REPORT OF

ARMY SCIENTIFIC ADVISORY PANEL

AD HOC GROUP ON LORAN MANPACK

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OUTLINE

INTRODUCTION

An Ad Hoc Group of the Army Scientific Advisory Panel has reviewed the LORAN-D Manpack program. The principal purpose of the review, as stated in the Terms of Reference (Appendix 1), was to analyze the objectives and status of the present program as an assist in determining present and future direction.

The present report is based on information acquired principally in February and March, 1975. An earlier draft was circulated for comment during April and May 1975. Consequently the recommendations may have been overtaken, to some degree, by program actions in the intervening period.

FINDINGS AND RECOMMENDATIONS

1. The Army has a need for a common-grid navigation and location system for foot soldiers, vehicles, aircraft, and artillery. The system should be the same as that used by Tactical Air Force units. The Ad Hoc Group is quite concerned about the apparent loss of interest in LORAN C/D by TRADOC units and an associated growth of interests in self-contained systems which will be more costly, less accurate, less reliable, and not coordinated.

2. LORAN-D and the Global Positioning System will both fulfill the requirement for a common grid positioning system. Limited LORAN-D capability now exists while G.P.S. will not be deployable for a number of years. The study group sees no reasonable alternative to LORAN-D in the time period until G.P.S. is available. After deployment of G.P.S., LORAN-D will remain useful as a complementary system and may be superior to G.P.S. for Manpack applications.

3. The AN/PSN-6 Manpack LORAN-D is well along in development and appears to satisfy the specifications established for it. However, it appears to be too costly for widespread deployment as a Manpack (non-vehicular) unit. A major factor in the cost of the AN/PSN-6 is the inclusion of a general purpose computer to provide for time-difference to UTM coordinate conversion and for automatic transmission of position via the radio set.

4. Local conversion to UTM coordinates is not only costly, but also leads to operational difficulties due to terrain anomalies which can cause distortion of the LORAN grid. Unless each LORAN-D receiving unit had the same algorithms and constants for correcting such distortions, anomalies will lead to loss of coordination of locations.

5. A cost reduction program proposed by the contractor could significantly reduce the cost of the AN/PSN-6 with minimal reduction in capability. However, the study group feels that a more substantial cost reduction could be obtained by eliminating the UTM coordinate conversion as well as the automatic interface to the AN/PRC-25. A weight reduction can be obtained by operating Manpack units in an intermittent mode (requiring several minutes of settling and lock-on time) permitting use of the radio transceiver battery.

6. For Manpack applications the Teledyne microloran, developed for another government agency, appears to better satisfy the need for a simple, lightweight, low cost, man-portable LORAN-D positioning device. Either some modification would be required to the microloran unit to satisfy Army temperature-range specifications, or provisions would be required to temperature condition the receiving units before use in the field.

7. LORAN-D positioning devices for Manpack applications should not be burdened with key generators and decoders for ECCM functions.

8. Technology is now available for introduction of solid state transportable LORAN-D transmitters for field Army deployment.

9. The study group recommends that the Army proceed with a detailed large scale field evaluation of the utility of a coordinated LORAN-D positioning system for artillery, armored units, aircraft, and for vehicular-mounted and Manpack applications with Infantry. The objective of the evaluation should be to determine how beneficial such a coordinated positioning system is in a wide variety of Army unit missions. This should follow the currently planned DT/OT tests.

10. For the field evaluation (9 above) the Army should procure sufficient quantities of the AN/PSN-6 to permit evaluation in light vehicles, armored vehicles, and aircraft. The PSN-6 should be operated in time-difference as well as UTM coordinate mode to evaluate differences in utility in the two modes.

11. For Manpack applications in the field evaluation (9 above) quantities of the Teledyne microloran should be procured in addition to the AN/PSN-6 to permit evaluation by units in various tactical operations (forward observers, patrols, recovery, and platoon-level infantry tactics). This appears to be an appropriate task for Project MASSTER.

PROGRAM BACKGROUND SUMMARY

The AN/PSN-6 LORAN-D Manpack Set

The AN/PSN-6 Manpack set was developed by Litton Amecon Division. It was designed to Army specifications, and has grown to 13 pounds in weight and $15,600 (assuming a 95% learning curve) in cost in quantities of 4000, from original estimates of $13,900.

The PSN-6 has an average noise error (repeatable) of 20 meters. The position error will depend on relative transmitter location (GDOP factor) and will typically be several times greater. It displays position in UTM or time-difference coordinates. It can transmit position data in digital format back to a base through an associated AN/PRC-25 or -77 VHF transceiver. It is capable of computing, displaying and transmitting the UTM coordinates of an offset target point when the range, bearing and height of the target relative to the LORAN receiver are entered manually. The set can be mounted in a vehicle as well as backpacked.

The PSN-6 includes automatic signal acquisition and tracking. It includes a general purpose processor -- a repackaged CDC-469 with 6000 16-bit words of memory to perform a number of functions, one of which is the conversion from time-difference to UTM coordinates. Automatic notch filters for the rejection of CW interference are incorporated in the set.

Possible Approaches to Reducing LORAN-D Manpack Costs

Litton made a value engineering change proposal (VECP) to reduce the production unit cost of the set by $5,661, as follows:

	Dev. Cost	Prod. Unit Cost Saving
Replace the general purpose processor with a special purpose processor	$353K	$3,279
Redesign the notch filters	$116K	$1,441

	Dev. Cost	Prod. Unit Cost Saving
Eliminate nuclear hardening	$ 3K	$ 538
Eliminate the automatic position transmission via PRC-25, -77	$ 73K	$ 404
	$545K	$5,661

This proposal to eliminate $5 million to $20 million from production cost by spending $545 thousand and 10 months additional development time was rejected by AMC, who felt that the proposal was not credible.

During the course of the briefings, several Loran-D manufacturers indicated the feasibility of cheaper, lighter, Loran-D Manpack sets. Prices suggested ranged from $3000 to $10,000 in quantities of 1000. The cheaper suggested designs excluded one or more features such as automatic acquisition, conversion to UTM coordinates, automatic notch filters, digital transmission of coordinates and mechanical coupling to the AN/PRC-25 or -77. One such equipment (Micro-Loran) has been developed by Teledyne for another government agency.

Alleged Loran-D Systems Problems

The objections to the PSN-6 Loran-D manpack weight seem to arise in the context of its conjunctive use with the PRC-25, -77 radio set. Thirteen pounds including battery is not overly heavy for the Loran-D set alone, but when taken together with the 28 pound PRC-77 radio, battery and accessories, the load for one man becomes excessive.

In the source of discussion, it became clear that the Infantry School has doubts about many aspects of Loran-D: accuracy, susceptibility to jamming and deceptions, need for installation of base stations, susceptibility to physical damage of the base stations, the need for logistic support arising out of the requirement for registering Loran-D indicated positions with ground maps, etc., but that these deficiencies might well be acceptable if the cost and weight of user units were substantially less. TRADOC has indicated a desire to terminate the current program after DTOT tests.

It also evolved that the Army Aviation arm was beginning to voice doubts about the utility of LORAN-D in helicopters; and it was recalled from the 1974 ASAP Summer Study that there is no plan to include LORAN-D as a land navigation system for tanks.

The Ad Hoc Group received the clear impression that a very fundamental problem was that the Army fears that the Air Force, which has responsibility for LORAN-D transmitter development and deployment, will not carry out its responsibilities properly.

A further Army fear is that LORAN-D development, production and deployment may be overtaken by the advent of the Global Positioning System satellite navigation system. The real issue appears to be more LORAN-D procurement as contrasted with PLRS procurement. The latter, although heavier and more costly, appears well suited to a battlefield environment as computations are made at a central command station. It is, however, dependent on line of sight or relay communications. The advantages of LORAN-D standardization however, are so strong that dilution of effort and funding on competing systems by the Army appears counter-productive.

PROGRAM RELATED OBSERVATIONS

Readout Requirements

It is clear that the inclusion in specifications of the requirement for conversion from LORAN-D time differences to UTM coordinates has contributed very substantially to the complexity and cost of the PSN-6; and, moreover, that making such a conversion has some undesirable aspects. The requirement for coordinate conversion might now (in 1975) be very readily met by a hand-held calculator or the built-in equivalent using available LSI circuits. Thus the Litton change proposal may indeed be credible as to the cost reductions achievable in replacing a general purpose with a special purpose computer. However, whether a Manpack LORAN-D set should readout in UTM is questionable. The problem is that propagation anomalies in a LORAN chain coverage area may be such that there is not a simple correspondence between time-difference and UTM grid coordinates. For example, in rough country, or in areas interspersed with bodies of water, the phase of the 100 kHz LORAN signal may not vary uniformly with distance from the station. In such situations, if time differences are converted to UTM on the assumption of a smooth, homogeneous spherical earth, the position errors in UTM coordinates may be as large as 500 to 1000 feet. In a sophisticated and complex LORAN set, such as that in an Air Force aircraft, an appropriate coordinate conversion algorithm and enough data storage could be provided to permit correction of many anomalies, but such sophistication is not now practical in a Manpack set. Then, because of the differences in coordinate conversion accuracy, the aircraft set and the Manpack would not read the same UTM coordinates at the same place. They would, however, indicate the same LORAN time differences.

Thus, either the coordinate conversion process should be specified to be identical in all sets, or rendezvous by two or more LORAN-D equipped units should be accomplished only in time difference coordinates.

If the LORAN-D Manpack were restricted to time difference readout, it would be very substantially cheaper -- perhaps $5000 per unit cheaper in the case of the PSN-6 -- and probably more reliable.

There would be offsetting costs if it were important to relate time difference to map coordinates. Three different possibilities come to mind:

1) Overprinting standard maps with the computer or surveyed LORAN grid. This can and has been done both in the field and by map-making services, and does not seem to constitute a serious problem.

2) Providing a special purpose hand-held calculator to convert time differences to UTM. Such a calculator probably could be designed using existing LSI circuits, but a small non-volatile write-read memory would be a great convenience in that the LORAN station positions need be entered only once, when entering a new area.

3) Providing for performing coordinate conversion and reply transmission of the UTM coordinates at base station to which the Manpack set transmits time-difference coordinates.

Of these schemes, map overprinting with LORAN coordinates seems easiest and cheapest.

LORAN-D Manpack Weight

From the earlier discussion it is clear that the weight issue relates primarily to the combined weight on the LORAN and other equipment, not the LORAN Manpack weight in isolation. There are three obvious solutions, not including the unlikely one of completely redesigning the PSN-6:

1) Separate the two sets and have one man carry each.

2) Redesign the radio set to reduce its weight.

3) Use the battery of the PRC-77 in Manpack applications.

The AN/PSN-6 is planned to be used in conjunction with a standard Manpack transceiver which uses an identical battery pack. One possible option would be to keep the PSN-6 in a passive mode utilizing the transceiver batteries when a fix is required. Estimated warmup and settling time would be of the order

of three minutes, less than the five minutes specified in the MN. In some circumstances wherein a secure transmission device is also employed, the common battery may be unacceptable. Incorporation of all three devices, (comm, crypto and nav) in a single Manpack is unlikely and undesirable for aspects of combined weight.

4) Adopt the "Micro LORAN" for Manpack applications. This would probably imply buying a test quantity of the very much simpler and lighter weight (3 pound) "Micro-LORAN", to determine its utility under similated field conditions. Such testing would probably be appropriate to Project MASSTER. The AN/PSN-6 should, in any event, be retained for vehicular use.

LORAN-D Manpack Cost

A means for reducing the cost (and slightly reducing the weight) of the AN/PSN-6 is to do the redesign necessary to make the time difference to UTM coordinate processor and the PRC-25/PSN-6 interface optional separable modules. These modules would be included for those vehicular-mounted applications where the functions provided are sufficiently important to warrant the added cost and weight.

For most manpack applications and many vehicular mounted applications, the reduced capability version would be issued. The reduced capability version would provide position information in LORAN time-difference coordinates only and would require that such position information be transmitted by voice in T-D coordinates rather than digitally in UTM coordinates.

The results of eliminating these modules could be to reduce the cost of the equipment by about $5000/unit, and to reduce the weight of the unit by approximately one pound. Since the power consumption would be reduced by approximately 60%, it would probably be possible to eliminate the PSN-6 battery and power the unit from the PRC-25 battery. This would particularly be feasible if the PSN-6 was operated intermittently rather than continuously. We anticipate a worthwhile improvement in reliability as a by-product.

With this approach, a lower cost (perhaps manually operated) coordinate converter can be considered as an add-on module if field experience demonstrates the desirability of such a converter.

MOS LSI technology of comparable complexity is readily available in numerous low-cost commercial applications, while the new I^2L technology promises equivalent low cost, low power requirements, and much better environmental tolerances in the near future.

These technologies, if exploited, can provide substantially lower cost, weight and power consumption in any new design of processors as add-on units for TD systems or a new design of a PSN-6 Manpack equivalent.

LORAN-D System Jamming Susceptibility

The jamming susceptibility of the LORAN-D system has been dealt with at some length in other memoranda and reports. The problem can be dealt with in three ways.

1) Use of an encrypted LORAN-D signal format.

2) Direct physical attack on the jammer.

3) Ignore and attempt read-through.

The use of an encrypted signal format in tactical operations, particularly where Manpack sets are involved, leads to formidable difficulties in key distribution and protection in the field. On the other hand, locating a jammer by direction-finding and then by eye should be relatively easy, as the signals are strong and a large antenna is essential. Thus physical attack is a likely counter to jamming provided the jammer is accessible. The development of an antiradiation missile for this specific purpose has been suggested elsewhere.

It is not at all evident that the jamming threat, taking into account the possibility of physical countermeasures to the jammer, is critical to the determination of whether LORAN-D should be vigorously pursued for Army applications. The overriding requirement seems to be a need for a tactical land navigation system that provides an accurate navigation and common-grid reference system that is usable in coordinated operations by Air Force

tactical aircraft and Army aircraft artillery, vehicles and foot soldiers. LORAN-D is such a system, and its transmitters as well as the user equipment are well along in development for both the Army and the Air Force. The dead-reckoning navigator alternatives, such as doppler and inertial systems, are totally inadequate in accuracy for vehicular or foot soldier use, and do not provide the common-grid reference essential to coordinated operations.

Other Program Issues

The Ad Hoc Panel observes that what might make best sense is to preserve the PSN-6 for vehicular use, and undertaking procurement of a much lighter, simpler Manpack set based on other manufacturers' current designs.

In addition, LORAN C/D should be considered for use with mobile air defense systems (SHORADS, CHAPARRAL and GUNS) and other combat and support elements.

Based on the information presented, the development of newer type all solid state LORAN C/D transmitters for industry and other branches of government should do much to alleviate the Army concerns re transportability, set-up time and logistics support for tactical area transmitters. Very large reductions in volume, increases in efficiency and rapidity of set-up ($\approx$6 hours for a single 150' tower) have been demonstrated.

The panel observes that the requirements for EMP protection and other nuclear environment specifications have been deleted from the AN/PSN-6. The only specific hardware change was in the cabling. The panel notes that, as precise knowledge of location of all friendly units is particularly important in a limited tactical nuclear exchange, this may be an unwise economy.

LIST OF BRIEFINGS

The Ad Hoc Group received briefings from PM, Navcon (AMC, Ft. Monmouth), SCSOPS, and representatives of the following industrial organizations:

Litton Industries, Inc. Amecom Division
Megapulse, Inc.
Internav
Tracor
Teledyne Systems Co.
Lear Siegler, Inc.
Magnavox

TERMS OF REFERENCE

1. Background

The Army has a candidate LORAN navigation/positioning device in Engineering Development. The requirement which initiated this development has been revalidated on numerous occasions and remains current. Inputs from the field have indicated the present development may not be accepted as the device which will assist in fulfilling the navigation/positioning requirement. The need to analyze objectives of the present program, as an assist in determining present and future direction, is apparent.

2. Terms of Reference

The Ad Hoc Group should produce a report which will as a minimum address the following areas:

a. Evaluate the current Army approach to the LORAN Manpack development and assess the accomplishment towards satisfying the LORAN Manpack requirement through this effort.

b. Analyze the current program's economical feasibility in terms of satisfying the Army's LORAN Manpack requirements and consistency with policy. If there are more economical approaches, the possible impacts of reduced performance and availability dates should be addressed.

c. Determine if the existing navigation/positioning requirement will be fulfilled by this project in the time frame of concern (1977-1982). If not, identify any better way of fulfilling the field navigation capability even if some specifications need to be waived.

3. Termination

The Chairman of the Ad Hoc Group is requested to conclude his efforts at the earliest possible date. However, a final report should be submitted not later than 1 June 1975.

Defense Documentation Center Cameron Station Bldg #5 Alexandria, Virginia 22314	12
Library of Congress	8
Committee Management Office, OSA	1
Director Electronic Warfare Laboratory US Army Electronics Command Fort Monmouth, New Jersey 07703	2
HQDA (DAMA-WSA) Washington, DC 20310	2
HQDA (DAMA-CSC) Washington, DC 20310	25
HQDA (DAMA-CS) Washington, DC 20310	1
HQDA (DAMA-AR) Washington, DC 20310	2
HQDA (DAMA-RA) Washington, DC 20310	1
HQDA (DAMA-ZD) Washington, DC 20310	1
HQDA (DAMA-ZX) Washington, DC 20310	1
HQDA (DAMO-RQ) Washington, DC 20310	3
Commander Field Artillery School Fort Sill, Oklahoma 73503	1
Commander USACACDA Ft Leavenworth, Kansas 66027	2

Commander The Engineer School Ft Belvoir, Virginia 22060	1
Commander Intelligence School Ft Huachuca, Arizona 85613	1
Commander Infantry School Ft Benning, Georgia 31905	1
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