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955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

date: August 19, 1971

to: Distribution

B71 08026

from: I. Y. Bar-Itzhack, M. L. Carothers

subject: LRV Navigation Support at Bellcomm During the Apollo 15 Mission - Case 320

ABSTRACT

The authors report in this memorandum on their LRV navigation activities at Bellcomm during the Apollo 15 lunar EVA's when they were supporting MSFC. Alignment headings were computed using Bellcomm nomograms, and using Bellcomm's UNIVAC 1108, an analysis of the new second traverse was carried out to determine the location of stops at which realignments would have been necessary. It was concluded that the gyro virtually did not drift and that the system performed very well.

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MEMORANDUM FOR FILE

Upon the request of E. C. Smith of MSFC who was responsible for computational support to Mission Control Center Houston (MCCH) on the LRV Navigation (NAV) System, the authors monitored the lunar surface activities of the Apollo 15 astronauts and stood by to perform new traverse analyses. Such analyses would have been necessary in order to determine the new points on altered traverses at which the astronauts would have to realign the NAV system gyro in order to keep the NAV system position error under 600 meters. In order to estimate the gyro drift, a necessary parameter in the analysis, the authors also performed the realignment computation using data read by the astronauts and the nomograms prepared by W. G. Heffron and F. LaPiana of Bellcomm (Reference 1).

The authors were equipped with 1:25,000 photographic maps of the landing sites. The dimension of the grid on these maps was 1 cm which represented 250 meters. The grid lines were marked vertically by letters and horizontally by numbers. The astronauts, MCCH and E. C. Smith used identical maps. A new traverse would have been indicated by either E. C. Smith or by J. W. Head of Bellcomm who sat in the Surface Operations Room at MCCH. The traverse would have been outlined by the coordinates of the points at which straight lines approximating the traverse would intersect and by the time spent at the various stations. A transparent overlay of polar coordinates whose origin would have been at the LM would have graphically transformed the cartesian coordinates of those points into range and azimuth which were the suitable inputs to the computer program. A Datel terminal, connected to Bellcomm's 1108 computer, was ready to execute the realignment planning program.

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The first activity at Bellcomm started an hour before the landing on the evening of July 30. It terminated about an hour after the standing EVA when the landing point was tentatively identified and it was concluded that there would be no change in the first traverse. This had been established through E. C. Smith and J. W. Head.

The activity at Bellcomm on July 31 started at 8:00 a.m. (EDT). The LRV NAV system initial alignment occurred at about 11:00 a.m. The astronauts read the following data:

$P = 0.0$ (Pitch)

$R = -1.0$ (Roll)

$D = 0.0$ (Sun Dial Device reading) .

The computed headings were

$H_B = 279.4°$ (Computed at Bellcomm)

$H_M = 279.413°$ (Computed at MSFC)

$H_A = 279.0°$ (Read to the Astronauts) .

As recommended, the astronauts realigned the gyro at station #2 at about 12:10 p.m. and read

$P = 0.0°$

$R = 8.0°$

$D = 1.0°$

$H = 280.0°$ (Indicated heading) .

The computed headings were

$H_B = 282.15$

$H_M = 281.913$.

Since the difference between the indicated and computed heading was only 2°, no correction was given to the astronauts. The astronauts left the LRV and returned 48 minutes later and still read a heading of 280.0°. These results gave rise to the conclusion that the gyro virtually did not drift and the difference between the indicated and calculated headings at 12:10 p.m. was entirely due to alignment errors.

Before the beginning of the second traverse, J. W. Head and E. C. Smith advised the authors of a new second traverse. If indeed the gyro had no drift, this would not have required any action. Assuming a worse case of 3.5°/h gyro drift, the new second traverse was run on the UNIVAC 1108 and it was found that no realignment was required if we allowed 800 meters error at the end of the traverse. This result was relayed to MSFC where the secondary team, that is, the team which manned the consoles between traverses, ran the new traverse using Bellcomm's program and came also to the conclusion that no realignment was necessary.

The initial alignment for the second traverse took place on August 1 at 8:45 a.m. The data read by the astronauts were

$$P = -1.0°$$

$$R = -1.0°$$

$$D = 0.75° \quad .$$

The computed headings were

$$H_B = 283.88°$$

$$H_M = 283.95°$$

$$H_A = 283.0° \quad .$$

Note that the heading read to the astronauts was erroneously rounded to 283.0° rather than 284.0°. At about 11:05 a.m. realignment data read by the astronauts at Spur Center were

$$P = -3.0°$$

$$R = 5.0°$$

$$D = -4.0°$$

$$H = 290.0° \quad .$$

The computed headings were

$$H_B = 293.35$$

$$H_M = 293.2 \quad .$$

Note that about 1° of the difference between the indicated and the computed heading angles was induced by reading a wrong heading angle to the astronauts during the initial alignment. Approximately 45 minutes later the astronauts came back to the LRV and again read a heading angle of 290.0° which, similar to the result of Traverse 1, indicated that the gyro had virtually no drift. At that point MCCH asked the astronauts to torque the gyro to a heading of 293.0°, which they did.

The third traverse was very uneventful as far as the NAV System was concerned. It started with an initial alignment. The readings were

$$P = -2.0°$$

$$R = -2.0°$$

$$D = -0.5° \quad ,$$

and the computed headings were

$$H_B = 291.4°$$

$$H_M = 291.6°$$

$$H_A = 292.0° \quad .$$

No additional alignment was carried out on this traverse. This ended our activities during the Apollo 15 EVA's.

CONCLUSIONS

The authors have concluded that it will be a useful practice for MCCH to compare their alignment computation with MCC/NAV Support (Blucker) and MSFC (Smith) before reading a heading angle to the astronauts; that the use of the nomograms yields accurate results; that the gyro virtually did not drift; that the heading errors were alignment errors; and that the LRV NAV system performed very well.

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REFERENCE

1. W. G. Heffron and F. LaPiana, "The Navigation System of the Lunar Roving Vehicle", Bellcomm Technical Memorandum TM 70-2014-8, December 11, 1970.

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From: I. Y. Bar-Itzhack, M. L. Carothers

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