(2.8.J.) (No)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTERNAL NOTE MSC - EG - 69 - 6

PROJECT APOLLO

ANALYSIS OF RENDEZVOUS RADAR TRACKING REQUIREMENTS FOR ANGULAR BIAS COMPENSATION DURING MISSION D

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

February 18, 1969

INTERNAL NOTE MSC-EG-69-6

ANALYSIS OF RENDEZVOUS RADAR TRACKING REQUIREMENTS FOR ANGULAR BIAS COMPENSATION DURING MISSION D

PREPARED BY

Charles R. Price

Charles R. Price

APPROVED BY

Kenneth J. Cox

Kenneth J. Cox
Chief, Systems Analysis Branch

R. G. Chilton

Robert G. Chilton
Deputy Chief
Guidance and Control Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

FEBRUARY 18, 1969

SUMMARY

An investigation to determine the length of time of RR (rendezvous radar) tracking required to insure proper compensation for RR/IMU angular bias in the LM guidance computer has been made and is reported herein. Results of this analysis indicate that the LM Data Book Rule GNC-25 is conservative in require 15 minutes of continuous RR tracking prior to any maneuvers based on radar state vector updates. Simulations using tracking periods of 10 minutes maximum continuous tracking have shown no appreciable fuel penalty.

INTRODUCTION

The purpose of this internal note is to document the analysis that has been done in response to an action item assigned to the Systems Analysis Branch during the LM-3 Rendezvous Radar Integration Review, which was held on January 8, 1969. This analysis was made in order to evaluate the validity of the LM Data Book Rule GNC-25 which states that "fifteen minutes of continuous RR tracking should be completed prior to any maneuvers based on radar state vector updates." A violation of this minimum tracking period would supposedly result in a fuel penalty because of the inability of the LGC to compensate for the RR/IMU angular bias.

INVESTIGATION

The manner in which this analysis was approached was to evaluate first the LM/PGNCS navigation accuracy for Mission D using the design values and sighting schedule current at the time of the action item assignment. A variation in the value of W_b, the W matrix element for angular bias, was then investigated to achieve possible reduction in the bias estimate convergence time interval. Finally, a decrease in the length of the RR tracking intervals was investigated to assess fuel penalties.

INTERPRETATION OF RESULTS

In figure 1, the errors in shaft angle bias estimate is shown for three values of W_b for the time interval between phasing and insertion for Mission D. It is readily seen that the convergence time is strongly dependent on the value of W_b. The transients at 44 minutes are due to reinitialization of the W matrix and are more pronounced for the larger values of W_b. At the time of the assignment of the action item, the design value for W_b was 1 milliradian.

Figure 2 is a table which compares the navigational accuracy of the LM/PGNCS at the maneuver times in Mission D for the three values of W_b. These data indicate little change in the navigational accuracy for variation of W_b with two exceptions: (1) At insertion, the larger W_b values cause definite improvement, and (2) at MCC2, the larger W_b cause definite degradation. The improvement at insertion is due to rapid bias estimate convergence while the degradation at MCC2 is due to the transient introduced with the rediangonalization of the W matrix after MCC1.

D Techniques Data Priority Meeting.- The above data were presented at this meeting on January 22, 1969, along with the recommendations that (1) the value of W_b be increased, and (2) that tracking occur as close prior to insertion as crew procedures would allow. Somewhat similar recommendations to (1) and (2) were made by MIT and FCOD, respectively. The W matrix reinitialization procedure adopted at this meeting is as follows: The value of W_b initially is 5 mr; at all reinitializations, the value of W_b is 1 mr. The sighting schedule adopted is indicated in figure 3.

In figure 3, the RSS error in the onboard estimate of position is shown both for the finalized design schedule and for a schedule representing abbreviated tracking periods of 10 minutes maximum. This abbreviated schedule simulates what might happen if the radar begins to overheat in the second tracking interval past phasing: Radar tracking periods are limited to 10 minute intervals and are alternated with off/cool-down periods of at least 15 minutes. The values used for W_b initialization are the finalized design values.

As indicated by the timeline at the top of figure 3, the period of error propagation between each final sighting of a given tracking interval and the succeeding thrusting maneuver is consistent in the two schedules. This equivalent propagation of the navigation errors provides a meaningful evaluation of the navigation degradation due to tracking abbreviation. It is seen that during the abbreviated tracking intervals, the navigation errors are reduced to a level practically equivalent to that attained during the design interval. However, during the propagation to subsequent thrusting maneuvers, the abbreviated schedule errors increase at a higher rate than those of the design schedule. Thus, by judicious placement of the RR tracking, some reduction of the length of tracking intervals can be tolerated.

Figure 4 is a table summarizing the navigation accuracy of the design and abbreviated schedules at each thrusting maneuver. Also included is a summary of the delta V requirements. It is seen that the delta V increase due to the reduction in tracking is insignificant at all maneuvers except at MCCI and TPF where the increase is .7 fps and .6 fps, respectively.

CONCLUSIONS

An investigation of the fuel penalty associated with the violation of the 15 minute minimum of continuous RR tracking required by GNC-25 of the LM Data Book has been made and is reported herein. Results indicate that the 15 minute minimum requirement is conservative. Simulation of Mission D navigation with 10 minute maximum tracking intervals has shown no appreciable increase in delta V. However, navigation accuracy degrades considerably in the propagation periods after the tracking intervals. It was noted that reduction of the tracking intervals can be tolerated to 10 minutes as long as the propagation period between any corresponding tracking and the successive thrusting maneuver be kept as small as indicated by the design schedule or smaller, if possible.

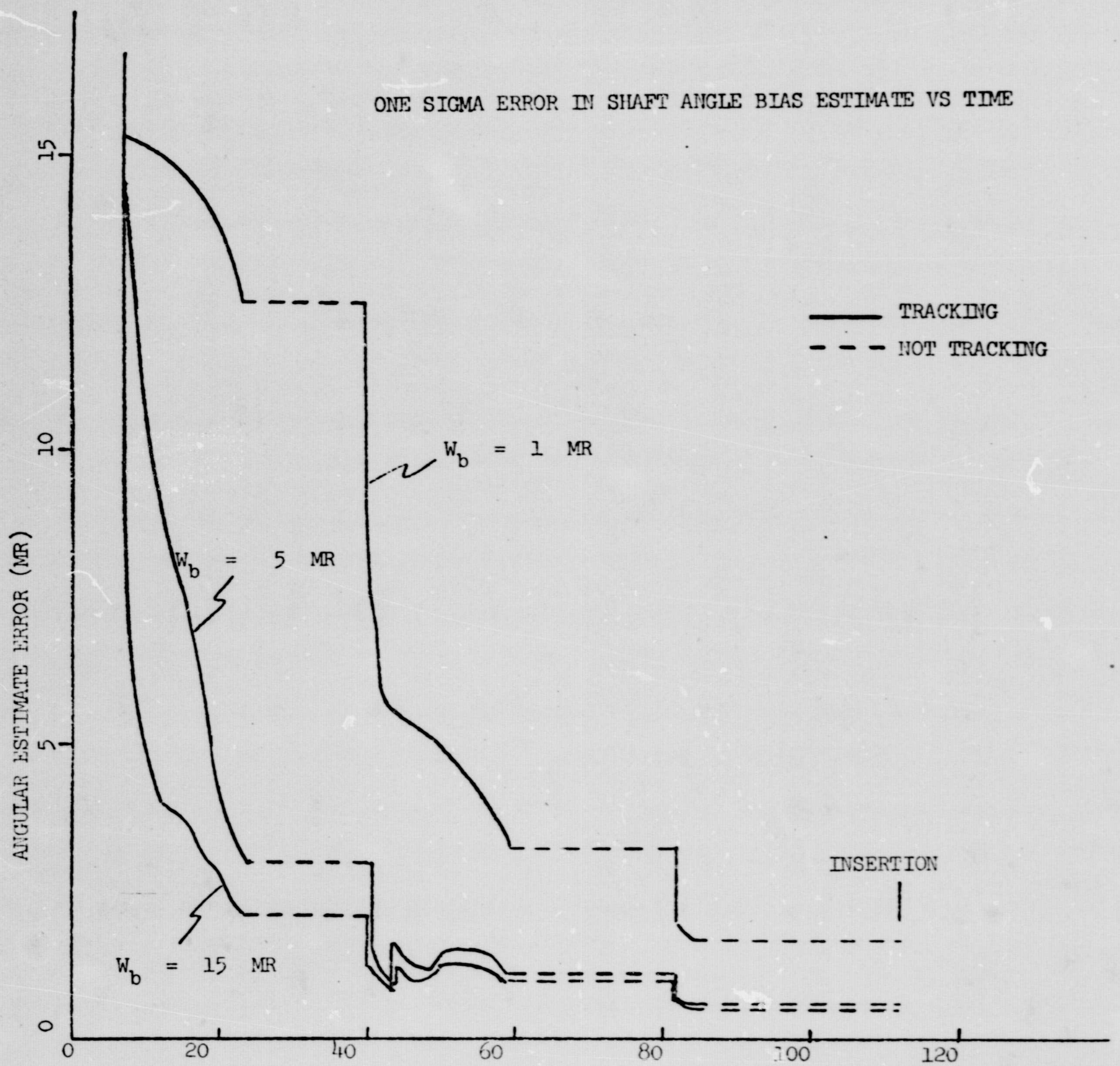

Figure 1.- TIME FROM PHASING (MINUTES)

Maneuver	W_b	RSSPOS	RSSVEL	σ_E	σ_A
INS	1	1218	.55	1.67	2.23
	5	531	.25	.64	.65
	15	534	.25	.65	.66
CSI	1	1265	.89	.80	1.96
	5	1338	.71	.92	1.15
	15	1355	.75	.94	1.32
CDH	1	1158	.68	.44	.45
	5	1304	.76	.64	.58
	15	1310	.78	.65	.64
TPI	1	460	.37	.46	.46
	5	474	.50	.60	1.10
	15	479	.52	.61	1.16
MCC_1	1	170	.32	.39	.33
	5	163	.31	.48	.39
	15	163	.31	.49	.39
MCC_2	1	123	.32	.37	.27
	5	123	.30	.97	1.31
	15	135	.42	2.47	5.42

Figure 2.- LM NAVIGATION ERRORS AT TIME OF THRUSTING MANEUVERS

NAVIGATION ACCURACY FOR NOMINAL AND ABBREVIATED TRACKING SCHEDULES

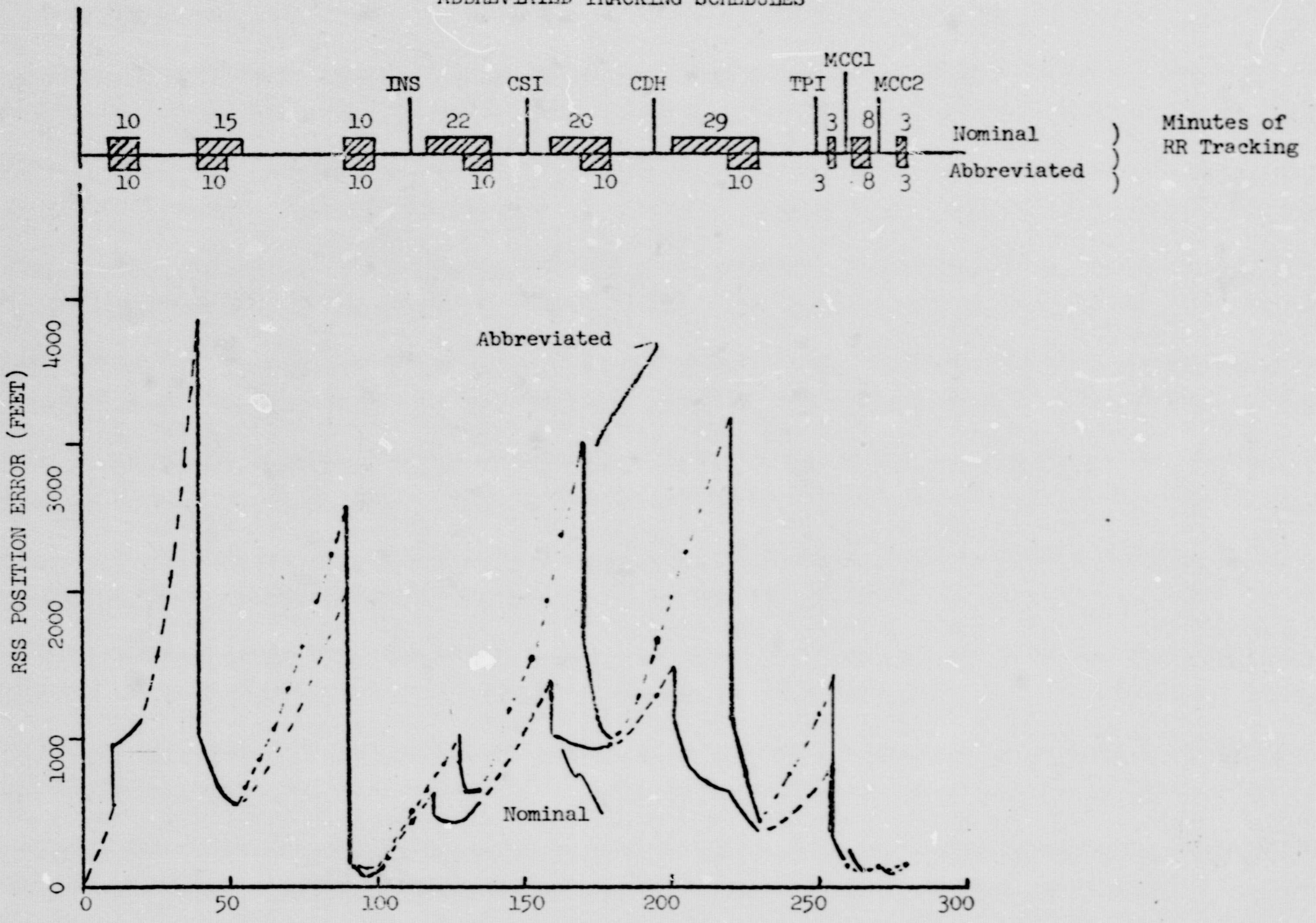

Figure 3.- TIME FROM PHASING (MINUTES)

Maneuver	*	(ΔV)	RSSPOS	RSSVEL	σ_E	σ_A
INS	n	(38.83)	434	.25	.69	.40
	a	(38.84)	507	.26	.72	.48
CSI	n	(37.79)	1136	.54	.58	.41
	a	(37.78)	1550	.95	.62	.44
CDH	n	(38.24)	1295	.66	.43	.29
	a	(38.25)	1676	.97	.48	.31
TPI	n	(22.88)	666	.43	.47	.40
	a	(22.95)	1194	.75	.49	.37
MCC_1	n	(1.53)	151	.58	.47	.39
	a	(2.20)	152	.59	.54	.39
MCC_2	n	(1.35)	125	.27	.46	.40
	a	(1.36)	125	.27	.55	.39
TPF	n	(31.9)	137	.14	.55	.39
	a	(32.5)	138	.14	.58	.39

* n = design schedule

a = abbreviated schedule

Figure 4.- LM NAVIGATION ERRORS AND DELTA V REQUIRED AT THRUSTING MANEUVERS