June 21, 1977
2-6926-0000-475

To: F. O. Shockley

cc: S. Datar
L. Geer
S. Gerson
J. Lynch
B. Shaw

Subject: Results of the Investigation into Flight 34

References: 1) Results of the investigation into flights 3-28 and 3-29, Memo 2-6926-0000-430 dated April 26, 1977

2) Flight Test Report, Thirty-Fourth Flight, B-1 A/C 40160, Dated March 29, 1977

3) Report of Results Obtained during Investigation Testing on TSE-20G Equipment, Memo 2-6926-0000-457 dated June 2, 1977

INTRODUCTION:

The purpose of this memo is to outline the observations found during a brief investigation into Flight 3-34. Three areas are emphasized. The first deals with the fly low phenomenum witnessed over level terrain; the second with the fly high phenomenum witnessed over water. The third topic deals with the G-command - angular error relationship first witnessed on Flight 29 and discussed in reference 1).

SUMMARY:

On Flight 3-34 three characteristics distinguish the fly low flight from normal flight over level terrain. The first is the lack of returns received by the automatic terrain following (ATF) system during the fly low period. The second is the region along the TF template in which the maximum delta gamma command is received. For the below set clearance flight the range at which the maximum delta gamma command is received is, on the average, farther out along the F_A face of the TF template than the returns received during normal flight. The third characteristic is the average angular error for each half scan is slightly larger in the negative sense while the A/C is flying below set clearance. If this characteristic is found on future flights it could account for some of the fly low behavior.

During the fly high period over water, returns are received above the surface which cause the A/C to go into a climb. The above surface returns last approximately seven seconds. Returns lasting for this length of time indicate the A/C did respond to an object off the shoreline and the fly high was not caused by a momentary TF anamoly. The angular error - g-command relationship found on Flight 3-29 and discussed in detail in reference 1) is also observed over an isolated peak on Flight 3-34.

LEVEL TERRAIN:

Tables 1 and 2 summarize the A/C performance over level terrain. Table 1 is for normal flight over level terrain. Table 2 is for below set clearance flight over level terrain. The second and third columns in each table compare the range at which the maximum delta gamma command is received to the range at which the maximum delta gamma command is expected. The expected range value is Rl. Rl is the distance from the A/C to the junction of the C_6 and F_A face of the TF template. In column 2 the comparison is made by subtracting Rl from RI. RI is the range at which the maximum delta gamma command is received when the maximum delta gamma command is calulated using the ideal Ho/R. The ideal Ho/R is calculated from the recorded values of range, gamma, velocity and set clearance. In column 3 Rl is subtracted from Ru. Ru is the range at which the maximum delta gamma command is received when the maximum delta gamma command is calculated using the Ho/R received by the TSE-20G. A positive value in either columns 2 or 3 indicates the return occurred along the F_A face. A negative value indicates a return along the C_6 face. For normal flight over level terrain the average returns relative to Rl in columns 2 and 3 are respectively 626 and 835 feet. The corresponding values for the below set clearance flight are 1207 and 1231 feet. This indicates the majority of returns occur along the Fa face for both normal flight over level terrain and below set clearance flight over level terrain with the largest discrepancy occurring for the below set clearance flight.

In addition to the different locations of the maximum delta gamma commands the below set clearance flight is characterized by lack of returns on a number of the half scans. In the TF analysis program the returns are grouped in 50 foot increments. The number of returns listed in Tables 1 and 2 are, in reality, the number of different range increments which were received on each half scan. Half scans one through 10 in Table 2 have 40 or less of these increments. There are no half scans listed in Table 1 which have 40 or less range increments.

The last two columns in Tables 1 and 2 show a slight difference in angular errors between the two flight profiles. Column seven lists the angular error associated with the maximum delta gamma that is obtained in each half scan when using the ideal Ho/R. Column eight lists the average angular error for all returns during the respective half scans. The data reveals a bias between the above set clearance flight and the below set clearance flight. The average values in columns seven and eight are .2° greater for the above set clearance flight than they are for the below set clearance flight. This is a small difference and could be a function of the errors inherent in the TF computer or TSE-20G instrumentation (see reference 3). On the other hand, if it is found on other flights when the A/C drops below set clearance over level terrain it could account for some of the fly low behavior.

TABL[illegible]

CHARACTERISTICS FOR FLIGHT ABOVE SET CLEARANCE OVER LEVEL TERRAIN

Half Scan #	(1) (2) RI-Rl (Feet)	(3) Ru-Rl (Feet)	Gamma (degree)	Clearance (feet)	Range Increments	Angular Errors Command (4) (deg)	Angular Errors Average (deg)
1	1574	1721	.526	319	57	.352	-.466
2	1633	1043	.443	319	60	-.235	-.628
3	1272	927	.460	319	67	-.150	-.448
4	250	742	.460	319	51	-.379	-.609
5	428	1092	.402	319	57	-.179	-.330
6	-52	218	.339	319	54	-.610	-.649
7	457	457	.296	323	55	-.241	-.453
8	-155	1272	.224	326	49	-.009	-.756
9	408	433	.160	320	61	.110	-.621
10	927	903	.131	319	50	-.647	-1.004
11	1444	--	.107	319	48	.099	-.460
12	-67	1753	.066	319	48	-.174	-.609
13	797	--	-.062	319	50	.142	-.429
14	1096	1145	-.127	316	44	-.162	-.594
15	225	914	-.131	313	47	-.356	-.587
16	204	179	-.066	306	45	-.549	-.806
17	1391	1440	-.066	306	52	-.087	-.829
18	-127	-53	-.066	300	44	-.761	-1.050
19	944	944	0	299	42	-.797	-.841
20	-121	-97	.131	298	42	-.597	-1.123
Average	626	835				-.26	-.66
Std. Dev.	620	553				.32	.22

(1) RI is the range at which the maximum delta gamma command is received, using the ideal Ho/R.

(2) Rl is the range from the A/C to the intersection of the C_6 - F_A face of the template.

(3) Ru is the range at which the maximum delta gamma command is received, using the recorded Ho/R.

(4) The maximum delta gamma command using the ideal Ho/R.

TABLE 2

CHARACTERISTICS FOR FLIGHT BELOW SET CLEARANCE OVER LEVEL TERRAIN

Half Scan #	(1) (2) RI-RI (feet)	(3) Ru-RI (feet)	Gamma (degree)	Clearance (feet)	Range Increments	Angular Errors Command(4) (deg)	Angular Errors Average (deg)
1	3420	3444	.392	293	35	-.447	-.712
2	574	-311	.273	293	34	-.524	-1.044
3	2794	2868	.263	293	34	-.922	-1.367
4	2373	2373	.230	293	26	-.313	- .851
5	472	472	.263	293	35	-.638	-.899
6	908	1720	.263	293	34	-.086	-.283
7	-73	1526	.175	293	26	-.464	-.765
8	1094	1094	.066	293	37	-.288	-.744
9	2774	831	.066	286	39	-.560	-1.345
10	451	475	.066	286	40	-.539	-.908
11	2145	227	.066	286	44	-.488	-.728
12	2843	--	.164	286	60	.160	-.585
13	96	121	.164	286	57	-.752	-.809
14	1315	1315	.164	286	56	-.383	-1.126
15	54	1505	.228	286	66	-.941	-1.049
16	1899	1530	.281	286	74	-.241	-.950
17	33	--	.394	286	69	-.581	-1.045
18	18	1764	.460	286	78	-.325	-.686
19	1	-24	.526	286	74	-.538	-.835
20	953	--	.526	286	74	-.088	-.558
Average	1207	1231				-.44	-.86
Std. Dev.	1156	1036				.28	.26

(1) Ri is the range at which the maximum delta gamma command is received using the ideal Ho/R.

(2) Rl is the range from the A/C to the intersection of the C_6 - F_A face of the template.

(3) Ru is the range at which the maximum delta gamma command is received, using the recorded Ho/R.

(4) The maximum delta gamma command using the ideal Ho/R.

FLYUP OVER WATER:

Figures 1, 2 and 3 summarize the A/C's performance over water. In Figure 1 the terrain generated from the radar altimeter is compared to the terrain generated from the TSE-20G data during a time when the A/C is in level flight. The -1.4° bias shown in Figure 1 is typical of the angular bias between the two terrains. The typical range at which the maximum delta gamma command occurs generally lies between 3800 and 5200 feet. In Figure 2 a corresponding radar map, taken while the A/C is in its flyup, shows a slight but important deviation from these terrain mapping characteristics. The A/C responds to a series of commands 470 to 670 feet above the terrain at a range of 11,000 feet. The information displayed in Figure 2 is typical of the seven second period during which the A/C was commanding positive g's. The g-command profiles during this period are displayed in Figure 3. Figure 3 shows the actual g-command profile steadily increasing over this time period, accumulating in a +1.4 g-command. The g-command generated from the TSE-20G data fails to rise as steadily as the actual g-command history but does accumulate in a +1.2 g-command. The conclusion drawn from the information displayed in Figures 1 through 3 is quite evident. There was something off the coastline which caused a number of returns to appear above the surface. The A/C responded to these returns.

ANGULAR ERRORS:

In Reference 1 a comparison is made between the mean angular error resulting from the difference in the two terrain mapping techniques and the actual g-command the A/C responds to during Flight 3-29. The observation made is that for positively increasing g-commands the mean angular error increases in a negative direction with a one to three second time lag. Conversely, for negatively increasing g-commands the mean angular error increases in a positive direction with a one to three second time lag. Similar behavior is observed on Flight 3-34. Figures 4, 5 and 6 show the angular error between the two terrain maps as the A/C proceeds over an isolated peak on TR 354. Figure 4 shows the terrain mapped from the TSE-20G lying below the radar altimeter terrain, a negative error, as the A/C begins its pull up over the peak. Later, agreement is achieved between the terrain maps for short ranges but not for the longer ranges. This is shown in Figure 5 and is just before the A/C clears the peak. Once the A/C has cleared the peak the angular error becomes quite positive. This is shown in Figure 6. The corresponding g-command and mean angular error profiles during this time period are shown in Figu es 7 and 8. In Figure 7 the g-command achieves its negative limit between 48580.5 and 48582.0 seconds. The maximum mean angular error (Figure 8) is attained at 48584.0, 2 seconds after the g-command comes off its negative limit. The next maximum g-command occurs at 48586.0 seconds. The corresponding maximum negative mean angular error occurs at 48587.0 seconds, one second later.

Prepared by_____ Reviewed by_____
J. Naylor K. Noess

Approved by_____
N. Walton

FIGURE 2. TERRAIN MAPPING DURING THE FLY UP OVER WATER