PRELIMINARY EXPERIMENT RESULTS FROM THE OMEGA POSITION LOCATION EQUIPMENT (OPLE)

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Summary of Test Results The analysis of data taken during the fixed platform, road and aircraft tests indicates that the OPLE system can locate a fixed or moving platform with reasonable accuracy. During the fixed platform interrogations, it was found that the error in the OPLE-derived position estimates were consistently correlated with the error in the position estimates of the OCC as derived from the local Omega monitors; that is, latitude and longitude errors of corresponding magnitudes were received at the OCC both from the PEP's and from the Omega receiver located at the control center.

Based on the data analyzed thus far for the fixed platforms, the overall contribution to the mean position error by the OPLE equipment ranges between 50 to 400 feet in latitude and 300 to 500 feet in longitude. The results have shown that the longitude errors are consistently greater than the latitude errors.

The results of the road test indicated that a moving vehicle could be located with good accuracy. Men the OPLE-derived position estimates were adjusted for the navigational errors of the Omega system, the vehicle was located to within 1500 feet of the roadway.

The results of the aircraft tests showed that an airborne platform moving at 160 knots could be located with reasonably good accuracy. During the daytime test, the position of the aircraft could be placed to within approximately 5 miles of GSFC. During the evening tests, the position of the aircraft was located to within 10 miles of the estimated center of the aircraft's circular flight pattern, the position being consistently to the east of the center of the circle. During these evening tests, the position of the OCC was calculated to be 4 miles east of its actual location.

Introduction The Omega Position Location Equipment (OPLE) Experiment is to demonstrate the feasibility of using the Omega Navigational System in conjunction with synchronous satellites to establish a global location and data, collection system. OPLE, as shown in Figure 1, consists of an OPLE Control Center (OCC) located at GSFC, a synchronous satellite, Platform Electronic Packages (PEP) and the Omega Navigational network. The OCC-satellite-PEP link operates at the VHF frequencies while the Omega

Navigational network operates in the VLF band. The experiment utilizes the ATS-3 satellite, whose VIIF communications transponder can provide for up to 40 simultaneous PEP transmissions in its 100-kHz bandwidth. For the experiment, however, only four platforms can be interrogated simultaneously.

Operational experiments were initiated on February 15, 1968. Platforms were placed at a number of fixed locations. Sufficient data were collected during the reporting period from two of the platforms to allow a statistical analysis to be performed. These two platforms consisted of a platform electronic package (PEP #1) located at GSFC and another (PEP #4) located at Communications and Systems, Inc., Falls Church, Va. The objectives of the fixed platform tests were to:

(1) Establish the accuracy with which the true position could be located based on the Omega Navigational System
(2) Determine the effect that the time of day has on the accuracy of the system, and
(3) Establish the contribution to the system error attributable to OPLE equipment. The analysis of data taken from these fixed platforms during the period February 15, 1968 through April 4, 1968 is presented herein.

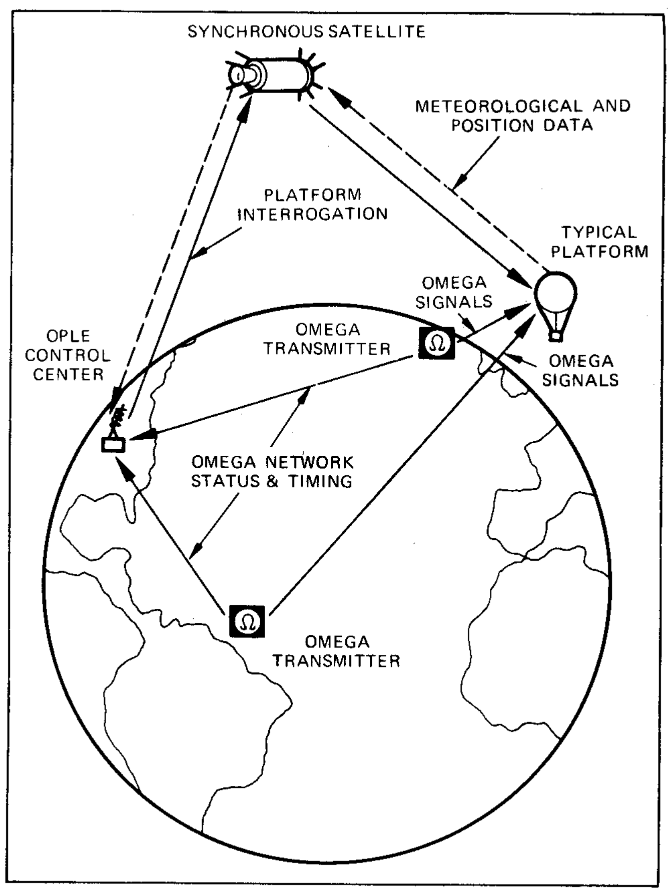

Figure 1-OPLE System Configuration

Automobile road tests were performed during the reporting period. A platform electronic package and cross-dipole antenna were mounted on a mobile platform tests were conducted in the vicinity of GSFC and on the Washington-Baltimore Par way. The purpose of these tests was to evaluate the capability of the OPLE system to establish the position of a mobile platform moving over ground terrain. These tests were performed during April.

An aircraft experiment was added to the OPLE test schedule during the reporting period. A platform electronic package was installed on board a NASA aircraft along with a blade type VHF antenna and VLF antenna. Tests were performed in vicinity of GSFC and over the Chesapeake Bay area on April 15, 1968. The objective of the test was to provide an initial assessment of the OPLE capability for locating moving aircraft.

Fixed Platform Tests The tests were performed with fixed platforms placed at a number of locations. Sufficient data were collected from the prototype electronic package (PEP #1) located at GSFC in Greenbelt, Maryland, and Platform Electronic Package #4 located at Communications & Systems, Inc., Falls Church, Virginia, to allow a statistical analysis. The data collected from 350 interrogations of the two platforms are included in the analysis.

Since the two PEP's were located within proximity of the OPLE Control Center and within the same skywave correction area as provided by the Omega Navigational system, a direct comparison could be made of system inaccuracies resulting from the OPLE equipment and from the Omega Navigational system.

During the experiment, platforms were interrogated by the OCC separately and concurrently, the latter allowing operational assessment of the effect of multiple platform transmissions on system operation.

Table 1 summarizes the mean and standard deviation associated with position estimates of the OCC based on directly monitored Omega signals. Table 2 presents the means and standard deviations from actual positions for the OPLE-derived position estimates of PEP's #1 and #4, respectively. Large variations are observed with respect to both parameters. The consistency in the results both in the OPLE-derived position estimates as shown in Table 2 and in the monitored Omega position estimates suggest inaccuracies in the skywave correction factors which are used to compensate for variations in propagation paths of the Omega signals.

Table 1
Statistical Summary (Position Estimates of OCC as Monitored b OCC Omega Receivers

	Latitude	Longitude
Actual (Degrees)	38.9933 N	76.8507 W
Mean (Degrees)	38.9911 N	76.8332 W
Mean Difference (Degrees)	0.0021 S	0.0175 E
Standard Deviation (Degrees)	0.0246	0.0241
Mean Difference (Feet)	791 S	4991 E
Standard Deviation (Feet)	8979	6886

Table 2
Statistical Summary (Position Estimates of PEP #1 and PEP #4 as Calculated by the OPLE Control Center

	PEP #1		PEP #4	
	Latitude	Longitude	Latitude	Longitude
Actual (Degrees)	38.9955 N	76.8517 W	38.8697 N	77.1705 W
Mean (Degrees)	38.9958 N	76.8328 W	38.8699 N	77.1556 W
Mean Difference (Degrees)	0.0003 N	0.0189 E	0.0002 N	0.0149 E
Standard Deviation (Degrees)	0.0206	0.0233	0.0212	0.0210
Mean Difference (Feet)	129 N	5405 E	81 N	4260 E
Standard Deviation	7495	6655	7725	6000

Since both platforms are located in the vicnity of GSFC, a comparison was made between the OPLE-derived position estimates for platforms #1 and #4 and position estimates of the OCC based on directly monitored Omega signals. The OPLE-derived position estimate is adjusted by eliminating the bias error contributed by the Omega Navigational system as determined at the OCC. The remaining offset represents the OPLE contribution to system error. This represents a paired data evaluation, the pairing being in terms of time of PEP interrogation. The results of this analysis are summarized in Table 3 for the two platforms and all four OPLE receivers. From the table, as indicated by the mean latitude and longitude, some residual error is introduced by the OPLE equipment. The differences observed in the four OPLE receivers are attributable to the variations in receiver implementation and the statistical fluctuation that result from the use of a limited number of samples in the analysis. Correlation between the OPLE receivers is approximately 100 feet in mean error and 300 feet in standard deviation. Since the standard deviations of the adjusted latitude and longitude differences as shown in Table 3 are less than 16 percent of the standard deviations as presented in Tables 1 and 2, they are a significant contribution to system error, as are the present inaccuracies of the Omega Navigational system.

Table 3
Position Deviation Attributable to OPLE Equipment

	Latitude		Longitude	
	Mean (ft)	Standard Deviation (ft)	Mean (ft)	Standard Deviation (ft)
PEP #1				
Receiver 1	394 N	670	415 E	645
2	306 N	737	338 E	607
3	368 M	807	386 E	620
4	280 N	792	359 E	613
PEP #4				
Receiver 1	155 S	819	563 W	719
2	126 S	953	443 W	759
3	48 N	834	472 W	756
4	129 S	616	499 W	482

During the period covered in the tests, the diurnal variations in Omega latitude and longitude were monitored at the OCC. Position deviations of 1.0 to 1.5 miles prevailed during the day and 4 to 5 miles at night.

Road Tests For these tests, a crossed-dipole VHF antenna was mounted on the roof of a NASA station sedan as shown in Figure 2. The ATLF whip antenna was mounted adjacent to the cross-dipole antenna. The PEP electronic package rode in the car bed along with ancillary equipment consisting of a PEP monitoring unit, power supply and two-way radio for direct communications with the OPLE Control Center. A battery eliminator was used during the test with the basic power being supplied by the vehicle ignition system.

The satellite position at the time of test was approximately 85° west longitude and the elevation angle at GSFC was approximately 45°. In the normal antenna mounting

Figure 2-Mobile Platform for OPLE Experiment

position the VHF crossed-dipole antenna has a vertical cone radiation pattern with a 3-dB loss occurring at an angle of approximately 50° relative to zenith or a 40° elevation angle. Since a near-marginal condition may have existed in the normal antenna position, provision was made to tilt the antenna if it was found necessary in order to improve the PEP-satellite RIP link.

Initial tests were conducted over the raods of the Agriculture Research Center. During these tests, the VHF transmission link between the mobile platform and the satellite was found to be satisfactory with the crossed-dipole antenna maintained in the normal vertical position. it was observed that communication was maintained while traveling in the shade of tall trees and through tree tunnels (i.e., based on reports f rom the vehicle to the OPLE Control Center on the two-way radio network). It was noted that OCC receiver phase lock was maintained when the platform passed through roadway underpasses where the transit time was less than a tenth of a second. The effect of VHF doppler was noted during these initial tests. The VLF data (i.e., received signal strength) indicated the effect of some shadowing in the vicinity of dense, woods, but this did not significantly affect the accuracy of the position data.

The position estimates derived during the tests showed the vehicle to be located at various positions off the roadways of the Agriculture Research Center. Due to the peculiar configurations of the traveled roadways, it was difficult to locate the true position of the vehicle with respect to the roadways. As a result, an accurate comparison could not be made between the OPLE-derived estimates and actual positions. Therefore, a second series of tests was conducted on April 22, 1968 using the Baltimore & Washington Parkway, a long, relatively straight, roadway.

The sequence of test interrogations made when the vehicle was moving over the Parkway resulted in a consecutive set of position identifications. The tests were performed over a period of 30 minutes with the vehicle moving at a relatively constant speed of 60 mph. The OPLEIsystem placed the position of the vehicle consistently to one side (east) of the roadway during the interrogations. The reference Omega position estimates of the OCC during this test period also placed the OCC consistently to the east of its actual position. By adjusting the OPLE-derived vehicular position for the deviations in position estimates of the OCC, one finds the adjusted OPLE positions quite close to the roadway. The deviation between the adjusted OPLE positions and the roadway reflects the contribution to the position deviation resulting from the OPLE equipment. Again, the contribution of the OPLE equipment to the overall error was rather insignificant in comparison to the Omega Navigational system. The contributions of the Omega Navigation system to position deviation is illustrated in Table 4 where the data on position deviations as calculated by the OPLE system is summarized. As seen from the table, the contribution to the vehicular position error by the Omega Network was about 1 mile. The location of the OPLE Control Center based on Omega signals received at the OCC has a latitude deviation of approximately 2200 feet and a longitude deviation of approximately 4500 feet. The calculated position of the OCC was located southeast of the true position and was seen to be shifting eastward during the test.

Table 4
OPLE Mobile Platform Test
(Position Data as Calculated b OPLE Control Center)

Int No.	Time (EST)	Vehicular Platform Location		Deviation From OCC (OPLE Estimate of OCC)					Adjusted Platform Position	
		Latitude (deg N)	Longitude (deg W)	Latitude		Longitude		Mag. feet	Latitude (deg N)	Longitude (deg E)
				deg S	feet	deg E	feet			
1	1400	39.0191	76.8416	.0067	2423	.0131	3722	4380	39.0258	76.8547
2	1404	39.0678	76.8125	.0062	2251	.0124	3535	4200	39.0740	76.8249
3	1408	39.1076	76.7647	.0062	2273	.0143	4003	4600	39.1138	76.7788
4	1412	39.1303	76.7414	.0057	2067	.0146	4142	4630	39.1360	76.7560
5	1416	39.0976	76.7783	.0056	2029	.0156	4437	4870	39.1032	76.7939
6	1420	39.0599	76.8160	.0055	2006	.0165	4684	5090	39.0654	76.8325
7	1424	39.0107	76.8285	.0056	2029	.0186	5274	5650	39.0163	76.8471

Position of OCC: Latitude 38.9933° (38° 59′ 36″) N., Longitude 76.8508° (76° 51′ 03″) W.

Vehicle Speed: 60 mph Average

Aircraft Tests This experiment was not included in the original OPLE Test schedule. It was added to the OPLE Test at the request of the ATS Project. STADAN calibration aircraft, NASA 428, was made available for the test. Installation of a Platform Electronic Package (PEP) on board the aircraft was performed on April 10 and 11, 1968. A blade type VHF antenna (124-135 MHz) and a long wire VLF antenna were employed on the aircraft.

After installation a successful post-installation static test was performed. The aircraft was located on the ramp to within 1,000 feet, while stationary, with and without engines running and while the aircraft was taxiing on the ramp. The VHF aircraft-satellite-link was adequate in view of the linear vertical polarization of the aircraft antenna. Signal-to-noise ratio of the VLF signals was found to be very good. Good correlation was observed in locating the aircraft PEP and the mobile platform PEP, which was parked nearby.

The flight plan called for the aircraft to fly criss cross passes directly over GSFC at an altitude of 10,000 feet and a velocity of 160 knots. The flight was to be concluded with a circular pattern Over GSFC with a radius of approximately 5 miles. The flight was to be repeated in the evening to allow comparison between nighttime and daytime location accuracies. During the daytime experiments considerable commercial aircraft communications traffic was encountered. As a result, in the evening experiment the flight plan was altered and the aircraft directed to Chesapeake Bay where circular flight paths are flown over the Annapolis and North Beach areas. The first circular flight pattern was flown over the Annapolis Airpark (38° 58' N. latitude, 76° 31' W. longitude) and was approximately 5 miles in diameter. A second circular flight pattern was flown over North Beach (38° 40' N. latitude, 76° 30' W. longitude) and was approximately 10 miles in diameter. A third circular pattern, 5 miles in diameter, was flown just north of Annapolis (39° 03' N. latitude and 76° 30' W. longitude). The aircraft velocity during the daytime and evening tests was approximately 160 knots. The limited availability of aircraft and rapidity with which the flight test was scheduled precluded the coordinating of aircraft tracking by radar or other means. Therefore, the circular flight paths were based on visual estimates by the aircraft pilot.

During the afternoon flight tests conducted in the vicinity of GSFC, the position of the aircraft was found to be within approximately 5 miles of the OCC. Heavy commercial aircraft communications traffic in the area resulted in several interrogations being aborted, and as a result some difficulty was experienced in coordinating the flight pattern of the aircraft.

Table 5 summarizes the derived data obtained from these tests. From the table, it can be noted that the position of the OCC as computed by the OPLE Control Center deviated in magnitude from 1.0 to 2.0 miles east of the true position.

The analytical procedure used in computing the position of an OPLE platform is based on averaging 18 samples of VLF signals received from each Omega station over a 3-minute interval. During this interval, an aircraft traveling at a speed of 160 knots could travel a path distance of approximately 9 miles. For a straight line path, the OCC would establish the position as approximately 4.5 miles from the position of initial interrogation. For a complete circle during the data run, the mean position would be the center of the circle. Any path between the two extremes would result in a position location whose latitude and longitude would be the average of the platform's latitude and longitude during the 3-minute interval. In view of the averaging process performed by the OPLE system, location of the aircraft was obtained to within approximately 5 miles of GSFC.

Table 5
OPLE Aircraft Platform Test (Daytime)
(Position Data as Calculated by the OPLE Control Center)

Int No.	Time (EST)	Aircraft Platform		Deviation From OCC (OPLE Estimate of OCC)					Adjusted Aircraft Position	
		Latitude (deg N)	Longitude (deg W)	Latitude		Longitude		Mag. feet	Latitude (deg N)	Longitude (deg W)
				deg N	ft	deg E	ft			
1	1405	39.0339	76.8756	.0001	22	.0191	5417	5417	39.0338	76.8947
2	1415	39.0611	76.7847	.0017	628	.0176	5014	5053	39.0628	76.7923
3	1437	38.9801	76.8603	.0090	3262	.0281	7979	8620	38.9711	76.8884
4	1443	39.0573	76.8078	.0107	3907	.0304	8629	9472	39.0466	76.8382
5	1454	39.0053	76.8786	.0100	3640	.0301	8551	9294	39.0153	76.9087

Aircraft Speed: 160 knots

Aircraft tests were continued on the evening of April 15, 1968 over the Chesapeake Bay area. Examination of the position data shows that the aircraft was located within 10 miles of the estimated centers of the respective circles. For the combination of flight circle diameters and aircraft speed, the OPLE-derived positions should be a locus of points with a radius of approximately 3/4 of a mile and 3 miles, respectively, for the two circular patterns.

All three patterns show the OPLE-derived position of the aircraft to be consistently east of the center of each of the circles. The primary reason for this bias can be obtained from an assessment of the tabulated data for the evening tests as summarized in Table 6. In each of the tests, the position of the OCC as calculated by the OPLE Control Center was approximately 20,000 feet east-northeast of the true position.

In comparing the OPLE-derived position estimates for the OCC from Tables 5 and 6, considerably greater position deviation was experienced during the evening tests than occurred during the daytime tests.

Table 6
OPLE Aircraft Platform Test (Nighttime)
(Position Data as Calculated by the OPLE Control Center)

Int No.	Time (EST)	Aircraft Platform		Deviation From OCC (OPLE Estimate of OCC)					Adjusted Aircraft Position	
		Latitude (deg N)	Longitude (deg W)	Latitude		Longitude		Mag. feet	Latitude (deg N)	Longitude (deg W)
				deg N	ft	deg E	ft			
6	1849	38.9803	76.4817	.0240	8753	.0747	21,236	21,321	38,9563	76.5564
7	1854	38.9554	76.4324	.0244	8887	.0750	21,236	22,972	38,9310	76.5074
8	1858	38.9987	76.3404	.0248	9020	.0754	21,435	23,259	38.9739	76.4158
9	1902	38.9675	76.3724	.0245	8931	.0752	21,359	23,153	38.9430	76.4476
10	1917	38.6776	76.3851	.0222	8086	.0703	19,962	21,540	38.6554	76.4554
11	1921	38.6661	76.3720	.0217	7909	.0687	19,528	21,072	38.6444	76.4407
12	1932	38.6717	76.4045	.0179	6508	.0641	18,224	19,353	38.5538	76.3404
13	1936	38.6099	76.3543	.0182	6619	.0635	18,038	19,216	38.6231	76.4178
14	1939	38.8633	76.5282	.0159	5774	.0622	17,883	18,603	38.8474	76.6804
15	1944	38.6866	76.3803	.0159	5797	.0610	17,323	18,269	38.6707	76.4413
16	1954	38.7978	76.4259	.0181	6575	.0613	17,418	18,619	38.7797	76.4872
17	2001	39.1116	76.4273	.0186	6775	.0633	17,977	19,213	39.093	76.4906
18	2006	39.1090	76.4609	.0179	6508	.0626	17,791	18,700	39.0911	76.5235

Aircraft Speed: 160 knots