Bias	6.60	-0.04	0.54	34.90
Angle Rates Noise	6.10	0.10	0.81	145.10

however, the loss of inplane (x-axis) control was more pronounced due to the smaller acceleration capability in that axis. In addition, the x-axis acceleration of 0.5 ft/sec^2 used herein is approximately the maximum that is available. Table VIII presents delta performance data with respect to the reference values for the 10.0 second delay run.

TABLE VIII - MISSION 3B RENDEZVOUS PERFORMANCE DELTAS FOR A 10.0 SECOND POST MANEUVER TIME LAG

PARAMETER	UNITS	MEAN	SIGMA	MEAN +3 SIGMA
Translation ΔV	fps.	-11.4	-0.25	-12.2
Delta Time To Stationkeeping	min.	0.01	0.01	0.04
Thruster Duty Time	%	-1.3	-.07	-1.53
Attitude Propellant	lbs.	-278.4	-30.92	-372.19

Note the decrease in attitude propellant which results from the increased delay causing fewer attitude correction maneuvers to be performed during the terminal control. The decrease in the ΔV requirement results from less thruster on-time for LOS rate control maneuvers as is also reflected in the thruster duty time. The 15.0 second run performance data is not presented as most cases resulted in an unsuccessful rendezvous. The unsuccessful nature of the 15.0 second delay run is better indicated by the relative trajectory and the range rate, and LOS rates as a function of time. Figure 1 presents a portion of the inplane relative motion for case 1 of the reference run (2.0 second delay), the 10.0 second delay and the 15.0 second delay. The 2.0 and 10.0 second delays were both successful with little difference between the two trajectories. As the 15.0 second delay trajectory indicates, it was unsuccessful. Figure 2 presents time histories of range, range rate, and the LOS rates for the case 1 10.0 second and 15.0 second delays. (Note the 10.0 second delay is almost identical to the 2.0 second delay and the 2.0 second data is not presented.) As is clearly shown, the LOS rate control failed due to delay constraints and a rendezvous failure resulted.

Once again, the point is made that, while 15.0 seconds is unsatisfactory if the full time is delayed, there are considerations open to investigation concerning maneuver execution with degraded accuracy. One can cite performance data for 50% degraded accurracy as noted previously as an indication that some degradation could be accepted. On the other hand, there are questions which can be raised with respect to the 10.0 second delay being acceptable. Namely, the fact that associated with the delay there will be a degradation of accuracy during the maneuver which was not modeled

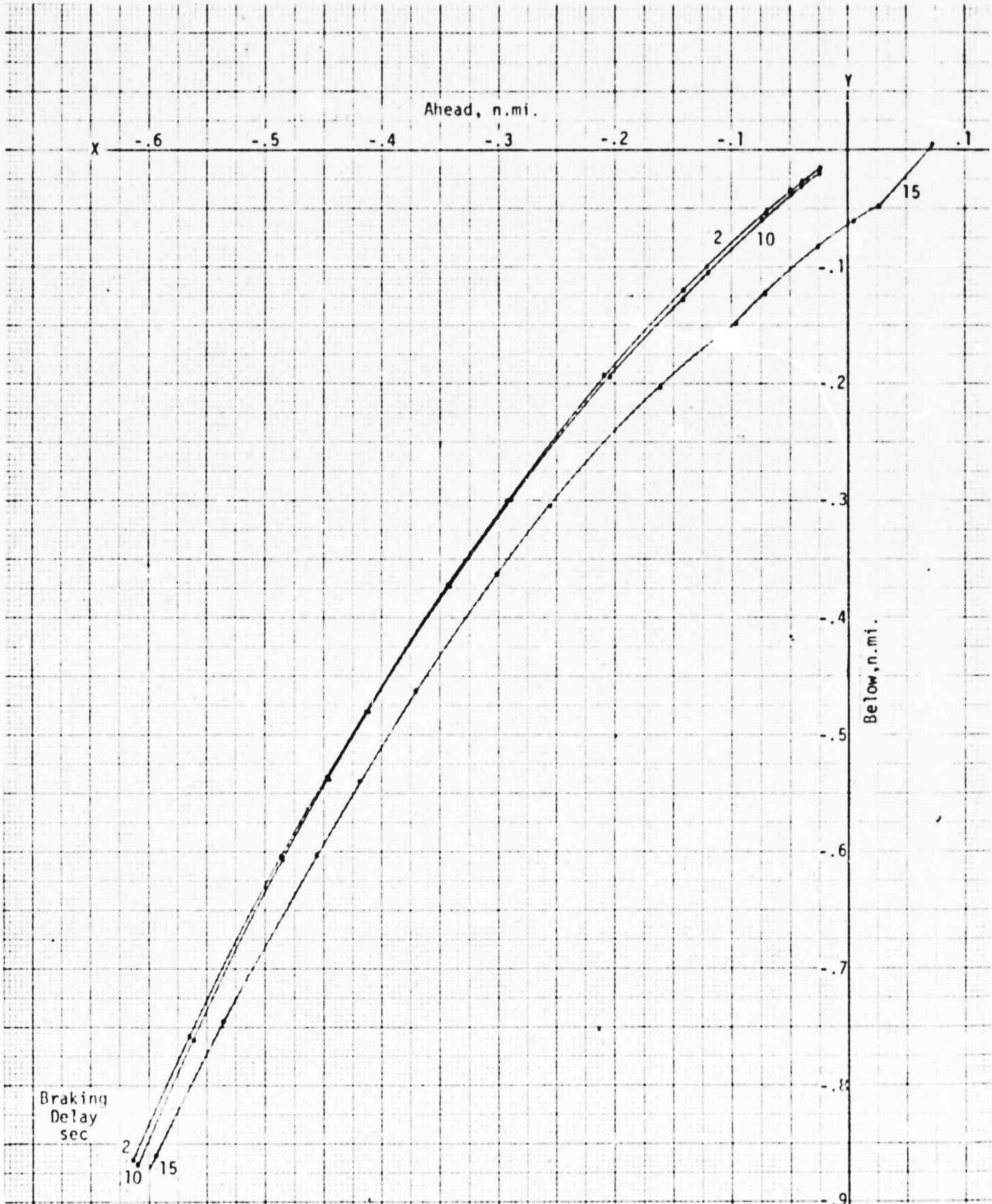

Figure 1 - ORBITER RELATIVE MOTION FOR TIME LAGS OF 2.0, 10.0, AND 15.0 SECONDS

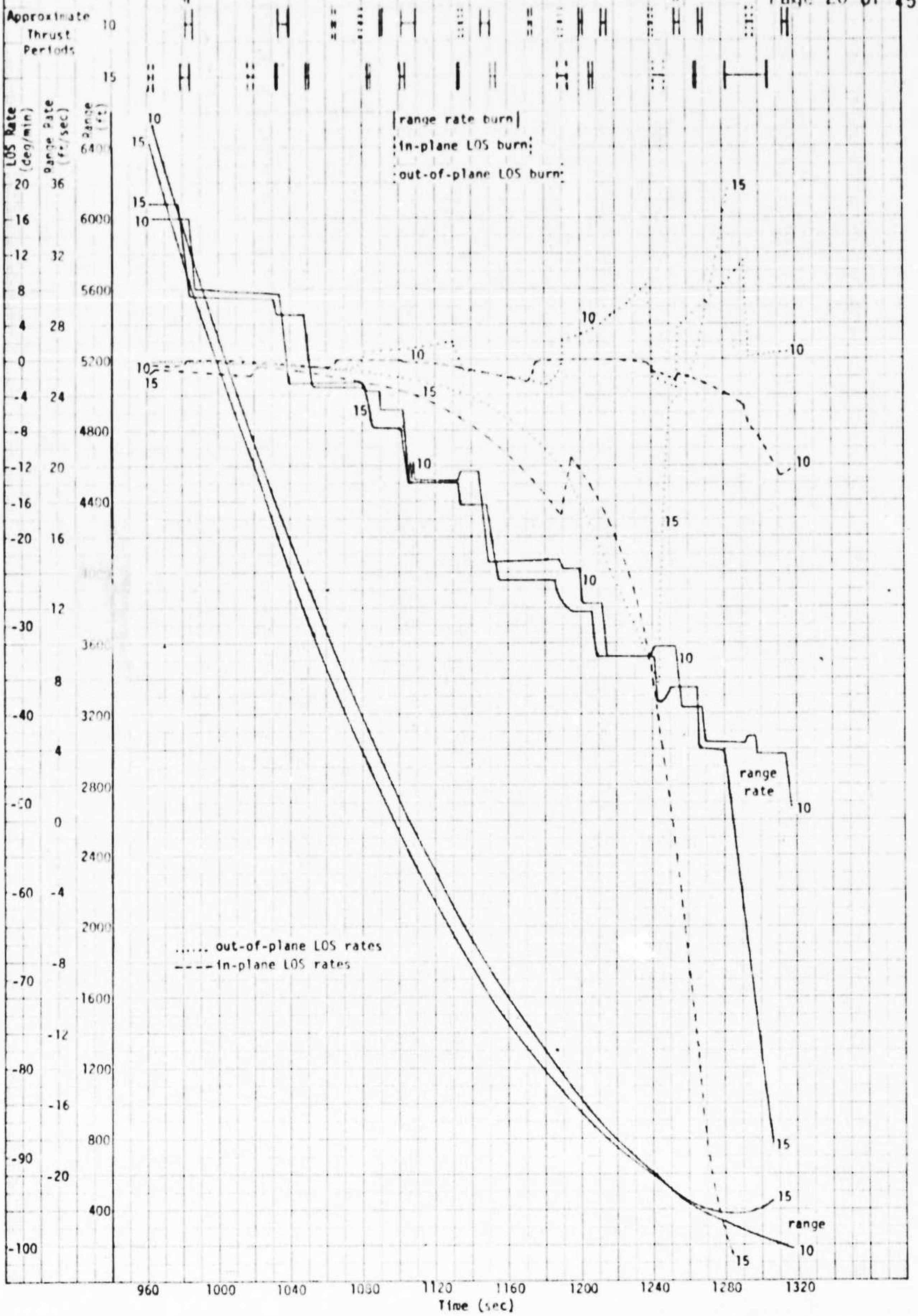

Figure 2 - TYPICAL RANGE, RANGE RATE, AND LINE-OF-SIGHT RATE TIME HISTORIES FOR 10.0 AND 15.0 SECOND TIME LAGS

and which could degrade the rendezvous performance. With respect to braking maneuvers, it is felt that experience has proven they can be performed effectively if reasonably accurate data is available for maneuver initiation. The LOS rate control maneuvers and the attitude correction maneuvers have in the past been performed using visual target movement within a reticle. Since the loss of control occurs toward the later portion of the rendezvous it may be possible to visually track the target in the reticle and perform backup LOS rate control and attitude correction maneuvers if the radar data is inaccurate. So, it appears that increases in the post maneuver time lag may be possible. Extensions of the time lag to even 10.0 seconds will require more detailed investigations concerning maneuver execution with several degraded measurements, availability of visual techniques for LOS rate control and attitude corrections, the effects of larger trajectory dispersions at insertion, and the effects of various acceleration levels.

The final area of investigation concerns the performance deltas associated with the relative downrange position dispersions at insertion. Two runs were made for comparison with the reference run which has a one-sigma relative downrange dispersion of 0.56 n.mi. The first run utilized a one-sigma value of 1.12 n.mi., and the second run tripled the one-sigma value to 1.68 n.mi. All cases of both runs were successful and the delta performance data are presented in Table IX.

TABLE IX - MISSION 3B RENDEZVOUS PERFORMANCE DELTAS FOR DOUBLE & TRIPLE RELATIVE DOWNRANGE DISPERSIONS AT INSERTION *

PARAMETER	UNITS	δ(MEAN)	δ(SIGMA)	δ(MEAN+3SIGMA)
Downrange Sigma - 1.12 n.mi.				
Translation ΔV	fps.	6.10	2.68	14.1
Delta Time To Station-keeping	min.	0.14	0.11	0.5
Thruster Duty Time	%	0.94	0.27	1.75
Attitude Propellant	lbs.	53.20	3.64	64.10
Downrange Sigma - 1.68 n.mi.				
Translation ΔV	fps.	13.50	5.46	29.80
Delta Time To Station-keeping	min.	0.31	0.28	1.13
Thruster Duty Time	%	2.21	0.49	3.69
Attitude Propellant	lbs.	16.41	17.03	67.50

* The reference run relative downrange dispersion is 0.56 n.mi.

An increase in the relative downrange dispersion one-sigma value from 0.56 n.mi. to 1.68 n.mi. will cost approximately 30 fps (mean +3 sigma) and will increase the mean +3 sigma time to rendezvous to just over 25 minutes. The associated duty time increases to over 28%. The 1.68 n.mi. dispersion appears to be acceptable with the rendezvous technique currently proposed. The sensitivity of the performance parameters to relative downrange dispersions indicates that a review of the 3B rendezvous capability should be made once trajectory dispersion data is available from 3B ascent studies. It is also noted that the relative downrange dispersion is also attributable to knowledge of the target vehicle which would depend on the type of target (active or passive) and the available tracking prior to Orbiter liftoff.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The currently proposed accuracies for rendezvous sensor measurements (i.e., those presented in Table II) are adequate for Mission 3B terminal control maneuver support. In addition, a margin exists which will allow some accuracy degradation without imposing severe performance penalties. For example, single measurement bias and noise accuracy degradation of up to 50% were found to produce no severe penalties. Should the limits of acceptable degradation be desired then additional analysis should be performed.

A post maneuver time lag for accurate rendezvous radar data of 2.0 to 10.0 seconds appears acceptable for the trajectory dispersions investigated while a time lag of 15.0 seconds is unacceptable as failure to rendezvous occurs. The time lag investigations herein indicate a possibility of increasing the value above the currently specified 2.0 seconds. However, it is noted that the acceleration level used for x-axis LOS rate control was approximately the maximum that will be available and that it is the loss of the associated LOS rate control which is predominant in the 15.0 second time lag rendezvous failures. In addition, the sensitivity of the acceptable time lag to trajectory dispersions and to terminal control operations is unknown. It is therefore recommended that prior to committing to any new value, additional investigation be conducted with respect to a) maneuver execution with degraded data (prior to total lag time passage), b) the acceptability of visual target tracking techniques for LOS rate control and attitude corrections, c) the impacts on the acceptable time lag of increased relative trajectory dispersions at insertion (particularly in downrange), and d) the impacts on the acceptable time lag due to available acceleration levels (e.g., reduced x-axis acceleration due to failures).

The 3B rendezvous performance is significantly dependent on relative downrange dispersion at insertion. An increase in the relative downrange dispersions from 0.56 n.mi. one-sigma to 1.68 n.mi. one-sigma costs approximately 30 fps in ΔV (mean +3 sigma), over a minute in total time to rendezvous (mean +3 sigma), and over 3.5% thruster duty time (mean +3 sigma). The increase to 1.68 n.mi.increases the mean +3 sigma total time to rendezvous to just over the proposed 25 minute limit and requires a significant amount of additional RCS propellant (∿ 30 fps mean +3σ for translation and ∿ 70 lbs mean +3σ for attitude). It is recommended that when insertion dispersion data is available from 3B ascent studies, a review be made of the resulting Orbiter/target relative state uncertainties at insertion to verify consistency with reference data used in the 3B rendezvous, dispersion analyses performed to date. If significantly different from the reference dispersions used herein then in particular, investigations concerning time to rendezvous and RCS propellant requirements are recommended.

6.0 REFERENCES

A. JSC Internal Note No. 73-FM-47, "Space Shuttle System Baseline Reference Missions Volume III - Mission 3A and Mission 3B Revision 1", NASA, dated 7 May 1974.

B. JSC-08934 (Vol.1), "Shuttle Operational Data Book, Volume 1 Shuttle Systems Performance and Constraints Data", June 1974 (Ammendments, 20 May 1975).

C. JSC-007700 (Vol. XIV - Revision C), "Space Shuttle Systems Payload Accomodations, Level II Program Definition and Requirements Vol. XIV", NASA, 29 January 1975.

APPENDIX A

MISSION 3B

RENDEZVOUS PERFORMANCE DELTAS FOR VARIOUS RADAR MEASUREMENT ACCURACIES

The deltas in the Mission 3B rendezvous performance parameters are presented in the following figures as percentages of the performance parameter value obtained from the monte carlo run used as a reference. The specific reference values for the individual parameters are noted on the figures.

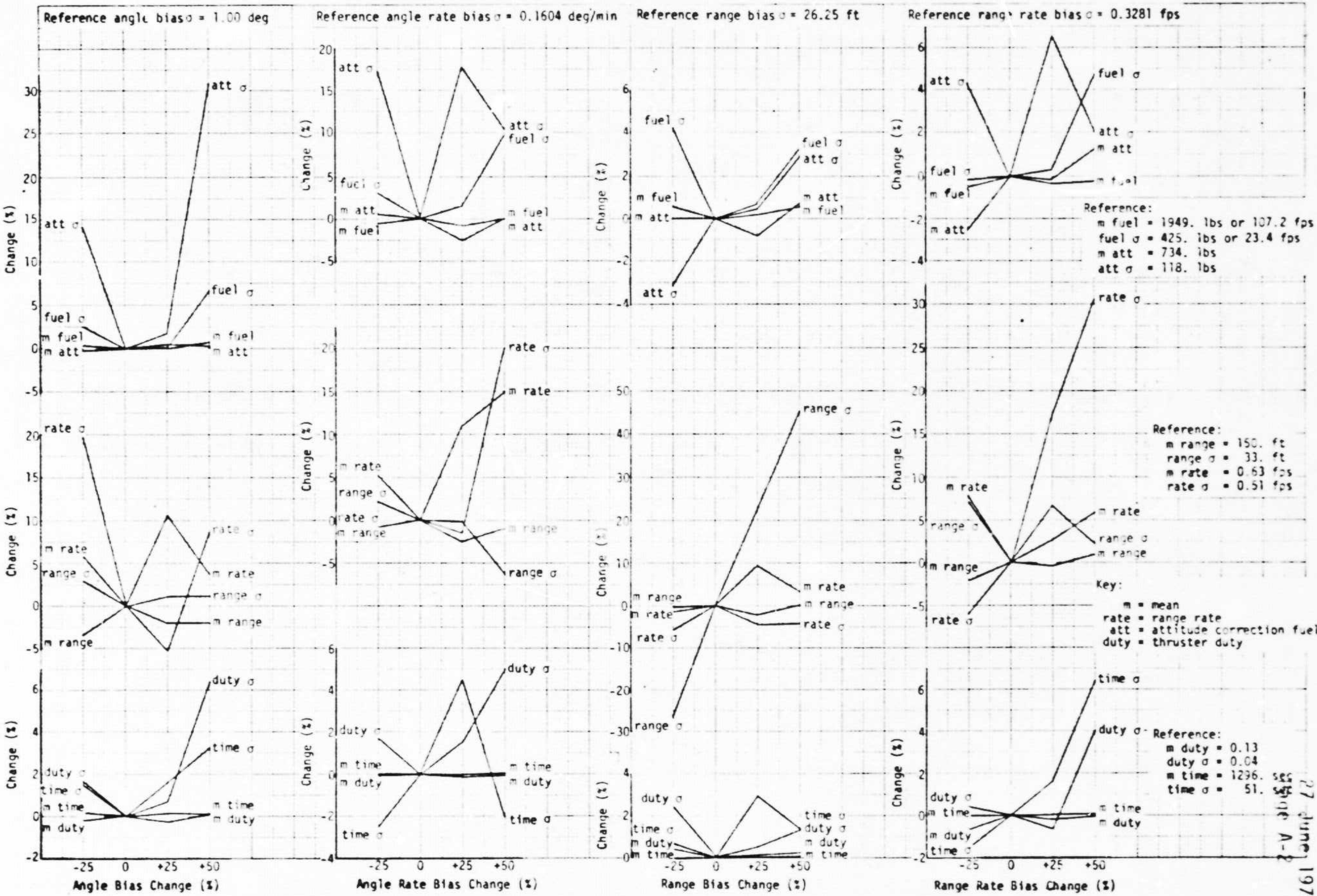

Figure A1 - MISSION 3B RENDEZVOUS PERFORMANCE DELTAS VERSUS RADAR MEASUREMENT BIAS ERROR SIGMAS

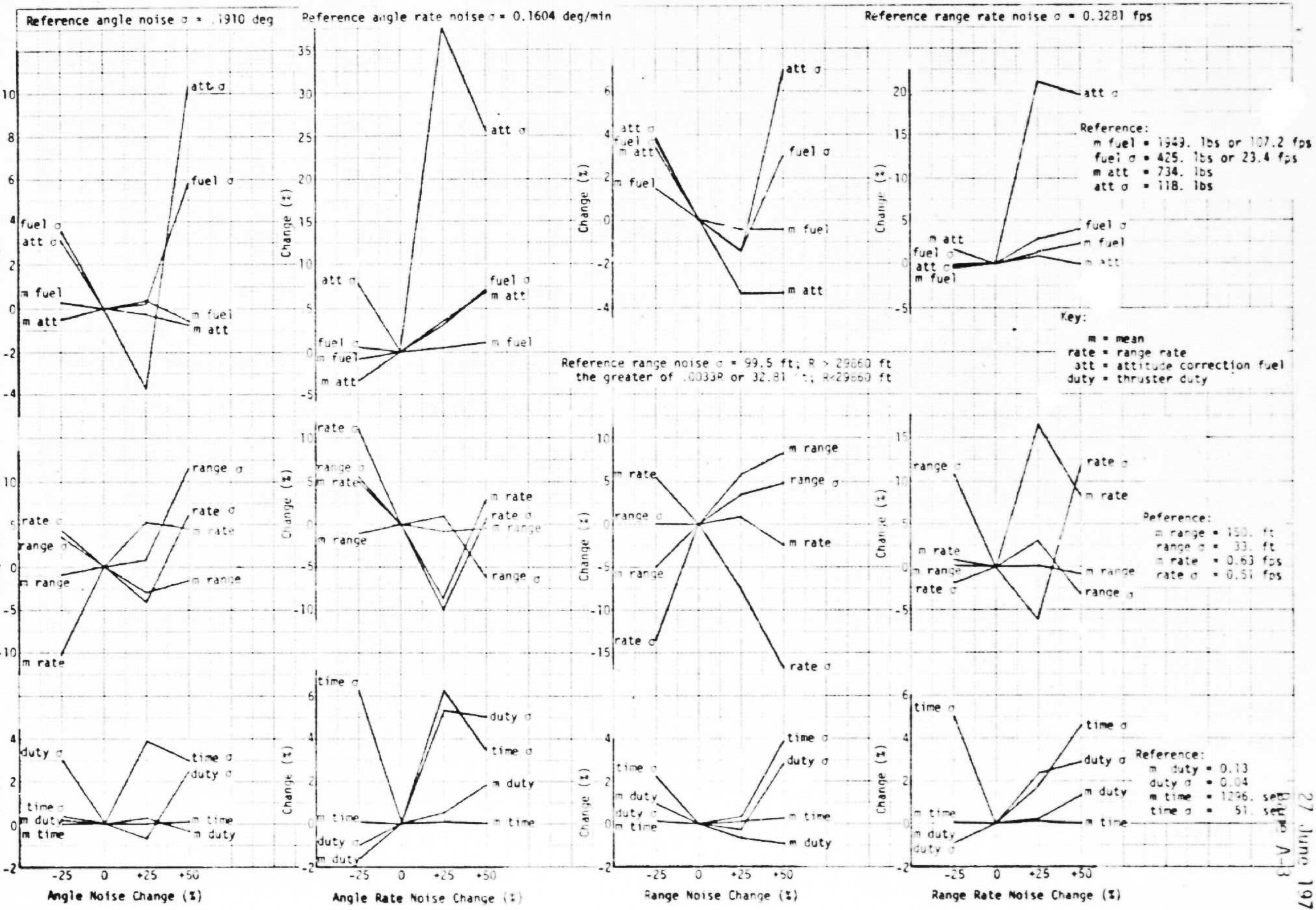

Figure A2 - MISSION 3B RENDEZVOUS PERFORMANCE DELTAS VERSUS RADAR MEASUREMENT NOISE ERROR SIGMAS