Chapter 3

DESERT NAVIGATION

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ABSTRACT

Navigation in the Western Desert of Egypt has traditionally been done by using celestial sightings with a theodolite, using a sun compass developed during the 1930's, relying on native guides who are familiar with the terrain, and most frequently by dead reckoning using a compass and odometer readings. As an improvement on the dead reckoning method, a vertical card compass was used on this expedition mounted on the windshield of one of the vehicles. In addition, a satellite-relayed remote access measurement system (RAMS) was used as a check on our positions as plotted by dead reckoning. For stationary satellite transmissions, the locations computed by the RAMS system were accurate to within 3.4 km, while for transmissions en route, the computed positions were much less accurate than those derived from traditional methods of navigation.

INTRODUCTION

During the early days of Western Desert exploration, navigation was either celestial, by the use of theodolite (Hassanein Bey, 1925; Hussein, 1928) or by Bedouin guides who navigate by making use of various combinations of landmarks, sun angle, Polaris, experience, intuition, and luck (Harding-King, 1925). Normally, the former method was the most precise. In the 1930's Bagnold (1953) and his associates navigated by use of his sun compass, and by astronomic observations with theodolite at evening halts (Newbold, 1931). Further refinements were made by the Long Range Desert Group (LRDG) during World War II and later (Hall, 1967). During the 1978 trip, we were equipped with a transmitter that relayed a signal via Nimbus satellite to a ground receiving station. The position of the transmitter was computed nominally three times a day, so that our location could be determined and compared to navigated locations.

NAVIGATION METHODS

Dead reckoning by magnetic compass and odometer is somewhere in between celestial navigation and the use of native guides in both simplicity and accuracy. Some guides, however, have little or no difficulty relocating an area as long as there is reasonably good visibility. Some, in fact, have remarkable abilities in this regard. Two such guides, Saleh and Ayed Marif Salem have worked for the Geological Survey of Egypt in this capacity for years, and accompanied us on this journey.

The main problem with dead reckoning is in the use of magnetic compasses (Sheppard, 1970). With hand-held compasses, such as the Brunton type, one must step away from the magnetic vehicle, sight along the desired heading and select a landmark (rock, hill, contact between color changes, etc.) as far ahead as visibility and terrain will allow. In irregular or broken ground this is not usually very far, and one must rapidly select alternate marks along the heading as hills and dips obscure the initial mark. As the landmark is approached, it is sometimes possible to prolong the heading by lining up with another distant object, but this can lead to serious error if true direction is not checked frequently.

On the flat, featureless sand sheets where there are no landmarks, one must rely on a properly compensated compass mounted on the windshield. Dead reckoning in this way, while less accurate, is faster and less tedious than with the seemingly incessant stops needed with the hand-held compass, but the main difficulty is overriding by the liquid-filled compass as one bumps along over irregular surfaces. In extensive areas of broken terrain, frequent stops are needed to allow the compass to settle and to line up a new mark. Because such marks are seldom more than a few kilometers away, one is constantly looking for additional marks farther ahead and alternate marks in between as the main target disappears from view. Only those who have experienced this kind of desert driving can appreciate how exhausting it can be. One often does not realize the degree of their fatigue until the stop at the end of the day, but an objective successfully reached makes it all worthwhile.

Wherever possible, the objective of dead reckoning should be a clearly recognizable or identifiable landmark, and the route must be faithfully plotted on the map. Only in this way are discrepancies apt to be discovered in time to be usefully corrected. With this degree of care and a distinct landmark as the day's objective, one is impressed with the accuracy with which distant locations can be reached. After a field season or two, as one becomes more familiar with the landscape, a high degree of confidence can be attained. This is the stage at which one has to guard against being overconfident and therefore careless. The desert is notorious for the unforeseen to happen. In a sandstorm visibility is commonly reduced to only a few meters, and patterns or tracks on the desert surface can be obliterated in minutes.

One of the most common mistakes of desert travel is the attempt to rely on old tracks. It is incredible how subtly the wrong track can lead one astray, and now with ever more people motoring in the Western Desert, such as petroleum exploration parties, scientific expeditions, and even desert tours, there are many tracks that are not a part of the traditional routes of Bagnold or the LRDG. In following one's own tracks, distance and direction records should be faithfully continued as a check and as a backup in case the tracks have been obliterated. This is particularly true at night, and more than one desert traveler has been embarrassed by going the wrong way on his outbound tracks.

A significant factor noticed when being guided by a native guide was a bias for the left whenever a choice had to be made in deviating from the main course. In one case, it was apparent from dead reckoning that we were veering too far to the south from our intended southwesterly heading (Haynes and others, 1979). By knowing the direction in which we were off course we were able to head due north and pick up the lost caravan track. When dead reckoning over long distances, it can be useful to maintain a slight bias in order to err toward familiar ground or to know on which side an objective may be in case it is missed.

When avoiding difficult ground such as dunes, the most reliable procedure is to take a new course until the obstacle can be passed by one or two more straight legs. In so doing, one is often tempted by apparent short cuts that can lead to cul de sacs. Needless to say, it takes very few deviations of this type to introduce large errors in one's navigation. One solution is to have a second vehicle (it is always best to proceed with no less than two vehicles in desert travel), wait while the first explores the route. If a way through is found, the second vehicle can proceed after a preset waiting time. If not the first vehicle can return and pick up where it left off. All of these cautions and good intentions are not, however, always followed.

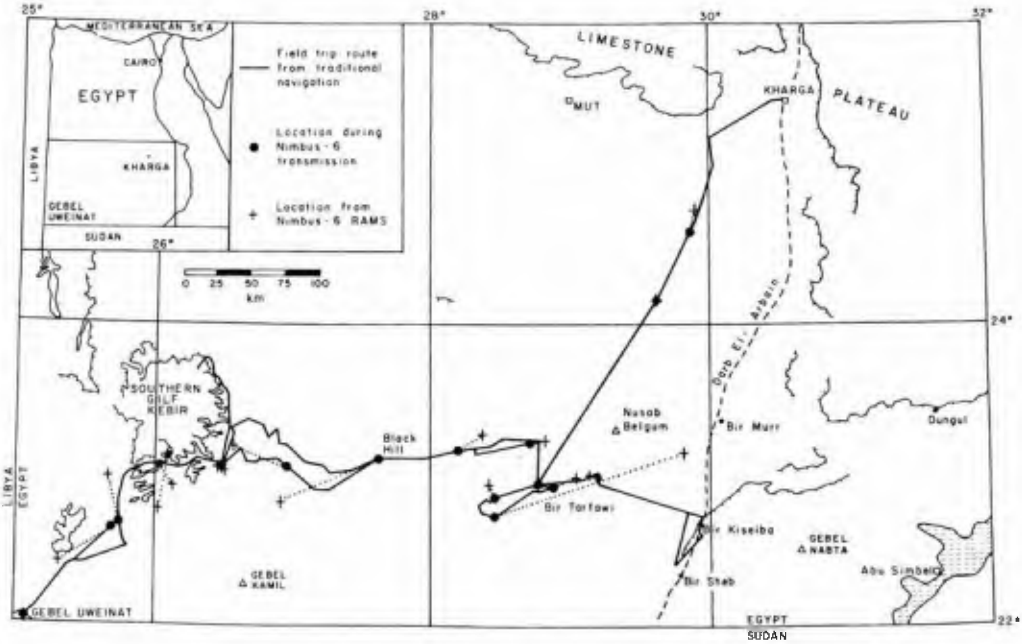

Figure 3.1 Route map showing comparison of navigated route to that obtained from Nimbus-6 RAMS satellite tracking.

Figure 3.2 Vertical card compass mounted on windshield of Volkswagen Type 181 desert vehicle.

Vertical Card Compass

On the present journey while being guided by Saleh and Ayed we maintained a dead reckoning course log and map plot (Fig. 3.1) by use of a properly compensated vertical card magnetic compass manufactured for aircraft by Hamilton Instruments, Inc., Houston, Texas. The advantages of this instrument over the standard liquid filled compass is that the motion is damped so there is essentially no override, and vibrations are not detrimental. Thus, the compass can be read while underway even over fairly rough terrain. With the compass mounted on the windshield of our Volkswagen Type 181 (Fig. 3.2), and centered between the two seats, both the driver and navigator could monitor it. Over rough ground, the navigator advised the driver of any course corrections necessary, leaving him free to maintain visual contact with the route. Also, the driver advised the navigator whenever a significant change in course was made or anticipated.

Periodically, the vertical card compass was checked by Brunton, with declination properly set, by either sighting back along the tracks if straight, or by sighting along the long axis of the vehicle from far enough in front to avoid its magnetic effect. If mapped landmarks were in view and positively identified, we would check our position by resection.

NIMBUS-6 RAMS EXPERIMENT

In addition to these traditional methods of desert navigation, the Nimbus-6 RAMS (Remote Access Measurement System) was used to obtain location data that would aid in plotting the field trip route. The system operates by transmission of a signal from the ground to a satellite, which is then relayed to a ground receiving station where frequency shifts in the transmitted signal are converted into ground locations by knowing the precise orbital track. The RAMS system was used for three reasons: 1) Available map coverage of the Gebel Uweinat - Gilf Kebir region is limited to 1:500,000 scale maps made on the basis of surveys done before and during World War II; 2) Uncertainties in the accuracy of desert navigation (essentially mileage and azimuth recordings) made an alternate means of plotting sample locations desirable; and 3) In order to test the "search and rescue" capabilities of the RAMS, and in the absence of any other means of communication, the transmitter was equipped with a switch that would relay a message signalling an emergency situation.

Logistics

The ground-based platform for the Nimbus-6 RAMS communications link consists of three parts; a power supply, transmitter and antenna. A 12 volt Gel Cel battery (fully charged before the trip) provided power to the transmitter continuously for two weeks. The transmitter (manufactured by Handar) had the capability to send messages on four channels during each transmission. For our use, however, it was preset for no message transmission during normal operation, and full-scale transmission on the first channel during an emergency. During operation, both battery and transmitter (wrapped in 1-inch foam for cushioning) were kept on the rear floor of the vehicle. No problems were encountered with either the transmitter or the battery.

Locating the antenna (manufactured by CHU Associates) at the highest point of a canvas-covered vehicle was much more difficult. A wooden antenna mount made before the trip proved unsuitable after one day in the field. Consequently, the antenna was bolted to the body of the vehicle (Fig. 3.3). This position resulted in 90-100° loss of the (circular) radiation pattern of the antenna, but using the predicted pass time, an attempt was made to favorably orient the vehicle with the antenna facing the spacecraft.

Results

The results of the Nimbus-6 RAMS calculated locations and those from navigation while en route are presented in Table 3.1. As a minimum, at least one location per day was expected, although up to three per day were possible. Before the trip, it was not known whether the Nimbus-6 communications link would be operating during the nighttime passes in order to provide additional coverage. For the 11 days of the Gilf Kebir - Gebel Uweinat trip, 31 transmissions were received at Goddard Space Flight Center in Greenbelt, Maryland. During the emergency test procedure on October 13, 2 transmissions were received. Of these 33 transmissions, sufficient data were received for computing 22 locations.

Locations computed from RAMS do not compare well with those plotted from the more traditional methods of desert navigation (Fig. 3.1). During the trip a record of mileage and direction was kept independently by both authors; one familiar with the terrain (C.V.H.), and one unfamiliar with the terrain (T.A.M.). Despite this observational bias, over one stretch of 367 km (from Bir Sahara to the Gilf Kebir), the final navigated positions fall within 10 km of each other. However, of the 22 total locations computed by the RAMS, only 11 were within 10 km of the navigated positions. Of these 11 locations, 9

Table 3.1 Comparison of Nimbus - RAMS and Navigated Tracking Data.

Day	Local Time	No. Transmissions Received	Location Method*	Error**	RAMS CALCULATED		NAVIGATED		Difference (km)
					LAT.	LONG.	LAT.	LONG.	
9/26	12:44pm	9	1PP	96.6	24.79	29.87	24.58	29.83	16
(9/27)	12:09am	15	1PP	100.0	22.93	28.76	22.93	28.76	±3
9/27	10:28am	12	1PP	99.9	22.99	29.03	22.91	28.90	14
	12:01pm	13	1PP	100.0	23.16	29.79	22.66	28.42	150
	1:50pm	10	1PP	99.9	22.89	28.43	22.83	28.77	6
	11:41pm	3	-	-	no location computed				-
9/28	11:21am 1:07pm	25	2PP	21.0	23.00	29.13	23.00	29.23	12
	10:49pm	10	1PP	38.7	22.91	28.76	22.80	28.52	±3
9/29	12:24pm	12	1PP	100.0	23.23	28.80	23.20	28.70	10
	2:16pm	4	1PP	58.9	23.29	28.80	23.20	28.43	8
(9/30)	12:05am	3	-	-	no location computed				-
9/30	10:04am	3	-	-	no location computed				-
	11:11pm	12	1PP	-	23.03	26.45	23.05	26.45	±3
(10/1)	2:51am	2	-	-	no location computed				-
10/1	11:03am 12:48pm	23	2PP	48.0	23.06	26.45	23.05	26.45	±3
(10/2)	12:27am	3	-	-	no location computed				-
10/2	10:25am	9	1PP	99.2	22.94	26.12	23.05	26.03	15
	12:08pm 1:55pm	21	2PP	37.0	22.98	25.66	22.67	25.76	33
10/3	11:35am 1:13pm	19	2PP	45.0	22.05	25.11	22.05	25.11	±3

10/4	10:45am	9	1PP	60.3	22.43	25.32	22.65	25.72	48
	2:18pm	5	1PP	50.2	22.78	26.00	23.10	26.08	40
	11:59pm	12	1PP	100.0	23.05	26.45	23.05	26.45	±3
10/5	10:07am	6	1PP	99.8	23.19	26.56	23.08	26.92	44
	11:58am 1:35pm	25	2PP	32.0	22.81	26.89	23.07	27.58	76
	11:18pm	10	1PP	99.0	24.15	29.61	24.17	29.57	±3
10/6	12:53pm	11	1PP	50.3	25.45	30.51	25.45	30.51	±3
Emergency Test									
10/13	11:35am	15	1PP	100.0	28.50	29.14	28.45	29.35	7
	11:00pm	3	-	-	no location computed				-

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* 1PP: one pass position; 2PP: two pass position (Location is computed for first transmission time).

** Test for accuracy; on one pass position, 100.0 is best score. On two pass positions, 50.0 is best score.

Figure 3.3 Nimbus-6 RAMS antenna mounted on rear of Volkswagen Type 181 desert vehicle.

were from camp or otherwise stationary positions. The average difference between RAMS and navigated locations is 3.4 km for stationary transmissions, and 36.3 km for transmissions while en route (tracking data are summarized in Table 3.2).

The lack of correspondence of navigated versus RAMS-calculated positions most likely results from a combination of several factors, although orbit geometry, placement of the antenna, and the roughness of the terrain are thought to be most important. For example, the 12:01 PM location on September 27 (discrepancy of 150 km) was transmitted from the middle of the Abu Hussein dune field while the

Table 3.2 Summary of Nimbus - RAMS Tracking Data.

Total No. Transmissions received	33
Total No. Locations computed	22
Minimum expected locations (No. days in field)	11
DISCREPANCIES	
No. Locations in camp or stationary	9
Average error of stationary locations	3.4 km
No. Locations while _en route_	13
Average error of _en route_ locations	36.3 km
Total Locations computed	22
Total Locations < 10 km off	11

vehicle was making a wide turn from west to north. The angle from horizontal to the spacecraft at this time was 85°, greater than the 10°-80° needed for optimum locations.

The test of the emergency switch on October 13 performed as expected, and indicated that the battery had remained fully charged. The battery voltage was further confirmed upon return to Goddard Space Flight Center, and no significant loss of power had taken place throughout the trip.

Recommendations

Equipment. Neither the transmitter nor battery created any problems during the trip. However, for the extremely rough terrain, suitable means of strongly anchoring the antenna is necessary. Since most desert vehicles have canvas tops, the antenna cannot be bolted directly to the top of the vehicle, as the struts that support the roof are not strong enough to support the antenna. Any vertical-pole mount must be secured by guy lines attached as close as possible to the top of the antenna. Judging from the results of this experiment, however, the most important consideration is keeping the antenna stationary for the duration of a pass. Consequently, predictions of pass times are a necessity, as are predictions of the groundtrack (spacecraft sub-point) so that a proper antenna-spacecraft orientation can be maintained. Even this mode of operation can create problems for a large caravan, since it means that at least one of the vehicles must stop for each pass. At present, however, this seems to be the only feasible method to improve the accuracy of location data.

Data Handling. During this experiment, two-pass positions were calculated for 5 of the locations. Although these locations would theoretically be more accurate than one-pass positions, the actual location of the transmitter had changed several tens of kilometers between the times of the two transmissions. A potential improvement in the calculation procedure would be the capability to calculate these transmissions as one-pass positions.

Potential for Remote Desert Studies

In spite of the large discrepancies in location resulting from this experiment, the Nimbus-6 RAMS has great potential for studies of the remote regions of the world. With suitable accuracy, this system will aid future desert studies by:

1. Allowing a group (or several groups) to remain in the field with a communication device that could be relied on in an emergency situation.

2. Providing location data that would be useful for both locating samples and checking navigation.

3. Providing real-time data (locations while still in the field) that could be used for field checks on the locations of known landmarks and other features, and for correcting the field trip route during travel.

4. Adding two-way communication with the outside world. In addition to the added sense of security, this would provide an internal test on the operating condition of the system.

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