MEMORANDUM

From: OP-35
To: Distribution List

Subj: Navigation Requirements

1. The Electronic Warfare Division (OP-35) has prepared the enclosed document to present the Navy's navigation requirements and programs in one document. The goal is to obtain a CNO approved objective to meet Naval requirements.

2. Your comments and suggestions for improvement are invited and requested by 24 October.

3. Additional appendicies may appear in the final draft.

M. B. Freeman

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1. The purpose of this paper is to present the Navy requirements for navigation, to show the present position of the Navy in meeting these requirements, and to outline the long range program which will meet these requirements.

2. **General Statement.** In broad terms, the Navy requires a world-wide system or systems which will permit ships and aircraft to define their positions with sufficient accuracy to carry out all assigned tasks. It is required to be operable day and night in all kinds of weather and invulnerable to enemy attack and to enemy countermeasures. Accuracies may be divided into two categories: (a) for general purpose navigation, 1 to 2 miles; (b) for precise navigation, 0.1 to 0.2 miles.

3. **General Purpose Requirements.**

   a. For most naval tasks, general purpose accuracies are sufficient.

      (1) In carrier task force and ASW task force operations, there is a requirement to correlate target information in widespread formation or received from other sources.

      (2) Amphibious forces are required to know their positions accurately during an approach because of the exact timing required.

      (3) In submarine barriers, the navigation error determines the amount of overlap required and hence the number of ships or loss in probability of detection in the case of a limited number of ships.

      (4) In laying or sweeping minefields, an accurate reference is required as a starting point. Systems or devices other than general navigation systems are then required to provide accuracies on the order of a few yards.

      (5) For aircraft navigation, a system is required in order that missions may be carried out under adverse weather conditions.

      (6) For submarine operations, a system is required which will permit reception in a fully submerged condition in order to achieve maximum stealth.
(7) TENOC is a ten year general plan for the oceanographic survey of all ocean areas. A world-wide navigation system with general purpose accuracies is required for this program.

b. Amplifying Remarks:

(1) The requirements for all types of ships, less submarines and attack carriers, may be summarized as follows:

(a) Complete coverage over all navigable waters.

(b) Continuous coverage or on a fixed schedule with intervals not to exceed six hours, available in all conditions of weather.

(c) A fix accuracy between 1 and 2 nautical miles.

(d) Must require no electromagnetic radiations from the ship in the atmosphere.

(e) Redundant systems are required in order to provide for failures either in equipment or as a result of enemy countermeasures.

(2) The requirements for attack submarines may be summarized as follows:

(a) The system must permit a high degree of security to the submarine. It must be usable with the submarine submerged with no more than a periscope, or mast exposed. If possible, it should be usable with no periscopes or masts exposed and with the submarine below the layer.

(b) The system must be available continuously or on a fixed schedule with intervals not to exceed two hours.

(c) The system must provide world-wide coverage.

(d) The system should provide a fix accuracy of 0.5 nautical miles and must provide a fix accuracy of less than 2 miles.

(e) The system should possess a high degree of invulnerability.

(f) Systems must be redundant to the extent that should one system fail from mechanical or natural causes a second system of different principles is available.
(g) The system must provide fixes to a submarine located under at least 12 feet of ice in the Arctic and Antarctic.

(3) Aircraft requirements for general purpose navigation systems are limited to long range aircraft engaged in the following missions: reconnaissance, AEW, ASW and minelaying. System requirements are listed below:

(a) Provide world-wide coverage.

(b) Provide continuous coverage or on a fixed schedule with intervals not to exceed two hours in all kinds of weather.

(c) A fix accuracy between 1 and 2 nautical miles.

(d) Redundant systems are required in order to provide for failures either in equipment or as a result of enemy countermeasures.

4. Deficiencies. To meet today’s requirements, we depend upon three fundamental systems, LORAN, celestial navigation and dead reckoning, all of which have severe limitations which detract from effectiveness. LORAN covers an extremely small portion of the oceans. It is a highly vulnerable system in case of hostility. Celestial navigation is dependent upon weather which can be unfavorable for extended periods of time. Dead reckoning provides poor accuracy at best which deteriorates as a function of time.

5. Precision Requirements.

a. POLARIS. The POLARIS program places the most stringent accuracy requirements upon a navigation system. These submarines require at all times a position accuracy of 0.1 mile and must be capable of establishing an azimuth reference within an accuracy of 160 seconds of arc for the A-2 missile and 90 seconds of arc for the A-3 missile. To accomplish this, the Ship Inertial Navigation System (SINS) must be corrected periodically, about every two hours. This places a requirement for a system external to the ship which will provide accuracies of 0.1 mile r.m.s. The LORAN C program was instituted to fill this need with the A-2 missile and is accomplishing its purpose today. Another means of fulfilling this requirement is by an accurate bottom survey in limited areas which was made possible by the accuracies provided by LORAN C. These surveys are now going on and will provide an invulnerable system to back up LORAN C in critical areas where LORAN C cannot be depended upon in the event of hostilities.
b. Increased Coverage. In order to take advantage of the additional sea room to be made available through the increased range of the A-3 missile, extended coverage beyond the present capabilities of LORAN C is required. In effect, it establishes the requirement for a highly precise system which affords practically world-wide coverage and is invulnerable.

c. Additional Requirements.

(1) Attack aircraft are dependent upon SINS to perform a mission over enemy territory. This places a requirement of 0.1 nautical on the navigation accuracy of attack carriers in order to provide an accurate reference for SINS. Other requirements which are set forth for ships in paragraph 3.b.(1) above also apply.

(2) Transoceanic expansion of both Atlantic and Pacific missile ranges have generated a requirement for the positioning of training stations, range ships and impact location sound arrays. A system, active or passive, capable of accuracy of + 0.1 nm at 2000 nm range is required.

(3) SOSUS systems, consisting of a variety of Underwater Sound Surveillance Systems including CAESAR, ARTEMIS and TRIDENT require positioning for the arrays. Accuracy of + 100 yards at a range of 100 nm for bathymetric surveys is required. After laying arrays, accuracy of final position to + 1 foot is required. Provision for improved control of standard hydrographic surveys is required. Repeatability of ± 20 feet at 10 nm and ± 200 feet at 100 nm is desired.

(4) The Atlantic Underwater Test and Evaluation Center, AUTC, is to be established in the Bahama Islands for the service test of underwater weapons. Accuracy of + 100 yards at 100 nm is required for bathymetric and Oceanographic surveys. Positioning of arrays and equipment on bottom is to be within ± 1 foot at the same range.

(5) Precise positioning is also required for airborne surveys for geomagnetism in support of the FBM program, for the positioning of ferrous wreckage for ASW operations and also for large scale photo mapping of coastal terrain.

6. Description of Systems. Celestial and dead reckoning navigation have been mentioned above. Needless to say, they will always be with us and perform a very vital and useful function.
a. LORAN A is an electronic hyperbolic navigation system which has been in use since 1942. It has an effective range of approximately 500 miles and provides accuracies on the order of 2 - 5 miles. There are 68 LORAN stations presently operating with an additional 11 planned for NATO. This covers approximately 10% of the ocean areas and is used universally by ships and aircraft.

b. LORAN C is an extension and refinement of the technique of the current operational LORAN A system. LORAN C operates in the 90 - 110 kcs band and is superior to the high frequency, 1.3 - 2.0 mcs, LORAN A system now used by military and maritime ships. LORAN C is capable of providing an accuracy of 0.1 mile out to a range of 1500 miles. Seventeen stations are now in operation. Fifteen more have been authorized in order to provide additional coverage as the number of POLARIS submarines increases. The advent of the A3 missile, additional coverage will be required and is currently under study. Environmental tests have been successfully completed on the AN/APN-145, an airborne LORAN A/C receiver. Accuracies in the order of 500 yards have been obtained.

c. OMEGA is an earth referenced hyperbolic system using time-shared sequential transmissions in the VLF band between 10 - 14 kcs. OMEGA uses only phase comparison, thus it is ambiguous to "lane count". OMEGA promises accuracies of 1.5 nm out to ranges of 5000 miles. However at sunrise and sunset accuracies on the order of 2.5 are anticipated. OMEGA information will be usable by fully submerged submarines. An airborne OMEGA receiver (breadboard model) is installed in a WV-2 aircraft being tested by NRL. No test data is available at this time. It is estimated that seven transmitting stations will be required to provide world-wide coverage.

d. TRANSIT is a satellite navigation system intended to provide accurate earth referenced position based on a measurement of the Doppler shift in the radio frequency of a passing satellite. TRANSIT is expected to provide, eventually, accurate positions to 0.1 nm. This system will operate in all weather conditions providing fix information at least every 90 minutes. TRANSIT will be world-wide and relatively invulnerable. Ten ground receiving stations are operable. One experimental computing center and injection center are in operation. Four satellite tracking stations, one computer and control center and one injection station are required to obtain orbital data and inject orbital constants every 12 hours for rebroadcast to system users. Present plans are to have an operational capability by 1962. For detailed information on the above mentioned systems see appendix.
7. System Relationships. The sextant will not be replaced in the foreseeable future regardless of what navigation system or systems are approved to meet Navy requirements. The sextant has the advantages of low cost, mid-ocean availability and high mechanical reliability. However, the sextant is limited by weather dependence and moderate accuracy. LORAN A with its limited coverage about 10% of the ocean and modest accuracy (2 - 3 nm) is presently used by military and maritime ships. Although technically obsolescent, LORAN A does meet the present requirements of its commercial users and many military general purpose requirements. LORAN A receivers presently installed, in excess of 60,000, will inhibit phasing out LORAN A. Tentative plans are to phase out LORAN A in favor of LORAN C. Both LORAN A and LORAN C are hyperbolic systems which yield unambiguous position information. LORAN C employs not only the pulse envelope as does LORAN A but also employs phase comparison as a vernier correction to the time measurement. LORAN C with a hi-accuracy receiver provides the best combination of range and accuracy of all operational systems and meets the Navy precise navigation requirement in the limited areas in which it provides coverage. The combination of a LORAN A receiver with an inexpensive LORAN C converter meets the Navy general purpose accuracy requirement and provides the advantage of greater range with LORAN A accuracy. The Navy requirement for LORAN C has been the POLARIS ocean survey except for the U.S. east coast chain which was built to evaluate POLARIS navigation equipments. LORAN C hi-accuracy receivers are installed in some SSB(N) and have performed very satisfactorily. A valuable product of the LORAN C installation in SSB(N) has been the repeated correlation of LORAN C against underwater land work fixes. Correlation has been excellent, within a few hundred feet. LORAN C also has been adopted for international timing.

a. As mentioned previously LORAN C, with OMEGA not operational, is an obvious replacement for LORAN A. When and if LORAN A will be phased out is difficult to predict. For the Navy, the completion of the POLARIS survey in each LORAN C chain will mark the end of that chain's essential contribution. However, the completion of the LORAN C chain must be regarded as necessary.

b. OMEGA promises to provide worldwide coverage and like both LORANS is a hyperbolic system. However, OMEGA uses only phase comparison and thus is ambiguous as to lane count. For ship navigation this is a negligible problem since each lane at the system's frequency of 10.2 kcs is
roughly 9 miles wide. Aircraft will require a receiver with automatic lane counting capability. The accuracy of OMEGA which varies with the time of day should meet general purpose accuracy requirements. During daylight when all three OMEGA Stations are available to a single receiver, consistent repeatability and .5 mm accuracy is achieved. At night the accuracy degrades to about 1. - 2. mm. During diurnal changes the accuracy degrades to several miles. Because of its low frequency, OMEGA will be usable by fully submerged submarines and has another VLF advantage, very long transmission paths. An analysis of VLF propagation measurements indicate that 7 or 8 OMEGA Stations should provide full world coverage. The cost of OMEGA for full world coverage should be substantially less than that of LORAN C which provides coverage for about 25% of the world's ocean area. OMEGA cannot compete in accuracy with LORAN C but should provide about the same accuracy as LORAN A. If LORAN C works out as a high accuracy system when the POLARIS survey is completed and becomes a prospective replacement for LORAN A at LORAN A accuracy, OMEGA and LORAN C could be competitors. Cost, coverage and reception by submerged submarines appear to favor OMEGA. The OMEGA lane count ambiguity favors LORAN C. OMEGA cannot provide the high accuracy required by the POLARIS program. However, OMEGA with its feature of submerged reception should meet the accuracy requirements for non-POLARIS submarines.

c. The system which promises to provide a combination of hi-accuracy and world-wide coverage is TRANSIT. TRANSIT appears to meet Navy requirements for precise and general purpose navigation. TRANSIT will not depend on foreign sites like LORAN and OMEGA and it promises high accuracy in mid-ocean as well as at the shore line. While-LORAN C is entirely adequate for support of the POLARIS A-2 it is quite inadequate, because of its limited coverage for support of the A-3. The large ocean area opened up by the A-3 for operation by POLARIS submarines is beyond the accurate range of LORAN C and beyond the range of an ocean survey monitored by LORAN C. Full utilization of A-3 POLARIS submarines will require a high accuracy mid-ocean navigation system. TRANSIT shows promise of meeting this requirement. For improved aircraft navigation TRANSIT is expected to be marginal. TRANSIT hi-accuracy receivers will require a computer similar to the USG-20 presently installed on NTDS ships. The computer and the receiver costs are high. TRANSIT equipment being procured by SP for SSBN costs about $350,000 per unit. However TRANSIT general purpose receivers which will require only manual computation or the use of a simple calculator and tables
will cost about $5 per unit.

d. Completion of the bathymetric survey of the ocean bottom should be the ultimate goal of a Navy long range navigation plan. Underwater landmark navigation is invulnerable, operational in peacetime as well as wartime, highly accurate and with an all-weather capability. POLARIS surveys have proven the accuracy of underwater landmark navigation (within a few hundred feet of the survey accuracy). A 2 - 5% non-uniform slope gradient is required for accurate charting of the sea bottom. On the light of present knowledge based on exploratory sampling of the ocean bottom, it is estimated that about 65-75% of the sea floor could be surveyed and charted in sufficient detail to meet high-accuracy navigational requirements. The Mid-Atlantic ridge, the sea mountains of the Pacific and any other underwater precipitous terrain are examples of ocean areas that will be unusable for high-accuracy navigational position recovery. However these terrain features can be used for position checks of general purpose accuracy comparable to celestial fixes.

c. To date LORAN C accuracy has been used in plotting underwater marks within the area of LORAN C coverage. The transfer of TRANSIT accuracy to underwater landmarks by extension of the POLARIS ocean survey, must ultimately be completed. Presently using conventional echo-sounders, an AN/SON-6, three TAG's (Survey Ships) are capable of surveying nine 12-mile-square sites monthly. However, General Instrument Corporation has submitted a technical proposal for BOMAS (Bottom Mapping Sonar), new conformal array echo-sounder, which if successfully developed should revolutionize bathymetric surveying. BOMAS is a conformal array echo-sounder with a wide sweep and an automatic contouring feature that promises to provide complete highly accurate (fine grain) bathymetric surveys of the sea floor. For comparison using present survey methods three TAGs complete 9 twelve-mile-square sites monthly. It is estimated that BOMAS techniques and equipments utilizing three TAGs could complete a fine grain bottom survey in an area 100 by 300 miles in size in one month roughly equivalent to about 208 twelve-mile-squares. Using present methods it costs $31,500 per site survey. BOMAS cost per site is estimated at about $3,150. BOMAS is more secure than present methods since large sea floor areas could be charted without disclosing the specific points of interest within each area. If BOMAS is proven to be acceptable operationally, it will be possible to survey strip charts on 60-mile centers (today's POLARIS landwork spacing) at a rate of about 2 million square miles.
per ship per year as compared with today's POLARIS survey pace of about 1/3 million square miles per ship per year. It is estimated that 50 ship years will provide the support necessary to complete the bathymetric survey providing DOMAS techniques are proven successful and utilized. 50 ship years could be programmed 10 ships for 5 years, 5 ships for 10 years or any other combination. At an estimated cost $1.6M per ship year the cost of the world-wide survey will approximate the cost of the construction of a world-wide OMEGA. The secure echo-sounder required for submarines would cost approximately $100K per unit. The precision depth recorder required for surface ships to be used in conjunction with installed echo-sounders will cost about $10,000 per unit. The complete cost, survey, ship and submarine equipment is estimated at about $100M. This is a long term project but its successful completion should provide sea floor topographic charting that would satisfy Navy navigation requirements.

3. Funding

a. LORAN A has 68 stations operational. 59 LORAN A Stations are Coast Guard manned and supported at an annual cost of about 5M. The remaining 13 operational stations are supported and financed by host nations and NATO, 11 additional stations are planned for NATO to be financed by cost sharing by NATO Nations. No RDT&E costs for LORAN A are available.

b. RDT&E costs for LORAN C were kept to about 1M by the use of CYTAC research and development work. CYTAC, now obsolete, was an Air Force project to develop a blind bombing system. Completion of the LORAN Installation Plan 1967 cost about 71M for 17 LORAN C and 6 LORAN A operational stations. Completion of the LORAN Installation Plan 1961 will cost about 67M and provide an additional 13 LORAN C and 3 LORAN A/C stations. The estimated completion date of the LORAN Installation Plan 1961 is 1966.

<table>
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<th>Total Funding:</th>
<th>Prior 1961</th>
<th>FY 62-66</th>
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<tbody>
<tr>
<td>RDT&amp;E</td>
<td>1M</td>
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<tr>
<td>MILCON</td>
<td>71M</td>
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<tr>
<td></td>
<td>Total</td>
<td>67M</td>
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Equipment Costs
- Hi accuracy receiver 30K per unit (est)
- Applicable Ship Types 156
  - AGS, AGOR, SSBN, ESN
  - and CVA
- General Purpose Receiver 2.5K per unit (est) (converter)
  - Applicable Ship Types 714
  - Total

TOTAL COST RDT&E Installation Ships Equipment - 145.3M

The above figures do not include costs of aircraft installations.
c. OMEGA. Three stations now are operating to test and demonstrate the range and position fixing capability of the OMEGA system. An OMEGA station will require a VLF antenna system and housing for shore equipment and personnel. The antenna system and real estate represent the major costs of the shore facility. A typical antenna station may require 4 antenna towers each about 650 ft. high. A circular area approximately 3/4 miles in diameter will meet the requirements for the antenna site. Costs to date and planned are as follows:

<table>
<thead>
<tr>
<th>FY</th>
<th>Prior 61</th>
<th>61</th>
<th>62</th>
<th>63</th>
<th>64</th>
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<td>RDT&amp;E</td>
<td>5.698 M</td>
<td>1.4M</td>
<td>1.4M</td>
<td>1.37M</td>
<td>1.37M</td>
<td>595K</td>
<td>11.7M</td>
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</table>

8 Operational Sta 7. M (est.) each  Total 56M

Equipment Cost
Hi-Accuracy receiver 15 K per unit (est.)
Applicable Ship types AGS, AGOR, SSBN
SSN NTDS equipped ships

General Purpose Receiver 2 K per unit (est.)
Applicable Ship types 613
Total 1.2

Total Cost (RDT&E Installations and Ships Equipment) 82.7M

The figures above do not include costs of OMEGA equipment for aircraft.

d. TRANSIT funding through 1964 will cost about 123.7M. Funding costs include design fabrications and launching of the 4 satellites required for an operational system. It also includes funding necessary for construction of both the experimental and operational receiving stations (4 stations) computing center (1 center) and injection station (1 station) and initial shipboard and airborne navigational installations. In addition the funding required for the design fabrication and launching of 6 experimental and initial operational satellites are covered.

Equipment Cost
Hi-Accuracy receiver 75 K (est.)
Applicable ship types AGS, AGOR, SSBN & CVA
102
Total 7.7M

In some of the ship installations listed above a computer will be required in addition to the receiver.
General Purpose receiver 7K
Applicable Ship types 768

Total 5.4M

It is planned to use the general purpose receiver with manual computation, tables and a simple desk calculator.

Total 140.7M

The above costs do not include airborne equipment or replacement satellites which will be on the order of 2 per year during the first years the system is operational and later 1 per year.

See appendices _ _ and _ _ for additional cost data.
   a. General.

   (1) The Navy cannot be dependent on any one navigation system which is vulnerable to enemy countermeasures.

   (2) World-wide coverage is required for ships and aircraft and also before complete mapping of the ocean bottom is possible.

   (3) The Navy requires all systems discussed herein, LORAN C, OMEGA and TRANSIT.

   b. Specific System Conclusions.

   (1) LORAN C

   (a) Required to realize the capabilities of the A-2 POLARIS program.

   (b) Required to provide a reference for the bottom survey program to backup LORAN C in the event of hostilities.

   (c) Required in order to follow through on international agreements and commitments.

   (d) Inadequate to meet the requirements of expended coverage incident to the implementation of the A-3 POLARIS missile.

   (e) Is a relatively vulnerable system which cannot be relied upon in the event of war.

   (f) Provides a practical means of extending general purpose coverage from 10% (LORAN A) to 25% (LORAN C converter) of the world ocean areas.

   (g) Offers promise of including a highly precise time signal which has many potential users.

   (h) Required by missile ranges, SOSUS, AUTEC and others.

   (2) OMEGA

   (a) Required to provide world-wide navigation information to submerged submarines, including under ice.
(b) Does not meet the FRM requirements but is an excellent backup for SINS, LORAN and TRANSIT.

(c) Required as a successor to LORAN as a worldwide general purpose navigation system for military and commercial applications both sea and air.

(d) Is a relatively vulnerable system in event of war.

(e) Provides world-wide coverage at a substantially less cost than LORAN C covering only 25% of the ocean area.

(f) Required to provide the necessary coverage needed to fulfill the TENCC program.

(g) Meets the requirement for a world-wide aircraft navigation system.

(3) TRANSIT

(a) Required to realize the capabilities of the A-3 POLARIS program.

(b) Required to provide a reference for bottom survey program in extended ocean areas.

(c) Required as backup for LORAN C in the event of hostilities.

(d) Provides a world-wide system that is secure and less vulnerable than other proposed systems.

(e) Required to carry out political commitments made in offering to all nations the benefits of American Technology and Science.

(f) Required to provide the hi-accuracy of initial areas to be surveyed to accomplish the TENCC program.

(g) Is not particularly adapted for airborne use, however, adaptability to airborne requirements is under study.

(h) Is the most difficult of all systems to jam.

(i) Does not have any submerged capability.

(j) Is not a continuous coverage, but provides fixes approximately every 90 minutes (could be 4.5).

10. Recommendations. To be included in the final draft.
1. At the present time, the primary long range navigation systems in use are LORAN A and LORAN C:

   a. LORAN A (1300 - 2000 kcs) is a pulsed hyperbolic system which employs envelope matching to measure time difference. The time difference reading is transferred by the use of charts or tables to a geographic hyperbolic line of position. Ground wave coverage extends to a range of 700 nm from transmitting station with an accuracy of ± 2 - 3 nm; skywave coverage extends to a range of about 1400 nm with an average accuracy of ± 5 nm. LORAN A, which has been in use since 1942, has 68 stations presently operating with an additional 11 stations planned for NATO. LORAN A is used by military and commercial ships and aircraft; the number of LORAN A receivers in use numbers in excess of 60,000. LORAN A coverage extends to about 10% of the ocean areas of the world.

   b. LORAN C (90 - 110 kcs), an extension and refinement of LORAN A, is a pulsed hyperbolic system which employs not only envelope matching but also phase comparison to measure time difference. Basically both LORAN A and LORAN C are the same, the major difference being in frequencies and time measuring techniques with LORAN C providing longer ranges and higher accuracy. Ground wave coverage extends to a range of 1300 - 1500 nm with an accuracy of ± 0.25 nm; skywave coverage extends to a range of about 3000 - 3500 nm. The accuracy of skywave coverage currently under study is expected to be considerably better than LORAN A. Repetition rates used in LORAN C are compatible with the repetition rates used in LORAN A and LORAN A receivers by the addition of a converter can utilize LORAN C signals.

   (1) There are 17 LORAN C stations at present operating in strategic locations in support of FBM program. The JCS 141/107, the Loran Installation Plan 1961, approved by DOD, is the current plan for LORAN installations. This plan also provides for an additional 5 LORAN A, (4 are in NATO AZORES chain), 13 LORAN C and 3 LORAN A/C stations to be operational by 1966. The JCS plan 141/107 calls for phasing out of LORAN A as LORAN C receivers come into general use.

   (2) Although LORAN C receivers are not in general use, the FBM submarines have been equipped through an accelerated procurement program. LORAN C is capable of 7' depth reception and is considered the best operational system now available. The system is currently operational in limited areas. Up to
the present, LORAN C stations have been deployed to meet specific Navy navigation requirements without regard to world-wide coverage. World-wide coverage would require additional stations, the number of which is under study.

(3) The Secretary of the Navy in a letter of 23 January 1959, on the U.S. Navy position concerning long range aids to navigation stated the following: "The U.S. Navy will seek and support U.S. sponsorship of LORAN C for international adoption as the world-wide navigation system within the 90 - 110 kc band."

2. Two systems currently under development are:

a. OMEGA, formerly RADUX and RADUX-OMEGA, is an earth referenced hyperbolic system using time-shared sequential transmissions in the VLF band between 10 - 14 kcs. OMEGA promises to give reliable accuracy of 1 1/2 miles out to ranges of 5000 miles. The low frequencies are effected by the sun to some extent so that range of coverage will vary with the time of day particularly at sunrise and sunset. The planned operational frequency of about 12 kcs yields positional ambiguities of about 8 miles. If current standard shipboard navigation procedures are followed this ambiguity should not prove to be a problem other than for submarines, not equipped with SINS, which have been out of contact with the OMEGA system for some time. High performance aircraft will probably require a simple computer or counter to keep track of the number of phase areas crossed in order to eliminate position ambiguity. NRL has under development an OMEGA airborne receiver installed in a WV-2 for test purposes. No test data has been reported thus far.

(1) It is estimated that about 8 OMEGA transmitters will provide world-wide coverage. At present there are three experimental stations one at Balboa, Canal Zone, Haiku, Hawaii and Forest Port, New York. Haiku and Balboa share VLF transmitters presently installed. However, future developments will require a separate transmitter for OMEGA. The above stations form a triad that will permit more accurate propagation, possible solution to ambiguity problems, and accuracy determination.

b. TRANSIT (54 mc, 324 mc, 150 mc, 400 mc) is a satellite navigation system intended to provide accurate earth referenced position based on a measurement of the Doppler shift in the radio frequency of a passing satellite. Four TRANSIT satellites

2 APPENDIX I
in appropriate orbits can provide position information at least every 90 minutes anywhere on earth. Four satellite tracking stations, one computation and control center and one injection station, are required to obtain orbital data and inject orbital constants every 12 hours for rebroadcast by the satellite to system users. Since TRANSIT is not a continuous information system, additional navigation equipment such as SINS, is required in order to provide navigation information between satellite passes.

(1) Present plans are to have an operational capability using the TRANSIT navigation system ready by October 1962. The program is now in the research and development phase, which has lasted for a little more than two years. Six satellites have been launched to date. One is to be launched later this year. Ten ground receiving stations are operable, others are being designed and constructed and will be used for operational systems. An experimental computing center and injection center are in operation. Mathematical analysis of computation procedural development, ionospheric refraction, geodesy and navigation are being made. These analyses will be continued for some time.

(2) Statement by the Honorable James H. Wakelin, Assistant Secretary of the Navy (R&D) to the House Committee on Science and Astronautics:

"With TRANSIT as an example of a space system that is superior to other navigating systems, let me state these points: TRANSIT utilizing any one of four satellites in orbit will give precise navigation at every spot on earth, land or sea, just as accurately as McMurdo Sound in the Antarctic as it does off the coast of Norfolk. An all-weather system, it will operate in stormy weather, through overcasts, by day and by night. There is no effect of solar flares, being independent of ionospheric disturbances. TRANSIT is a passive system and so a ship need not transmit to fix its position as is the case with radar navigation. The operating TRANSIT system we plan does not depend on foreign sites; all the tracking stations, computer centers, and injection stations can be located in the continental United States, or in the oceans and seas of the world. It is more accurate than any world-wide system we have.

The Navy plans to make the TRANSIT satellite navigation system available to sea farers of the world beginning in late 1962. This space system will be one of the earliest space
technology benefactions to mankind. TRANSIT will make possible precision navigation "shipways" similar to our airways; it will become feasible to reduce, if not entirely eliminate, collisions at sea, such as the recent Andrea Doria tragedy."
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<tr>
<th>Characteristic</th>
<th>TORCH A</th>
<th>TORCH B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (MHz)</td>
<td>0.1 to 600</td>
<td>1800 to 2000</td>
</tr>
<tr>
<td>Net Power:</td>
<td>1400 W</td>
<td>600 W</td>
</tr>
<tr>
<td>Day:</td>
<td>1600 W</td>
<td>700 W</td>
</tr>
<tr>
<td>Night:</td>
<td>2000 W</td>
<td>800 W</td>
</tr>
<tr>
<td>Continuous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 - 14 kC</td>
<td>1000</td>
<td>1200</td>
</tr>
<tr>
<td>90 - 110 kC</td>
<td>1100</td>
<td>1300</td>
</tr>
<tr>
<td>1800 - 2000 kC</td>
<td>2000</td>
<td>2200</td>
</tr>
</tbody>
</table>

- **Vulnerability:** High risk
- **Concealment:** Revealed to jam
- **Security:** None
- **Costs:** None
- **Users:** Under Water Service

- **Accuracy (m):**
- **Coverage:**
- **Range (m):**
- **Frequency:** 700 - 6000 MHz
<table>
<thead>
<tr>
<th>Exceedent</th>
<th>94.8 M</th>
<th>12.6 M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required to be ship, submarine, and none</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Art. Periscope depth</td>
<td>20 - 50 ft.</td>
<td></td>
</tr>
<tr>
<td>2. Underwater time of day</td>
<td>0.1 at 500 miles</td>
<td></td>
</tr>
<tr>
<td>5. Visible range (to day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous - World-wide at least</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of sink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any 90 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>5000 - 6000</td>
<td>10 - 14 kc</td>
</tr>
<tr>
<td>IONIAN C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKRA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>2000</th>
<th>1500</th>
<th>900 - 1100 kc</th>
<th>1300 - 2000 kc</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIGHT</td>
<td>1400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAY</td>
<td>700 - 800</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: The table contains technical specifications related to underwater communication and detection.*
1. LORAN C

FY         PRIOR 61         62 through 66
RDT&E       1 M              67 M
MILCON      71 M

a. The above funds have been allocated by DOD to implement JCS 141/107 LORAN C Installation Plan of 1961. When LORAN C Stations are operational Coast Guard assumes funding responsibility. Completion of the LORAN Installation Plan 1957 required the expenditure of 71 M. It is estimated that the implementation of LORAN Installation Plan 1961, will require approximately 67 M of which 9 M has been transferred to the Coast Guard to initiate the plan and 10 M has been included in the DOD FY 62 appropriations for LORAN construction. However, the LORAN Installation Plan 1961, approved after the appropriations of FY 1962 funds, requires the construction of a fourth Station in the Northwest Pacific by March 1963, and 3 additional Stations by January 1964. If the scheduled on-air dates for these stations are to be met, it will be necessary to provide additional funds in FY 1962 in the amount of 5 M for the procurement of electronics, power and antenna equipment.

b. 210 LORAN C high-accuracy receivers have been procured and have been installed on SSB(N) Survey Ships, ground monitor Stations and Training activities. Equipments have not been operationally evaluated or service approved. 348 LORAN C converters general purpose receivers have been procured for installation on ships not requiring a high-accuracy receiver.

c. The AN/APN-145 is an airborne LORAN A/C receiver which has been tested extensively by BUWEPs. Environmental tests have been completed successfully. Test data thus far has been encouraging with fix accuracy of + 500 yards for the equipment. The Navy has procured 20 AN/APN-145 receivers; 14 for Navy, 6 for Air Force. Operational evaluation of the AN/APN-145 is scheduled by OPTEVFOR in FY-March 1962.
2. OMEGA

<table>
<thead>
<tr>
<th>FY</th>
<th>PRIOR 61</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDT&amp;E</td>
<td>5.589m</td>
<td>1.4m</td>
<td>1.4m</td>
<td>1.37m</td>
<td>1.37m</td>
<td>585k</td>
</tr>
</tbody>
</table>

Additional Costs - Site Survey - 500k

a. If the system is approved for service use and OMEGA is recommended for implementation, 7 to 8 transmitting stations will be required at 7m each for a total of 49m, which amount should be reflected in the MILCON Budget; 25m in FY 64 and 24m in FY 65.

b. 20 OMEGA receivers have been procured and are being tested in the operational evaluation of OMEGA. 10 Type I receivers to be used in monitoring the tests, and 10 Type II receivers which incorporate improved design features over the Type I equipments including automatic synchronization, improved r.f. receiver and improved design to meet shipboard environmental conditions. Auxiliary equipments such as digital converters and printers, submarine loop antenna couplers, and hyperbolic position computers are also being procured. The position computer is an analog device that derives the position of the vehicle in terms of latitude and longitude from OMEGA position information.

c. NRL is testing a breadboard airborne OMEGA receiver installed on a WV-2. No test data is available as yet.

3. TRANSIT

<table>
<thead>
<tr>
<th>FY</th>
<th>PRIOR 61</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDT&amp;E</td>
<td>15.6m</td>
<td>27.8m</td>
<td>17m</td>
<td>25.7m</td>
<td>15.2m</td>
</tr>
<tr>
<td>PAMN</td>
<td>5.3m</td>
<td>12.7m</td>
<td>4.7m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPN</td>
<td>750k</td>
<td>3.2m</td>
<td>1m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OMN</td>
<td>3.2m</td>
<td>3.5m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MILCON</td>
<td>456k</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL - 128.7m
a. The above figures include the funding necessary for the design, fabrication, and launching of the four search satellites required for the operational system. It also includes the schedules and funding necessary for design and fabrication of both the experimental and operational receiving stations, (4 stations) computing center (1 center) and injection center (1 station) and initial shipboard and airborne navigational installations. In addition, the schedules and funding required for the design, fabrication, and launching of six experimental and initial operational satellites are covered. The initial shipboard and airborne installations have not yet been planned.

b. SP funding has been provided for the following submarines:

   FY 61 - 9 SSB(N)

   62 - 10 SSBN
   9 SSBN (backfit)

The TRANSIT installations listed above include an AN/UYK computer.

c. CNO Serial 0103F54 of 7 July 1961 requested the Bureau of Ships to provide OPN FY 63 funds to install TRANSIT on 17 NTDS ships providing the NTDS computer is capable of satisfying the shipboard computation requirements for the high accuracy.