RG 107 - Office of the Secretary of War

Entry 118

Box 7

*Summarization of Loran Program up to VJ Day*

# LORAN SYSTEM

## SUMMARIZATION OF PROGRAM UP TO V-J DAY

## POST WAR PROPOSALS

### 1. General

This paper has been prepared as a basis for discussions by AAF representatives with the Navy Department, the British, and other military or civil agencies upon post war applications of the Loran System of navigation. It includes a brief description of the Loran System, a review of the ground and aircraft program up to V-J Day, a discussion of the merits and disadvantages of Loran compared to other long range navigation devices, and proposals for a Post War Loran Program including a continuation of equipment development.

### 2. Description

#### a. System

The Loran System is a navigational aid wherein position is determined by electronic measurements on pulsed radio transmissions from fixed ground stations. The term "Loran", which is derived from the words "LOng RAnge Navigation", implies a usable service area and range greater than that provided by any other radio navigational device. Extended range at night is made possible by the use of sky waves; ground waves only are used during the day. The positional accuracy of Loran fixes is dependent upon several factors; for example, the distance between the receiver and the ground stations, and the crossing angle of different lines of position at a given location in the service area. However, in general, accuracy exceeds that of celestial navigation; usually it is less than 1% of the distance from the measureing point to the ground stations. Operational experience has proved that the utility of Loran to a large extent is independent of weather conditions; also that navigators can become proficient in use of the equipment with one-tenth or less the training required for celestial navigation.

#### b. Ground Stations

(1) In conventional Loran applications, ground stations in groups of three or more are located several hundred miles apart along the shoreline of ocean areas where coverage is desired. For certain special overland applications, the distance between stations is reduced to the order of 75 miles resulting in a localized system similar to British "Gee"; or baselines are increased up to 1000 miles or more and sky wave synchronization (SS) employed. SS Systems are usable only at night; however, accuracy is high and this type system has been valuable in several specific instances.

(2) The pulsed transmissions from any two stations in a group (chain) are rigidly controlled (synchronized) resulting in a hyperbolic pattern of position lines throughout the service area, each line representing the difference in time of arrival at the measuring point between pulses from the two stations. The aircraft (or ship) receiving equipment measures this time difference which is then referred to a special chart to determine a line of position. A second position line from another set of paired stations furnishes a Loran fix.

(3) Approximately 25 people are required for operation, maintenance and housekeeping at each Loran ground station; 75 for operation of three stations to provide fixes in a specified service area.

c. Aircraft Receivers

(1) A special Loran receiver is required in each aircraft if Loran ground station transmissions are to be utilized. This receiver employs a cathode ray tube which enables the operator to take time readings accurate to within one or two microseconds. A skilled operator (approximately 20 hours training and experience) can obtain a Loran fix with the equipment in two or three minutes on daytime ground wave signals; two to five minutes on sky waves at night.

(2) To date, the AN/APN-4 and AN/APN-9 Loran Receivers have been employed by the AAF.

3. Loran Ground Program Prior to V-J Day

a. History

The advantages inherent in Loran as a long range navigational aid were recognized early in the war by both the Army and Navy. The first experimental ground stations designed and built by Radiation Laboratory were successfully tested in the spring of 1942. Cognizance of Loran was assumed almost immediately thereafter by the Joint Chiefs of Staff in order that the limited equipment available could be deployed to the best advantage of all service users. The first installations for military purposes were made in 1942 on the eastern coast of the North American continent to assist North Atlantic convoy and anti-submarine operations. In early 1943, additional stations were installed in the Aleutians where poor visibility during most of the year made navigation extremely hazardous. Thereafter, the system was expanded as rapidly as equipment could be produced and installed, until on V-J Day 72 Loran ground stations were in operation throughout the world. In Europe, an "SS" system which furnished highly accurate fixes over Germany at night was used to advantage by the RAF from late 1944 until V-E Day. Due to the U. S. policy of precision daylight bombing, the AAF made little use of Loran over the continent. However, in the Pacific and Far East, Loran has become an important navigational aid for all U. S. Forces, both air and sea.

b. Ground Installations

These appendices, attached herewith, summarize ground aspects of the program up to V-J Day:

(1) Appendix "A": Loran Stations in Operation on V-J Day.

(2) Appendix "B": Daytime Loran Coverage on V-J Day.

(3) Appendix "C": Nighttime Loran Coverage on V-J Day.

(4) Appendix "D": Report on Serviceability of Loran Ground Stations.

4. Loran Aircraft Program Prior to V-J Day

a. History

Concurrently with the decision in midsummer of 1942 to install Loran ground stations, action was taken to develop and procure suitable receiving equipment; the AAF to handle all aircraft types, the Navy all shipboard equipment. Initial delivery of aircraft sets was scheduled for the Spring of 1943. However, due to serious design and production problems, it was not until the Spring of 1944 that a receiver was produced with satisfactory characteristics. Consequently, the aircraft program lagged the ground program by a considerable amount; it was late 1944 before any substantial number of AAF planes were Loran equipped.

b. Aircraft Installations

Through August 1945, approximately 44,000 AN/APN-4 and 27,000 AN/APN-9 Loran Receivers were produced. Out of this total, the Army Air Forces was allocated 34,360 receivers of both types through July 1945; the remainder was delivered to the U.S. Navy and the British. It is estimated that approximately 20,000 Loran Receivers are now installed in AAF aircraft. All very heavy, and most heavy and medium aircraft of all types operating in areas where coverage is available, are fitted with a receiver.

c. Examples of Field Use

(1) Appendix "E", attached, gives some idea of 21 Bomber Command's utilization of the Loran System in B-29 operations; data on the serviceability of aircraft receivers is included.

(2) The following excerpt has been taken from an official report of the Air Transport Command on the use of Loran in the India/Burma and China Theaters:

> "Calcutta- Though not yet widely used in the India-Burma and China Theaters, Loran is proving to be a superior navigational aid. First planned to supply highly accurate multiple homing paths for ATC aircraft flying the congested Hump Routes,

it is now being used by Combat Cargo Task Forces and Troop Carrier Squadrons. Before long Loran will be employed on offensive missions by the 14th Air Force. Loran's efficiency as a navigational aid far exceeds that of homing and ranges. One CCTF plane, unable to get a clear homing signal in instrument weather, decided to try Loran and was led directly across the runway of its base. Another CCTF plan, flying at night a load of ammunition to an advanced Burma strip, became lost. About to dump the load because fuel was low, the crew turned to Loran. The fix received said their destination was 70 miles away on a course of 28 degrees. When the 70 miles had ticked off, the ship was over the field. Loran makes most Hump trips uneventful. The plane simply gets on course and stays there. And strain is diminished because the pilot knows exactly where he is. It seems clear that before long Loran will become the most valuable navigational aid in this area. ATC pilots on Hump routes are being instructed to take Loran fixes every 30 minutes and 14th Air Force navigators to use Loran as their primary instrument of navigation."

5. Comparison With Other Systems

a. General

With the defeat of Japan accomplished, it is appropriate that use of Loran as a post war navigational aid be considered. In this connection, it would be desirable that a common system be utilized to satisfy both civil and military needs. This immediately poses the question as to whether Civil Aviation and the Merchant Marine contemplate use of Loran; if not, whether the system finally settled upon by civil agencies will satisfy AAF post war requirements as well.

b. Comparison of Long Range Systems

In order to shed some light on this problem, Appendix "F", entitled "Characteristics of Long Range Navigation Systems", has been prepared, wherein the characteristics of all long range navigation systems known at present are compared to standard Loran. These other systems are:

(1) LF (Low Frequency) Loran

(2) Sonne

(3) P.G.P.I.

(4) QM (Decca)

(5) Omni-Directional Range

(6) ADF

c. Advantages of Loran

It is apparent upon study of Appendix "F" that Loran has these outstanding advantages over any of the other devices listed:

(1) High accuracy at all times due to its ability to differentiate between sky and ground wave transmissions.

(2) Superior performance under conditions of high noise level.

(3) Equipment, both ground and airborne, is available in quantity.

(4) Proven reliability during several years use in war.

With the possible exception of LF Loran, it is not believed that any other system now known would fully satisfy AAF long range navigation requirements. That this may be true likewise for Civil Aviation is indicated in a recommendation of the recent CERCA conference held in London to the effect that Loran be adopted as the standard long range navigation system for long oversea air routes.

6. Post War Loran Coverage Plan

a. General

On the assumption that Loran should be standardized as the primary long range navigation aid for both the civil and military, it is important that:

(1) A post war coverage plan be prepared which would satisfy USAAF requirements.

(2) Insofar as it concerns U. S. interests, suitable bases be secured which will permit implementation of post war Loran planning, particularly in the Pacific.

b. Planning Criteria

For planning purposes, the overall coverage requirements for post war Loran installations might be listed as follows:

(1) For Occupational Air Forces and Air Forces in forward areas.

(2) ATC routes connecting outlying bases and the U. S.

(3) For AAF training within or bordering the continental limits.

(4) U. S. Navy.

(5) Military requirements of other United Nations.

(6) For civil aviation and the Merchant Marine not included in the strictly military requirements.

c. Post War Plan for USAAF

A Post War Loran Plan which it is believed would satisfy USAAF requirements is attached herewith as Appendix "G". The coverage of the proposed stations is shown on Appendix "H". It is possible that this plan will also meet the needs of the U. S. Navy.

d. Other Requirements

No attempt has been made to prepare a plan covering the military requirements of other United Nations, Civil Aviation, or the Merchant Marine. These requirements, when determined, must be coordinated with the USAAF plan with regard to coverage and frequency allocations.

7. New Developments and Research

a. Low Frequency Loran

(1) Late in 1944, development of a Low Frequency Loran System was initiated by the AAF whereupon an experimental chain of three stations was placed in operation on 180 Kcs. on the east coast of the United States.

(2) It was considered that LF Loran offered these important advantages:

(a) Compared to standard Loran, the total number of ground stations required to cover any specified area possibly could be reduced by about one-third to one-half, due to the extended range anticipated.

(b) Operator training and use would be simplified due to absence of humerous sky wave components.

(c) Design of automatic aircraft equipment might be feasible.

(3) However, the following questions pertaining to the utility of LF Loran still remain to be resolved:

(a) Firm determination of range on a 24 hour basis.

(b) Final evaluation of accuracy.

(c) Effect of precipitation static and atmospheric disturbances on serviceability.

(4) Results of field trials to date indicate the presence of unresolvable propagation errors which may seriously limit LF accuracy. A final evaluation of the system, therefore, must await the tabulation of a mass of monitoring data which has been collected during the past few months. For the present, it is considered that LF Loran has not yet demonstrated sufficient promise to warrant its supplementing or replacing standard Loran in the immediate future.

b. Direct Reading of Automatic Receivers

(1) In its optimum form, a Loran Receiver should provide the navigator with a continuous direct indication of the aircraft's position. Due to the presence of numerous sky wave components, it has not been possible up to the present time to build a satisfactory automatic receiver for standard Loran. Moreover, the transition from Loran coordinates (based on a hyperbolic pattern) to a standard grid system can be accomplished at the present time only with complex and bulky equipment.

(2) However, Loran Receivers in which the time reading would be shown directly on veeder counters are now considered practical. A receiver of this type will reduce the time taken by a navigator to complete a fix and otherwise facilitate use of the system. In addition, it is believed that a direct reading receiver of proper design might satisfy long range fighter navigation requirements. Just prior to V-J Day, a development project was initiated for both a standard and fighter type direct reading receiver.

c. Improvements in Ground Station Equipment

(1) A serious limitation now imposed by present ground station equipment is the requirement for excessive radio frequency channel width and separation. In order to secure worldwide Loran coverage in the immediate future, it will be necessary to utilize a band from 1700 to 2000 Kcs.; this is discussed further in Appendices "G" and "I".

(2) Reduction in transmitter band width is considered essential. This will involve the development of crystal controlled transmitters with suitable band pass filters following the power amplifier.

(3) The present band width of receivers does not constitute a serious limitation in view of present transmission characteristics; however, receiver band widths could be reduced still further in the future to conform with a narrower transmitter spectrum, thereby improving cross channel selectivity.

d. Basic Research

The projects mentioned in the preceding paragraphs fall in a development category. In addition to these and other development problems, it is considered important that basic research continue on hyperbolic navigation systems. A program of this type should result in valuable improvements to Loran as it is known today; also may make available new ideas and techniques which might be of inestimable benefit in any future war. In this connection, the precise control of robot missiles at long range might be quoted as an example.

8. Conclusions

a. Standard Loran is the most suitable known and proven system for long range navigation of aircraft over sea routes.

b. Sufficient Loran equipment is available, both air and ground, to satisfy to a large extent civil and military post war requirements.

c. Continued development of ground and airborne Loran equipment should result in worthwhile improvements of the system; agressive research on hyperbolic navigation systems is advisable.

d. The merit of LF Loran needs further evaluation before operational use can be considered.

9. Recommendations

It is recommended that:

a. Loran be continued in the post war period as a long range navigational aid for U. S. Air Forces.

b. In the interest of standardization, every effort be made to influence a favorable decision by civil agencies to use Loran for long distance oversea routes.

c. A post war plan similar to the one presented in Appendix "C" be agreed upon by U. S. military services, and implementing action taken including clearance of suitable RF channels.

d. Conferences be held with the Navy Department, and such other U. S. agencies as may be necessary, to determine the Government or civil agency which will be responsible for installation and operation hereafter of ground stations of interest to this country.

e. Loran requirements of other United Nations, together with those of Civil Aviation and the Merchant Marine, should be determined and coordinated with the final plan adopted for U. S. military interests.

f. Research and development programs for improved ground and air equipment be continued or initiated as required in the post war period.

g. A training program for Loran operators be included in training plans for the post war Air Force.

h. LF Loran development and tests should be continued, if forthcoming reports are considered favorable.

J. M. HERTZBERG
Major, Air Corps

## Loran Stations in Operation on V-J Day

| | Location | Chain | Agency (See Note #3) | Equipment | Service |
|---|---|---|---|---|---|
| 1. | Bodie Island, No. Carolina | North Atlantic | USCG | Fixed | Standard |
| 2. | Siasconset, Nantucket | " | " | " | " |
| 3. | Baccaro, Nova Scotia | " | Royal Canadian Navy | " | " |
| 4. | Deming, Nova Scotia | " | " | " | " |
| 5. | Port-aux-Basques, Newfoundland | " | USCG | " | " |
| 6. | Bona vista, Newfoundland | " | " | " | " |
| 7. | Battle Harbor, Labrador | " | " | " | " |
| 8. | Narsak, Greenland | " | " | " | " |
| 9. | Vik, Iceland | Northeast Atlantic | Royal Navy (See Note #1) | " | " |
| 10. | Skuvanes, Faeroes | " | " | " | " |
| 11. | Mangersta, Hebrides | " | " | " | " |
| 12. | Skaw, Shetlands | " | RAF | " | " |
| 13. | Folly Island, So. Carolina | Southeast U. S. | USCG | " | " |
| 14. | Hobe Sound, Florida | " | " | " | " |
| 15. | Cameron, Louisiana | Gulf of Mexico | AACS | Air Transportable | " |

| | Location | Chain | Agency (See Note #3) | Equipment | Service |
|---|---|---|---|---|---|
| 16. | Matagorda, Texas | Gulf of Mexico | AACS | Air Transportable | Standard |
| 17. | Padre Island, Texas | " | " | " | " |
| 18. | Point Arguello, California | West Coast U.S. (Temporary) | " | " | " |
| 19. | Point Sur, California | " | " | " | " |
| 20. | Point Arena, California | " | " | " | " |
| 21. | Cape Blanco, Oregon | " | USCG | Mobile | " |
| 22. | Point Grenville, Washington | " | " | " | " |
| 23. | Amchitka Island, Aleutians | North Pacific | " | Fixed | " |
| 24. | Attu Island, Aleutians | " | " | " | " |
| 25. | St. Mathew Island, Aleutians | " | " | " | " |
| 26. | St. Paul Island, Aleutians | " | " | " | " |
| 27. | Umnak Island, Aleutians | " | " | " | " |
| 28. | Port Errol, Scotland | SS Europe | RAF | " | SS |
| 29. | Bizerte, No. Africa | " | " | " | " |
| 30. | Oran, No. Africa | " | " | " | " |
| 31. | Brindisi, Italy | " | " | " | " |

| | Location | Chain | Agency (See Note #3) | Equipment | Service |
|---|---|---|---|---|---|
| 32. | Hawaii Island | Hawaii | USCG | Fixed | Standard |
| 33. | Niihau Island | " | " | " | " |
| 34. | French Frigate Shoals | " | " | " | " |
| 35. | Kwajalein Atoll | Gilbert-Marshalls | " | " | " |
| 36. | Majuro Atoll | " | " | " | " |
| 37. | Makin Atoll | " | " | " | " |
| 38. | Baker Island | Phoenix | " | " | " |
| 39. | Gardner Island | " | " | " | " |
| 40. | Atafu Island | " | " | " | " |
| 41. | Bathhurst Island | Northwest Australia | AACS (See Note #2) | " | " |
| 42. | Sir Graham Moore Island | " | " | " | " |
| 43. | Champagny Island | " | " | " | " |
| 44. | Mapia Island | SS Borneo | USCG | Mobile | SS |
| 45. | Suluan, Philippines | " | " | " | " |
| 46. | Ngesebus Island, Palau | Palau | " | Fixed | Standard |
| 47. | Pulo Anna | " | " | " | " |
| 48. | Morotai | " | " | " | " |
| 49. | Saipan | Marianas | " | " | " |
| 50. | Guam | " | " | " | " |
| 51. | Potangeras, Ulithi | " | " | " | " |

| | Location | Chain | Agency (See Note #3) | Equipment | Service |
|---|---|---|---|---|---|
| 52. | Charchapli, Bengal | Bay of Bengal, SS Burma | RAF | Fixed | Standard and SS |
| 53. | Puriorissa, India | Bay of Bengal | " | " | Standard |
| 54. | Cocanada, India | " | " | " | " |
| 55. | Hoorigan, Assam | Assam Hump | AACS | Modified Fixed | TG |
| 56. | Anguri, Assam | " | " | " | " |
| 57. | Paya, Sadiya | Assam Hump SS Burma | " | " | TG & SS |
| 58. | Lutze, China | China Hump | " | " | TG |
| 59. | Kunyang, China | " | " | " | " |
| 60. | Ami, Yunnan, China | China Hump SS China | " | " | TG & SS |
| 61. | Hanchung, China | SS China | " | Fixed | SS |
| 62. | Iwo Jima | Iwo-Okinawa | USCG | " | Standard |
| 63. | Okinawa | " | " | " | " |
| 64. | Naulo Point, Luzon, P.I. | W.P.I. | " | Mobile | " |
| 65. | Salampulan, P.I. | " | " | " | " |
| 66. | Palawan, P.I. | " | " | " | " |
| 67. | Mienyang, Szechwan, China | Chengtu AT | AACS | Air Transportable | TG |
| 68. | Suining, Szechwan, China | " | " | " | " |
| 69. | Jungchang Szechwan, China | " | " | " | " |

| | Location | Chain | Agency | Equipment | Service |
|---|---|---|---|---|---|
| 70. | Danville, Illinois | Central Interior U. S. | AACS | AT | TG |
| 71. | Pinkstaff, Illinois | " | " | " | " |
| 72. | Sturgis, Kentucky | " | " | " | " |

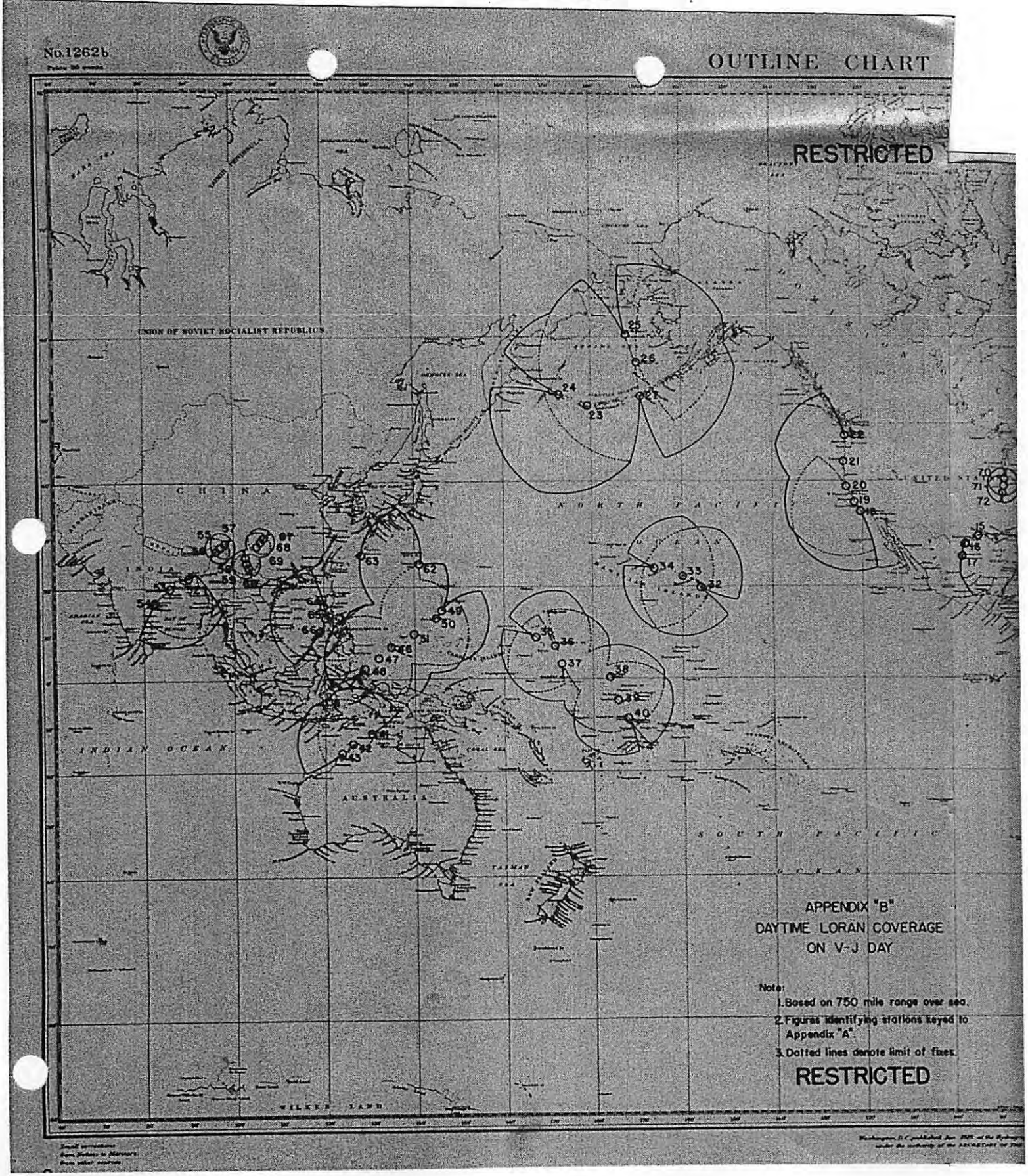
Note #1 Royal Air Force may assume operation of this chain.

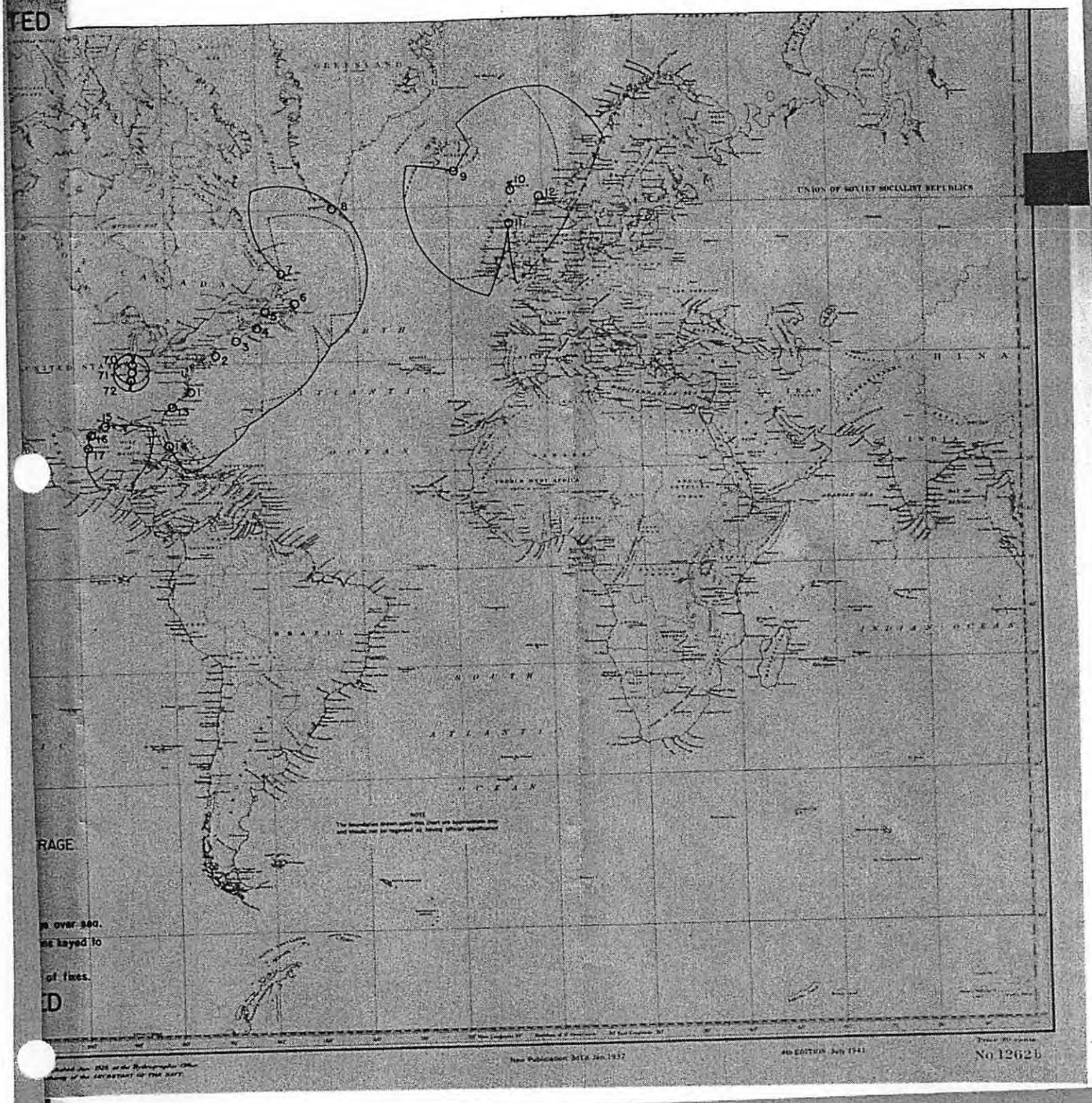
Note #2 Royal Australian Air Force has requested that this chain be turned over to them for operation.

Note #3 Division of operating responsibility as follows:

USCG - 37 RAF - 8 RCN - 2

AACS - 22 RN - 3





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# OUTLINE CHART

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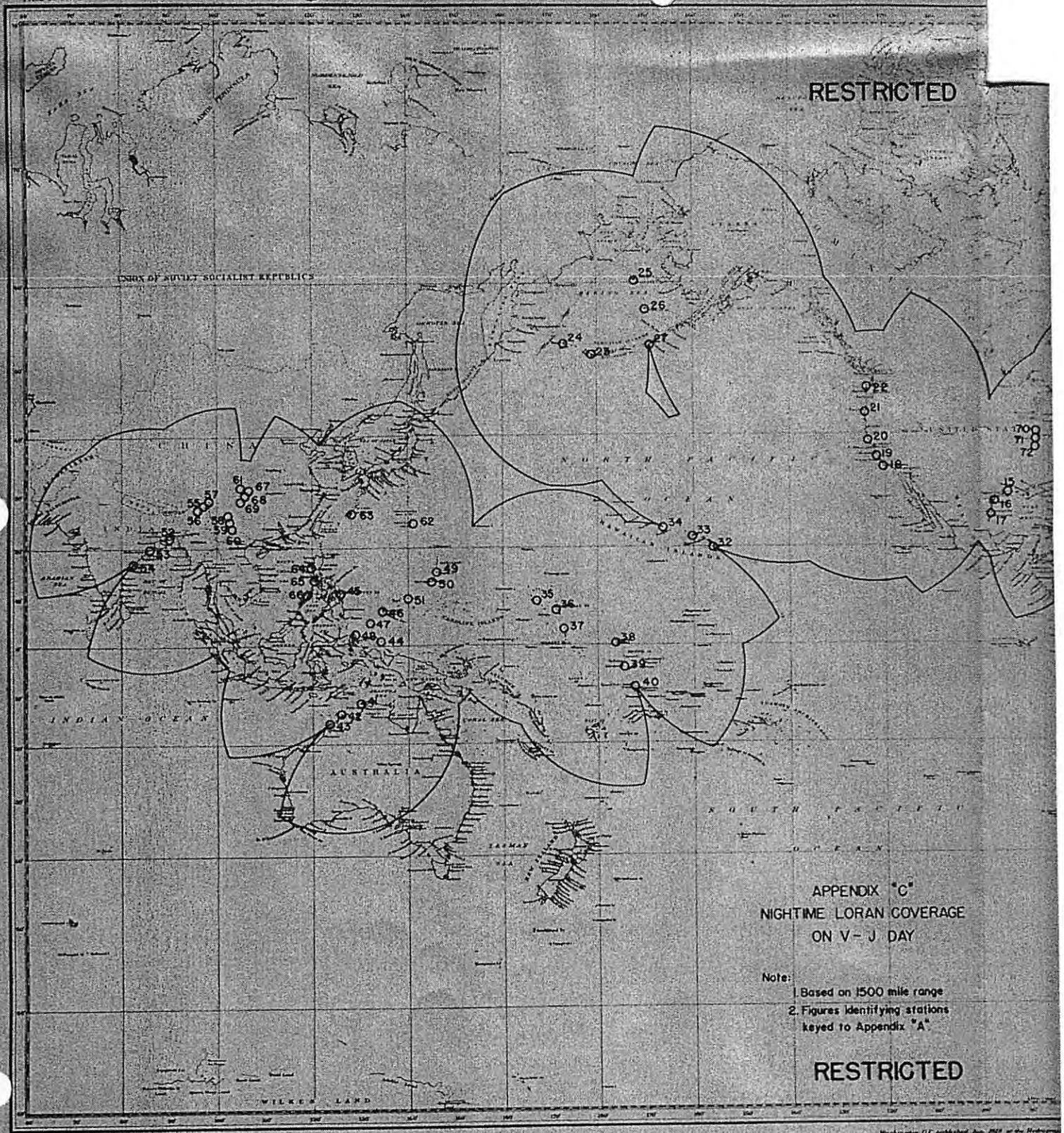


APPENDIX "C"
NIGHTIME LORAN COVERAGE
ON V - J DAY

Note:
1. Based on 1500 mile range
2. Figures identifying stations keyed to Appendix "A"

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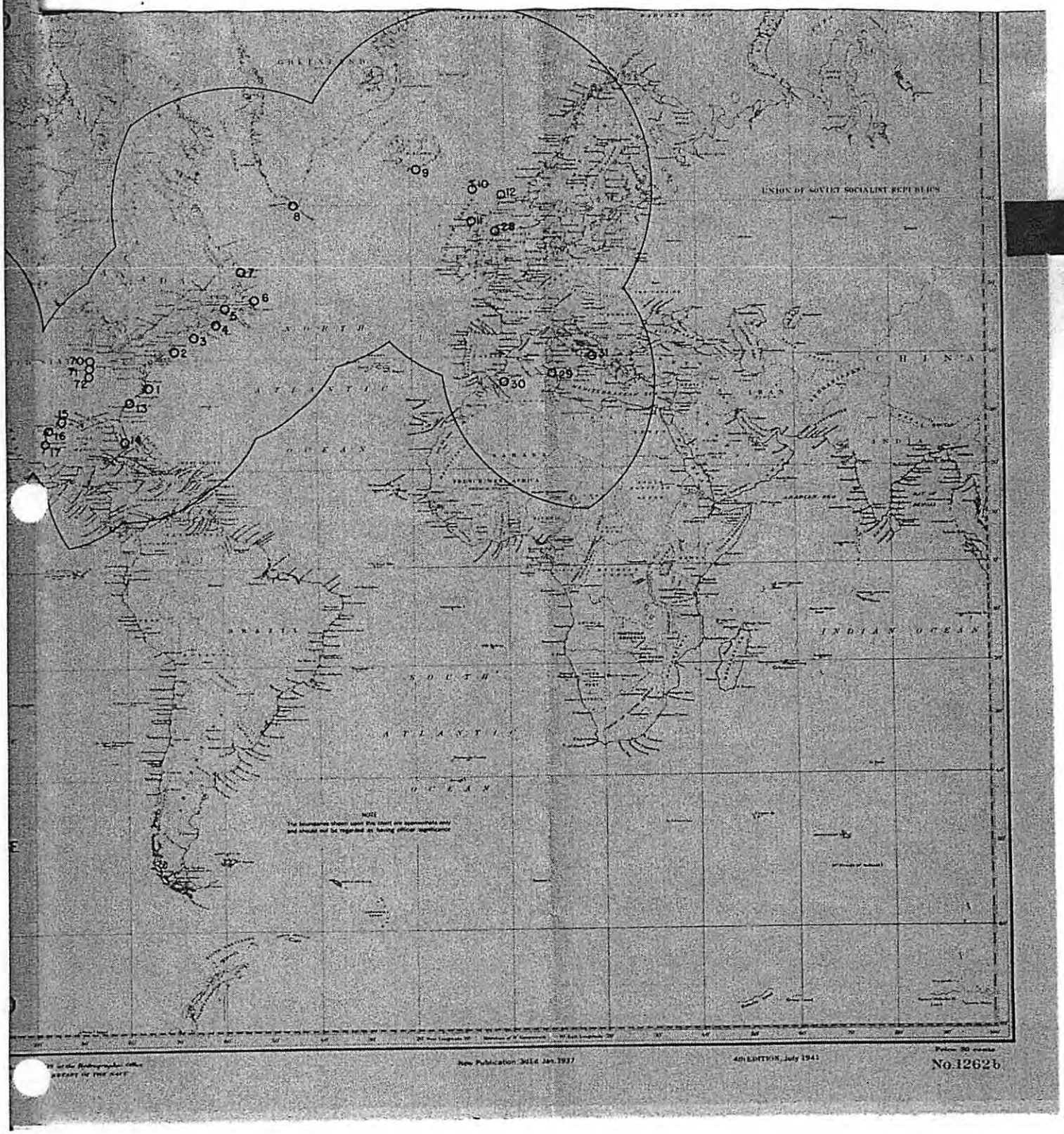


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APPENDIX "D"

Report on Serviceability of Loran Ground Stations

1. The information contained in this report has been derived from official records of the U. S. Coast Guard, Army Airways Communications System, Royal Air Force, and Royal Navy.

2. Tab 1 lists detailed operating information for a one month period for Loran stations in service on V-J Day. Data has been omitted in a few instances due to the lack of accurate field reports. Tab 2 is a graphical presentation of serviceability percentages.

3. Only one month's operation has been considered due to the work involved in making more extensive tabulations; the figures listed are considered representative of year round operation except for certain brief periods when atmospheric noise may be abnormally high.

4. It will be noted that, in general, ground stations are providing dependable service 98 to 99% of the time. During the periods covered in this report, serviceability dropped below 95% in five instances only. The following averages are derived from Tab 1:

a. Overall daily average percentage serviceable according to station records - 98.09%.

b. Daily average percentage serviceable (per station records) of selected group of stations where monitor checks are available - 99.24%.

c. Daily average percentage serviceable of selected group of stations included in b above according to independent monitor observations - 98.92%.

TAB 1

APPENDIX "D"

| Chain | Agency | Type | Period | Rate | Daily Schedule | Daily Av. Time Off In Min. | Daily Av. Blinking Time In Min. | Daily Av. % Serviceable (Station Records) | Daily Av. % Serviceable (Monitor Records) |
|---|---|---|---|---|---|---|---|---|---|
| North Atlantic | USCG | Fixed | 1 May-31 May 45 | 1-L-0 | 24 | 3 | 25 | 98.04 | 98.0 |
| North Atlantic | " | " | " " | 1-L-1 | " | 1 | 5 | 99.58 | 99.5 |
| North Atlantic | RCN | " | ---- | 1-L-2 | " | No figures available . . . . . | | | |
| North Atlantic | USCG | " | 1 May-31 May 45 | 1-L-3 | " | 1 | 2 | 99.84 | 99.5 |
| North Atlantic | " | " | " " | 1-L-4 | " | 1 | 1 | 98.99 | 99.0 |
| Northeast Atlantic | RN | " | 1 Jan-27 Jan 45 | 1-L-5 | " | Included in Blinking Time | 15 | 98.75 | ---- |
| Northeast Atlantic | " | " | " " | 1-L-6 | " | Included in Blinking Time | 25 | 98.25 | ---- |
| Southeast U.S. | USCG | " | 1 Jul-31 Jul 45 | 1-H-1 | " | No figures available . . . . . | | | |
| Southeast U.S. | " | " | " " | 1-H-2 | " | 9 | 32 | 97.15 | 96.1 |
| Gulf of Mexico | AACS | AT | 16 Jun-15 Jul 45 | 2-L-5 | " | 12 | 78 | 93.75 | ---- |
| Gulf of Mexico | " | " | " " | 2-L-6 | " | 12 | 52 | 95.55 | ---- |

| Chain | Agency | Type | Period | Rate | Daily Schedule | Daily Av. Time Off In Min. | Daily Av. Blinking Time In Min. | Daily Av. % Serviceable (Station Records) | Daily Av. % Serviceable (Monitor Records) |
|---|---|---|---|---|---|---|---|---|---|
| West Coast U.S. (Temp.) | AACS | AT | 15 May-15 Jun 45 | 1-H-6 | 24 | 65 | 31 | 93.3 | ---- |
| West Coast U.S. (Temp.) | " | " | " " | 1-H-7 | " | 50 | 26 | 94.7 | ---- |
| West Coast U.S. (Temp.) | USCG | Mobile | ----- | 2-H-4 | " | No figures available . . . . . | | | |
| No. Pacific (Aleutians) | " | Fixed | 1 May-31 May 45 | 1-L-0 | " | 1 | 2 | 99.78 | 99.2 |
| No. Pacific (Aleutians) | " | " | " " | 1-L-1 | " | 3 | 2 | 99.60 | 99.4 |
| No. Pacific (Aleutians) | " | " | " " | 1-L-2 | " | 3 | 10 | 99.10 | 99.0 |
| Hawaii | " | " | " " | 2-L-0 | " | 2 | 6 | 99.49 | 99.2 |
| Hawaii | " | " | " " | 2-L-1 | " | 3 | 4 | 99.53 | 99.2 |
| Gilbert-Marshall | " | " | " " | 2-L-2 | " | 2 | 5 | 99.5 | 99.0 |
| Gilbert-Marshall | " | " | " " | 2-L-3 | " | 2 | 2 | 99.69 | 99.4 |
| Phoenix | " | " | " " | 2-L-4 | " | 3 | 4 | 99.5 | 99.0 |
| Phoenix | " | " | " " | 2-L-5 | " | 3 | 3 | 99.6 | 99.2 |
| Northwest Australia | AACS | " | ----- | 2-H-4 | " | No figures available . . . . . | | | |
| Northwest Australia | " | " | ----- | 2-H-5 | " | No figures available . . . . . | | | |

| Chain | Agency | Type | Period | Rate | Daily Schedule | Daily Av. Time Off In Min. | Daily Av. Blinking Time In Min. | Daily Av. % Serviceable (Station Records) | Daily Av. % Serviceable (Monitor Records) |
|---|---|---|---|---|---|---|---|---|---|
| Palau | USCG | Fixed | 1 Jun-30 Jun 45 | 4-H-6 | 24 | 2 | 2 | 99.75 | ---- |
| Palau | " | " | " " | 4-H-7 | " | 3 | 1 | 99.7 | ---- |
| SS Borneo | " | Mobile | ----- | 4-H-0 | 18 | No figures available . . . . . | | | |
| Marianas | " | Fixed | 1 May-31 May 45 | 4-H-2 | 24 | 4 | 7 | 99.21 | 99.0 |
| Marianas | " | " | " " | 4-H-3 | " | 4 | 4 | 99.46 | 99.0 |
| Iwo-Okinawa | " | " | 1 Jul-31 Jul 45 | 4-H-4 | " | 7 | 7 | 99.0 | 99.0 |
| West Philippines | " | Mobile | ----- | 1-L-6 | " | No figures available . . . . . | | | |
| West Philippines | " | " | ----- | 1-L-7 | " | No figures available . . . . . | | | |
| Bay of Bengal | AACS | Fixed | 21 May-20 Jun 45 | 4-L-6 | " | 7 | 70 | 94.6 | ---- |
| Bay of Bengal | " | " | " " | 4-L-7 | " | 7 | 37 | 96.95 | ---- |
| SS Burma | " | " | " " | 4-L-5 | 18 | 5 | 76 | 92.5 | ---- |
| Assam "Hump" | " | Modified Fixed | " " | 4-L-3 | 24 | 8 | 10 | 98.75 | ---- |
| Assam "Hump" | " | " | " " | 4-L-4 | " | 8 | 16 | 98.3 | ---- |
| China "Hump" | " | " | " " | 4-L-1 | " | 16 | 29 | 97.55 | ---- |
| China "Hump" | " | " | " " | 4-L-2 | " | 16 | 23 | 97.3 | ---- |

| Chain | Agency | Type | Period | Rate | Daily Schedule | Daily Av. Time Off In Min. | Daily Av. Blinking Time In Min. | Daily Av. % Serviceable (Station Records) | Daily Av. % Serviceable (Monitor Records) |
|---|---|---|---|---|---|---|---|---|---|
| SS China | AAGS | Fixed | 21 May-20 Jun 45 | 1-L-0 | 24 (See Note 1) | 29 | 255 | 81.0 | ---- |
| SS Europe | RAF | " | 1 Sep-30 Sep 44 | 3-H-4 | 11 | Included in Blinking Time | 7 | 98.95 | ---- |
| SS Europe | RAF | " | " " | 3-H-5 | " | Included in Blinking Time | 4 | 99.4 | ---- |

Note 1: Figures not available for 18 hour operation.

# APPENDIX "D"

## LORAN GROUND STATION OPERATION

| DATE | AVERAGE DAILY PERCENTAGE SERVICEABLE TIME VS. UNSERVICEABLE TIME (75 80 85 90 95 100) | AGENCY |
|---|---|---|
| 1 May - 31 May 1945 | North Atlantic Rate 1-L-0 | USCG |
| " " | North Atlantic 1-L-1 | " |
| " " | North Atlantic 1-L-3 | " |
| " " | North Atlantic 1-L-4 | " |
| 1 Jan - 27 Jan | Northeast Atlantic 1-L-5 | RN |
| " " | Northeast Atlantic 1-L-6 | " |
| 1 Jul - 31 Jul | Southeast U.S. 1-H-2 | USCG |
| 16 Jun - 15 Jul | Gulf of Mexico 2-L-5 | AACS |
| " " | Gulf of Mexico 2-L-6 | " |
| 15 May - 15 Jun | West Coast U.S. (Temp.) 1-H-6 | " |
| " " | West Coast U.S. (Temp.) 1-H-7 | " |
| 1 May - 31 May | North Pacific 1-L-0 | USCG |
| " " | North Pacific 1-L-1 | " |
| " " | North Pacific 1-L-2 | " |
| " " | Hawaii 2-L-0 | " |
| " " | Hawaii 2-L-1 | " |
| " " | Gilbert-Marshall 2-L-2 | " |
| " " | Gilbert-Marshall 2-L-3 | " |
| " " | Phoenix 2-L-4 | " |
| " " | Phoenix 2-L-5 | " |
| 1 Jun - 30 Jun | Palau 4-H-6 | " |
| " " | Palau 4-H-7 | " |
| 1 May - 31 May | Marianas 4-H-2 | " |
| " " | Marianas 4-H-3 | " |
| 1 Jul - 31 Jul | Iwo-Okinawa 4-H-4 | " |
| 21 May - 20 Jun | Bay of Bengal 4-H-7 | AACS |
| " " | Bay of Bengal 4-H-6 | " |
| " " | SS Burma 4-H-5 | " |
| " " | Assam Hump 4-H-4 | " |
| " " | Assam Hump 4-H-3 | " |
| " " | China Hump 4-H-2 | " |
| " " | China Hump 4-H-1 | " |
| 1 Sep - 30 Sep 1944 | SS Europe 3-H-4 | RAF |
| " " | SS Europe 3-H-5 | " |

APPENDIX "E"

Use of Loran by 21 Bomber Command
4 February 1945 - 9 June 1945

1. The information included in this Appendix has been derived from the official Mission Reports of 21 Bomber Command. Tab 1, attached herewith, contains a tabulation of certain pertinent data; Tab 2, direct quotations from a number of reports which have a bearing on the use of Loran during the missions specified.

2. These observations on the data listed in Tab 1 are considered of interest:

a. In those missions where the number of Loran fixes secured by navigators were actually counted, 40,678 fixes were obtained in 5,091 aircraft; a total of 8 fixes per aircraft per mission.

b. In all the missions listed in Tab 1, the reports state that Loran was used extensively. However, in mine laying missions and others directed against air fields in Kyushu, no count was kept of Loran fixes. Assuming 8 fixes per aircraft per mission which seems conservative, a total of 114,032 Loran fixes were obtained in 21 Bomber Command operations during the five month period covered in this summary.

c. In many of the mission reports, the number of Loran sets which were inoperative is not given. However, in 35 separate missions where this data is available, there were 316 failures of the Loran receiver out of a total of 8,783 aircraft equipped; this averages 96.3% operational.

d. On Mission #176, 4,968 fixes were obtained in 516 aircraft; not a single equipment failure was reported. On only three missions of all those tabulated were set failures in excess of 10%.

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TAB 1

APPENDIX "E"

| Mission # | # A/C | # Sets Inoperative | % Inoperative | # Fixes | Max. Fix Range |
|---|---|---|---|---|---|
| 26 | 109 | 2 | 1.8 | NR (See Note) | 1000 |
| 29 | 112 | 0 | .0 | " | 750 |
| 34 | 117 | 2 | 1.7 | " | 800 |
| 37 | 145 | 5 | 3.4 | " | 850 |
| 38 | 229 | 8 | 3.5 | " | NR |
| 39 | 191 | 7 | 3.7 | " | 1000 |
| 40 | 313 | NR | — | " | NR |
| 41 | 310 | 20 | 6.5 | 4350 | 1200 |
| 42 | 295 | NR | — | NR | 1070 |
| 43 | 331 | " | — | " | 1500 |
| 44 | 298 | " | — | " | 1200 |
| 45 | 251 | 7 | 2.8 | " | 1200 |
| 46 | 161 | 5 | 3.1 | " | NR |
| 47 | 102 | 4 | 3.9 | " | " |
| 48 | 135 | 14 | 11.0 | 160 | 1200 |
| 49 | 94 | 5 | 5.3 | NR | NR |
| 50 | 149 | 13 | 8.7 | " | 1200 |
| 55 | 230 | 18 | 8.0 | 2225 | 1500 |
| 59 | 194 | 11 | 5.7 | 1312 | 750 |
| 60 | 53 | 4 | 7.5 | 364 | 1000 |
| 63 | 221 | 29 | 13.0 | 1400 | 1000 |

| Mission # | # A/C | # Sets Inoperative | % Inoperative | # Fixes | Max. Fix Range |
|---|---|---|---|---|---|
| 64 | 167 | NR | — | NR | 1000 |
| 67 | 348 | 15 | 4.3 | 2362 | 1250 |
| 68 | 337 | 41 | 12.2 | 2992 | 1425 |
| 70-95 | 627 | NR | — | NR | 1000 |
| 96 | 131 | 9 | 6.8 | 1050 | 1300 |
| 97-125 | 640 | NR | — | NR | NR |
| 126 | 106 | 0 | .0 | 790 | 900 |
| 139 | 195 | 3 | 1.5 | 1998 | 1150 |
| 146 | 170 | NR | — | 1428 | 712 |
| 163 | 343 | 11 | 3.2 | 2935 | 885 |
| 167-171 | 218 | NR | — | NR | NR |
| 172 | 102 | 2 | 1.9 | 681 | 895 |
| 174 | 524 | 3 | .6 | 4318 | 693 |
| 176 | 516 | 0 | .0 | 4968 | 1083 |
| 178 | 309 | 4 | 1.3 | 2148 | 842 |
| 181 | 514 | 7 | 1.4 | 2386 | 1200 |
| 183 | 452 | 12 | 2.6 | NR | 1091 |
| 186 | 510 | 8 | 1.6 | " | 911 |
| 187 | 509 | 10 | 2.0 | " | 893 |
| 188 | 523 | 16 | 3.0 | " | 911 |
| 189 | 449 | 15 | 3.3 | 1767 | 848 |
| 191 | 116 | 6 | 5.2 | 1044 | 900 |
| | 14,249 | | | | |

Note: "NR" means Not Reported.

TAB 2

APPENDIX "E"

Extracts from 21 Bomber Command Mission Reports:

Mission # 26

"Navigators in the 313th Wing criticized Loran inaccuracy but an investigation of the 73rd Wing returns indicate that the 313th Wing navigators need additional training in fix interpretation. The small angle of cut of the Guam and Ulithi Chains makes possible 10 mile plotting errors."

Mission # 29

"The 313th Wing complained of the inaccuracy of Loran fixes because of the poor cut of the Guam and Ulithi Chains. Several of their fixes and ground speeds gave poor positions, but inaccuracies can be greatly reduced by proper set calibration and accurate interpretation of sky waves."

Mission # 37

"Loran furnished adequate navigational aid during this mission."

Mission # 39

"All navigators were able to make good use of celestial and Loran aids."

Mission # 40

"Navigators were forced to rely on Loran and metro winds as a basis for their dead reckoning. Range was exceptionally good with many fixes being obtained on the coast of Honshu. Winds to the target were stronger than briefed and navigators who were unable to obtain celestial, radar, or Loran fixes were blown 10 to 30 miles east of course."

Mission # 41

"Loran was 90% operational and gave maximum ranges to the coast of Honshu. Because of low cloud cover, navigators had to depend largely on this method."

Mission # 42

"Cloud cover and turbulence hampered celestial observations forcing the navigators to depend almost entirely upon Loran. Loran was 90% operational with fixes obtained on the coast of Honshu."

Mission # 43

"Loran range was effective to the coast of Honshu with the average landfall error 10 miles east of the briefed point."

Mission # 45

"Navigation on the route out was relatively easy because of Loran."

Mission # 49

"Navigation was good, Loran and celestial being used in conjunction to enable all crews to make landfall within a 10 mile area."

Mission # 50

"APQ-13 and APN-4 gave excellent aid to navigation."

Mission # 64

"Navigation was accomplished by dead reckoning supplemented by Loran and radio. Celestial navigation was hampered by unsatisfactory weather conditions."

Mission # 146

"Navigators of the 58th Wing did not fully utilize Loran as a navigation aid due to their recent arrival into this area, and insufficient time for training in its use. However, a training program has now been initiated."

Mission # 163

"Full use was made of all navigational aids - celestial, radar, and Loran although the 58th Wing's inexperience with the latter was a handicap."

Mission # 174

"No difficulties were encountered in long range navigation."

Mission # 176

"Long range navigation was accomplished as briefed using celestial and Loran as aids."

Mission # 178

"Navigation was accomplished without incident using Loran and celestial as aids."

Mission # 181

"Bad weather hindered celestial navigation and limited visual observations." (2,386 Loran fixes were obtained on this mission.)

Mission # 183

"Aircraft proceeded to the target individually at briefed altitude and air speeds with celestial, Loran, and radar being used as navigational aids."

Mission # 189

"Navigation to the target was excellent and was accomplished without incident. Loran navigation and radar were used extensively."

APPENDIX "F"

## Characteristics of Long Range Navigation Systems

| System | Loran | LF Loran | Sonne | P.G.P.I. | QH | Omni-Directional Range | ADF |
|---|---|---|---|---|---|---|---|
| 1. Comparison Basis | Operational Use | Field Trials | Limited Operational Use | Tests and Theoretical | Tests and Theoretical | Tests and Theoretical | Operational Use |
| 2. Type | Synchronized Pulses | Synchronized Pulses | Keyed CW Phase Reversal and Phase Rotation | CW Phase Comparison | Synchronized CW Phase Comparison | CW Phase Comparison - Rot. Pattern | CW Direction Measuring |
| 3. Status | In Use | Under Development by NDRC | Test Stations Under Construction | UK Project Not Active | UK Project Not Active | Under Development by CAA | In Use |
| 4. a. Frequency | 2 mcs | 180 kcs | 200-500 kcs | LF | LF/MF | LF | LF/MF |
| b. Band Width | Wide | Wide | Narrow | Narrow | Narrow | Narrow | Narrow |
| 5. Range | | | | | | | |
| a. Day Over Sea | 700 | 750-2000 Miles Dependent on Noise Levels | 500-1500 Miles Dependent on Power, Frequency & Noise Levels | 500-1500 Miles Dependent on Power, Frequency & Noise Levels | Limited to Ground Wave Range | 500-1500 Miles Dependent on Power, Frequency & Noise Levels | Too Variable to Analyze |
| b. Day Over Land | 200 | | | | | | |
| c. Night Over Sea | 1500 | | | | | | |
| d. Night Over Land | 1200 | | | | | | |
| 6. Accuracy | | | | | | | |
| a. Day | Less Than 1% of Range - Usually Less Than ± 2 Mi. | Undetermined | ± ½° for LOP ± 3 Miles | ± 1° for LOP ± 13 Miles | Extremely Accurate at Short Ranges | ± 3° for LOP ± 40 Miles | Too Variable to Analyze |
| b. Night | Less Than 1% of Range - Usually Less Than ± 10 Mi. at Maximum Range | Undetermined | Subject to Serious Errors | Subject to Serious Errors | Subject to Serious Errors | Subject to Serious Errors | Subject to Serious Errors |
| 7. Ambiguity | On Opposite Sides of Base- | On Opposite Sides of Base- | Numerous - Resolvable by D/F | Numerous - Resolvable by Re- | Numerous - Resolved by Re- | Reciprocal Bearing - Resolvable | Reciprocal Bearing - Resolvable |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a. Night Over Land | 1200 | | | | | | |
| 6. Accuracy a. Day | Less Than 1% of Range - Usually Less Than ± 2 Mi. | Undetermined | ± ½° for LOP ± 3 Miles | ± 1° for LOP ± 13 Miles | Extremely Accurate at Short Ranges | ± 3° for LOP ± 40 Miles | Too Variable to Analyze |
| b. Night | Less Than 1% of Range - Usually Less Than ± 10 Mi. at Maximum Range | Undetermined | Subject to Serious Errors | Subject to Serious Errors | Subject to Serious Errors | Subject to Serious Errors | Subject to Serious Errors |
| 7. Ambiguity | On Opposite Sides of Baselines - Readily Resolvable | On Opposite Sides of Baselines - Readily Resolvable | Numerous - Resolvable by D/F or Other Means | Numerous - Resolvable by Receiver Adjustment | Numerous - Resolved by Receiver Counting Mechanism - Non-Resolvable if Count is Lost | Reciprocal Bearing - Resolvable | Reciprocal Bearing - Resolvable |
| 8. Noise Susceptibility | Generally Not Serious | Probably Serious in Bad Weather | Probably Serious in Bad Weather | Probably Serious in Bad Weather | Probably Serious in Bad Weather | Probably Serious in Bad Weather | Serious in Bad Weather |
| 9. Position Lines a. Type | Hyperbolas | Hyperbolas | Great Circle Bearings | Great Circle Bearings | Hyperbolas | Great Circle Bearings | Great Circle Bearings |
| b. Special Charts Required | Yes | Yes | Yes | Yes | Yes | Not Essential - Desirable | Standard Flight Charts |
| 10. Ground Stations a. Min. for LOP | 2 | 2 | 1 | 1 | 2 | 1 | 1 |
| b. Min. for Fix | 3 | 3 | 2 | 2 | 3 | 2 | 2 |
| c. Synchronization Required | Yes | Yes | No | No | Yes | No | No |
| d. Personnel Per Station (24 Hr. Op.) | 25 | 25 | 25 | 15 (Est.) | 15 (Est.) | 6 (Est.) | 6 (Variable) |
| e. Service Reliability | High 98% | Undetermined - Probably High | Undetermined - Probably High | Undetermined | Undetermined | Undetermined - Probably High | High 99.9% |
| f. Availability of Equipment | Available | Development Models | Development Models | None | None | Development Models | Available |
| 11. Aircraft Receiver a. Type | Special | Special | Standard Communications | Standard Communications plus Special | Special | Standard Communications plus Special | Standard Compass |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| b. Special Charts Required | Yes | Yes | Yes | Yes | Yes | Not Essential - Desirable | Standard Flight Charts |
| 10. Ground Stations | | | | | | | |
| a. Min. for LOP | 2 | 2 | 1 | 1 | 2 | 1 | 1 |
| b. Min. for Fix | 3 | 3 | 2 | 2 | 3 | 2 | 2 |
| c. Synchronization Required | Yes | Yes | No | No | Yes | No | No |
| d. Personnel Per Station (24 Hr. Op.) | 25 | 25 | 25 | 15 (Est.) | 15 (Est.) | 8 (Est.) | 8 (Variable) |
| e. Service Reliability | High 98% | Undetermined - Probably High | Undetermined - Probably High | Undetermined | Undetermined | Undetermined - Probably High | High 99.9% |
| f. Availability of Equipment | Available | Development Models | Development Models | None | None | Development Models | Available |
| 11. Aircraft Receiver | | | | | | | |
| a. Type | Special | Special | Standard Communications | Standard Communications plus Special Attachment | Special | Standard Communications plus Special Attachment | Standard Compass |
| b. Weight | 35 (Added) | 45 (Added) | 45 (None Added) | 60 (15# Added) | 80 (Added) | 58 (18# Added) | 45-85 |
| c. Presentation | CRT | CRT | Aural | Visual Meters | Visual Meters | Visual Meters | Aural & Visual Meters |
| d. Interpretation | Measurements Converted to Chart | Measurements Converted to Chart | Measurements Converted to Chart | Direct Bearing Indication | Measurements Converted to Chart | Direct Bearing Indication | Direct Bearing Indication |
| e. Pilot Operation | Subject to Test | Subject to Test | Yes | Yes | Yes | Yes | Yes |
| f. Antenna Requirements | Trailing Wire or Fixed | Trailing Wire Preferred | Trailing Wire, Fixed, or Loop | Trailing Wire, Fixed or Loop | Trailing Wire or Fixed | Trailing Wire, Fixed, or Loop | Loop or Fixed |
| g. Est. Min. Time to obtain Fix | 2 Minutes | 2 Minutes | 5 Minutes | 1 Minute | 1 Minute | 1 Minute | 2 Minutes |
| h. Availability | Available in Quantity | Limited Quantity Available | Available in Quantity | Not Available | Not Available | Not Available | Available in Quantity |

APPENDIX "G"

Proposed Post War Loran Plan for USAAF

1. It is proposed that the following Loran chains be operated hereafter to furnish suitable coverage for the AAF:

| | | | |
|---|---|---|---|
| a. | Continental Europe | 4 stations | 2 rates |
| b. | North Atlantic | 10 " | 8 " |
| c. | Panama Canal Zone | 6 " | 4 " |
| d. | Gulf of Mexico | 3 " | 2 " |
| e. | Central Interior U.S. | 3 " | 2 " |
| f. | West Coast U.S. | 6 " | 5 " |
| g. | Gulf of Alaska | 3 " | 2 " |
| h. | North Pacific (Aleutians) | 5 " | 3 " |
| i. | Hawaiian Islands | 5 " | 4 " |
| j. | Gilbert-Marshalls | 5 " | 4 " |
| k. | Phoenix Islands | 3 " | 2 " |
| l. | Marianas-Palau | 5 " | 4 " |
| m. | West Philippines-Okinawa-Iwo | 8 " | 7 " |
| | Total | 66 | 49 |

2. Tab 1, attached, lists locations both old and new which are proposed, current status, and the country which has jurisdiction. Tab 2 lists stations now operating which are to be discontinued or transferred. Coverage of the 66 stations is shown on Appendix "G".

3. The plan proposed herewith has been formulated on the basis that maximum daylight coverage should be provided in areas of post war military importance to the U. S. Undoubtedly, there will be Occupational Air Forces requirements for facilities other than those listed. However, pending clarification of such requirements, the only stations included in this category are those in the Continental Europe chain for which a formal request is on record.

4. It is felt that, insofar as possible, U. S. Government agencies should operate all Loran ground stations which are of prime interest to this country in order that satisfactory control may be maintained. Moreover, as far as practicable, installations should be made only at locations in the possession or control of the U. S. It is felt that AACS should operate those stations which will be used almost solely by the AAF such as the Continental Europe chain. In addition to the maintenance of close control of such facilities, AACS operation will furnish training and experience which should be valuable in the event of emergencies in the future. However, a final decision as to the specific organizations which will operate individual stations must be held in abeyance pending further discussions with the Navy Department, possibly the CAA, and other Governments.

G

5. Due to the wide frequency spectrum occupied by present day Loran transmissions, it will be necessary to use the radio frequency band between 1700 and 2000 Kcs. for some time in the future if excessive interference between Loran stations is to be avoided. 1800 to 2000 Kcs. has been approved for Loran use in the post war period. 1700 to 1800 Kcs. was used as an emergency measure by special agreement during the war. It will be necessary, therefore, to amend the frequency allocation established for post war Loran to include 1700-1800 Kcs. Tab 3, attached, presents what is considered to be an optimum frequency plan for the stations proposed herewith. Appendix "I" presents the technical data upon which this plan is based. Current allocations, chart considerations, and requirements for stations other than those mentioned herewith have been disregarded. It should be noted, however, that the proposed plan which utilizes the 1750 Kcs. channel could be expanded readily to provide allocations for a substantial number of additional stations in selected areas. Post war changes probably will necessitate reprinting the majority of charts; in most cases, however, recalculation will not be required. It was not possible to follow a straightforward frequency allocation plan during the war due to new and constantly changing requirements which were fitted into the existing structure. It is considered that any questions concerning chart availability or reprinting should not influence adoption of a revised frequency plan which would provide optimum operational advantages and reduce interference to a minimum.

6. The proposed ground station program may be summarized as follows:

a. Total number of stations in operation on V-J Day - 72

(1) U. S. Operated . . . . . 59
(2) Royal Navy . . . . . 4
(3) Royal Air Force . . . . 7
(4) Royal Canadian Navy . . 2

b. U. S. Operated stations to be discontinued - 18

(1) Dismantled . . . . . 15
(2) Transferred . . . . . 3
(or dismantled)

c. New stations proposed - 23

(1) U. S. Operated . . . . . 22
(2) Royal Canadian Navy . . 1

d. Total number of stations now operating or proposed - 80

(1) U. S. Operated . . . . . 63
(2) Royal Navy . . . . . 4
(3) Royal Air Force . . . . 7
(4) Royal Australian Air Force . . . . 3
(5) Royal Canadian Navy . . 3

Note: Royal Navy, Royal Air Force, and Royal Australian Air Force stations are not listed in Tab 1, nor is coverage shown on Appendix "H".

e. Country controlling site of stations included in this USAAF plan of 66 stations:

| | | | |
|---|---|---|---|
| (1) | U. S. . . . . | 50 | (including 4 in Germany) |
| (2) | New Zealand . . . | 1 | |
| (3) | Newfoundland . . | 3 | |
| (4) | Canada . . . . . | 3 | |
| (5) | Denmark . . . . . | 1 | |
| (6) | Nicaragua . . . . | 1 | |
| (7) | Columbia . . . . | 2 | |
| (8) | Panama . . . . . | 1 | |
| (9) | Costa Rica . . . | 1 | |
| (10) | Mexico . . . . . | 1 | |
| (11) | Great Britain . . | 2 | |

APPENDIX "G"

## Proposed Post War Loran Stations for USAAF

| | Location | Chain | Status | Possession |
|---|---|---|---|---|
| 1. | Germany | Continental Europe | Proposed | U.S. Occupied |
| 2. | Germany | " " | " | " " |
| 3. | Germany | " " | " | " " |
| 4. | Germany | " " | " | " " |
| 5. | Narsak, Greenland | North Atlantic | In Operation | Denmark |
| 6. | Battle Harbor, Labrador | " " | " | Newfoundland |
| 7. | Bona Vista | " " | " | " |
| 8. | Port-aux-basques | " " | " | " |
| 9. | Deming, Nova Scotia | " " | " | Canada |
| 10. | Baccaro, Nova Scotia | " " | " | " |
| 11. | Siasconset, Nantucket | " " | " | U.S. |
| 12. | Bodie Island, N. C. | " " | " | " |
| 13. | Folly Island, S. C. | " " | " | " |
| 14. | Hobe Sound, Florida | " " | " | " |
| 15. | San Juan del Norte | Panama Canal Zone | Proposed | Nicaragua |
| 16. | Colon, C. Z. | " " " | " | U.S. |
| 17. | Cartagena | " " " | " | Columbia |
| 18. | Buena Ventura | " " " | " | " |
| 19. | Coiba Island | " " " | " | Panama |
| 20. | Cape Blanco, Costa Rica | " " " | " | Costa Rica |
| 21. | Padre Island | Gulf of Mexico | In Operation | U.S. |

| Location | Chain | Status | Possession |
|---|---|---|---|
| 22. Matagorda Island | Gulf of Mexico | In Operation | U.S. |
| 23. Cameron, La. | " " | " | " |
| 24. Sturgis, Kentucky | Central Interior U.S. | " | " |
| 25. Pinkstaff, Ill. | " " " | " | " |
| 26. Danville, Ill. | " " " | " | " |
| 27. Guadalupe Island | West Coast U.S. | Construction Approved | Mexico |
| 28. Point Arguello | " " " | " " | U.S. |
| 29. See Note # 1 | | | |
| 30. Point Arena | " " " | " " | " |
| 31. Cape Blanco, Oregon | " " " | " " | " |
| 32. Point Grenville | " " " | " " | " |
| 33. Vancouver Island | " " " | " " | Canada |
| 34. Sitka | Gulf of Alaska | Proposed | U.S. |
| 35. Yakutat | " " | " | " |
| 36. Kodiak | " " | " | " |
| 37. Umnak | North Pacific | In Operation | " |
| 38. St. Paul Island | " " | " | " |
| 39. St. Mathew Island | " " | " | " |
| 40. Amchitka Island | " " | " | " |
| 41. Attu Island | " " | " | " |
| 42. Hawaii Island | Hawaiian Islands | " | " |
| 43. Niihau Island | " " | " | " |
| 44. French Frigate Shoals | " " | " | " |
| 45. Laysan Island | " " | Proposed | " |
| 46. Midway Island | " " | " | " |

| Location | Chain | Status | Possession |
|---|---|---|---|
| 47. Atafu Island | Phoenix Islands | In Operation | New Zealand |
| 48. Gardner Island | " " | " | Great Britain |
| 49. Baker Island | " " | " | U.S. |
| 50. Makin Atoll | Gilbert-Marshall | P " | Great Britain |
| 51. Majuro Atoll | " " | " | U.S. Occupied |
| 52. Kwajalein | " " | " | " |
| 53. Taongi | " " | Proposed | " |
| 54. Wake Island | " " | " | U.S. |
| 55. Pagan Island | Marianas-Palau | " | U.S. Occupied |
| 56. See Note # 2 | | | |
| 57. Guam | " " | In Operation | U.S. |
| 58. Potangeras, Ulithi | " " | " | U.S. Occupied |
| 59. Ngesebus, Palau | " " | " | " |
| 60. Pulo Anna | " " | " | " |
| 61. See Note # 3 | | | |
| 62. See Note # 4 | | | |
| 63. See Note # 3 | | | |
| 64. Palawan, P. I. | West Philippines-Okinawa-Iwo | " (See Note # 5) | U.S. |
| 65. Salampulan, P. I. | " " | " (See Note # 5) | " |
| 66. Naulo Point, Luzon, P.I. | " " | " (See Note # 5) | " |
| 67. Bojeador Point | " " | Proposed | " |
| 68. Batan Island | " " | " | " |
| 69. Okinawa | " " | In Operation | U.S. Occupied |
| 70. Rasa Jima | " " | Proposed | " |
| 71. Iwo | " " | In Operation | " |

Note # 1. AACS is now operating air transportable station at Point Sur which will be discontinued upon completion of the West Coast U. S. Chain.

Note # 2. Operation of existing station on Saipan to be discontinued. Will be replaced by Pagan Island station thereby increasing baseline length of this pair.

Note # 3. The Mapia (61) and Suluan (63) SS Borneo pair to be discontinued.

Note # 4. Station on Morotai Island to be discontinued.

Note # 5. Presently operating with mobile equipment. To be replaced with fixed stations, same locations.

TAB 2

APPENDIX "G"

Stations now Operating to be Discontinued or Transferred

| | Location | Chain | Reference | Recommended Action |
|---|---|---|---|---|
| 1. | Point Sur, Calif. | West Coast U.S. (Temporary) | #19 App. A & B<br>#29 App. H | Discontinue when permanent West Coast stations in operation. |
| 2. | Bathurst Island | NW Australia | #41 App. A & B | Transfer to Royal Australian Air Force or discontinue. |
| 3. | Sir Graham Moore Island | " | #42 App. A & B | Transfer to Royal Australian Air Force or discontinue. |
| 4. | Champagny Island | " | #43 App. A & B | Transfer to Royal Australian Air Force or discontinue. |
| 5. | Mapia Island | SS Borneo | #44 App. A & B<br>#61 App. H | Discontinue |
| 6. | Suluan, P. I. | " | #45 App. A & B<br>#63 App. H | " |
| 7. | Morotai | Palau | #48 App. A & B<br>#62 App. H | " |
| 8. | Saipan | Marianas | #49 App. A & B<br>#56 App. H | " |
| 9. | Hoorigan, Assam | Assam Hump | #55 App. A & B | Discontinue when theater approves |
| 10. | Amguri, Assam | " " | #56 App. A & B | " " " " |
| 11. | Paya, Sadiya | " " SS Burma | #57 App. A & B | " " " " |
| 12. | Lutze, China | China Hump | #58 App. A & B | " " " " |
| 13. | Kunyang, China | " " | #59 App. A & B | " " " " |
| 14. | Ami, Yunnan, China | SS China China Hump | #60 App. A & B | " " " " |
| 15. | Hanchung, China | SS China | #61 App. A & B | " " " " |

| Location | Chain | Reference | Recommended Action |
|---|---|---|---|
| 16. Mienyang, Szechwan, China | Chengtu AT | #67 App. A & B | Discontinue |
| 17. Suining, Szechwan, China | " | #68 App. A & B | " |
| 18. Jungchang, Szechwan, China | " | #69 App. A & B | " |

TAB 3

APPENDIX "G"

Proposed Frequency Allocations

1950 Low

0, 1, 2, 3, 4, 5, 6, 7 - North Atlantic
(Starts at Hobe Sound)

0, 1, 2, 3, 4, 5, 6 - West Philippines-Okinawa-Iwo
(Starts at Iwo)

6, 7 - Phoenix

1950 High

1, 2, 3, 4, 5 - West Coast U. S.
(Starts at Guadalupe)

1850 Low

0, 1 - Continental Europe

0, 1 - Gulf of Alaska

2, 3, 4 - North Pacific (Aleutians)

6, 7 - Central Interior U. S.

1850 High

2, 3, 4, 5 - Canal Zone

6, 7 - Gulf of Mexico

4, 5, 6, 7 - Hawaii
(Starts at Midway)

1750 Low

0, 1, 2, 3 - Gilbert-Marshalls
(Starts at Wake)

1750 High

4, 5, 6, 7 - Marianas-Palau
(Starts at Pagan)

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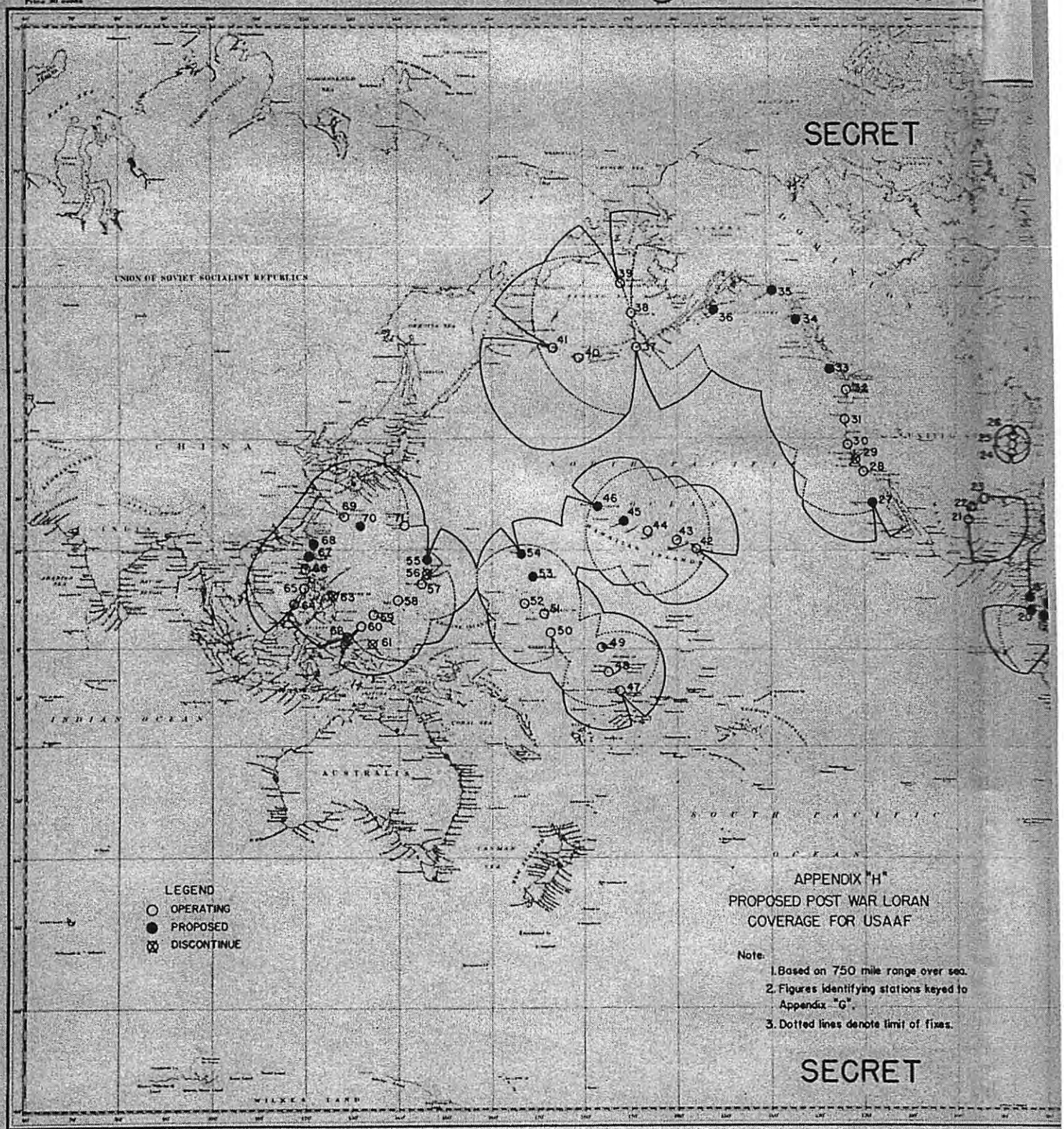


APPENDIX "H"
PROPOSED POST WAR LORAN
COVERAGE FOR USAAF

Note:
1. Based on 750 mile range over sea.
2. Figures identifying stations keyed to Appendix "G".
3. Dotted lines denote limit of fixes.

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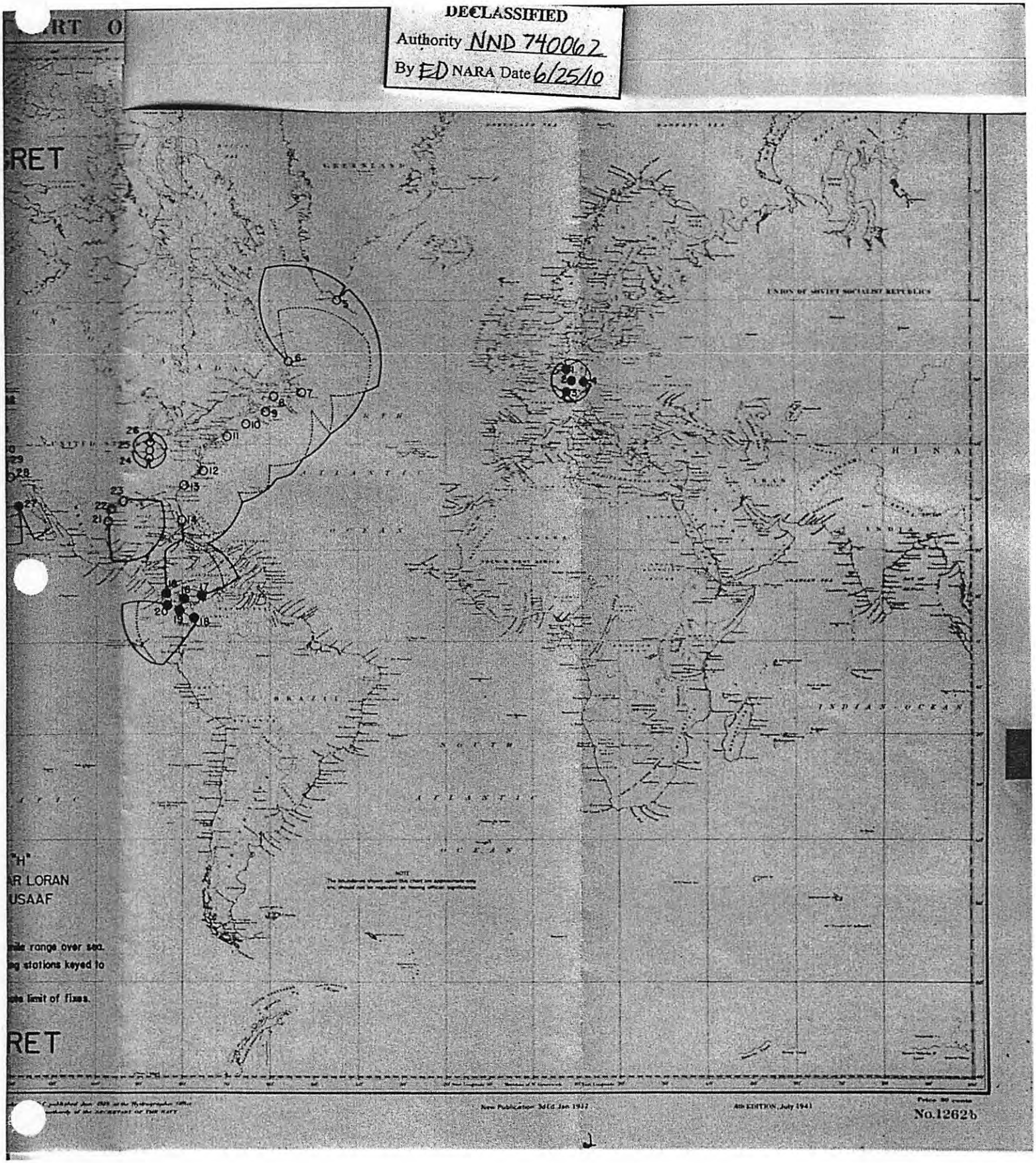


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# APPENDIX "I"

## Relation of Loran Transmitter Output and Receiver Band Width to Frequency Allocation Problems

1. The following graphs, attached, are part of this appendix:

   a. Tab 1
      Loran transmitter output in decibels as a function of frequency; also selectivity curves for the AN/APN-9 Receiver.

   b. Tab 2
      100 Kw. inverse distance field, ground wave attenuation curve, and quasi-maximum sky wave curve.

   c. Tab 3
      Same as Tab 1, but with transmitter curve revised in accordance with proposals for future standardization.

2. Referring to Tab 1, it will be noted that at point "A" the transmitter output is down 22db; the response of a receiver tuned 100 Kcs. lower in frequency likewise is down 22db. In other words, the receiver response to the transmitter energy at "A" is down 44db when referred to the center frequency at which the receiver is tuned. At point "B", the transmitter output is down 29db; however, the receiver furnishes no rejection to energy at "B", hence the overall rejection to the unwanted transmitter energy is 29db. It is apparent, therefore, that the attenuation of an unwanted Loran signal at the receiver is limited by the band width of the radiated energy from the transmitter, and not by the receiver band pass.

3. In order to determine the separation required in miles between two stations operating on identical base and specific rates, it is necessary to establish certain parameters. Therefore, it is assumed that:

   a. Night rather than day operation shall be considered due to the high sky wave fields at extended range at night.

   b. Due to higher noise levels at night, the minimum field strength of the wanted signal shall be 50 mv/M (34db) to be usable at 1400 nautical miles range.

   c. The wanted to unwanted signal ratio shall not be less than 3/1 to permit satisfactory readings; that is to say the unwanted signal shall not exceed 15 mv/M (24db).

4. Operational experience has indicated that separation between stations on the same radio frequency in the order of 4000-5000 miles is satisfactory particularly if there is an angular displacement between the service area bisectors, or opposition thereof. 100 and 200 Kcs. spacing, therefore, is considered in the following:

a. 100 Kcs. spacing.

| | | | |
|---|---|---|---|
| Wanted signal | 34 db. | | |
| Attenuation of unwanted signal 100 Kcs. off | 29 " | | |
| | 63 " | | |
| Less 3/1 ratio | 10 " | | |
| Range of quasi-maximum field | 53 " | = | 1300 N.M. |
| Add range from wanted signal stations | | | 1400 " |
| Required separation | | | 2700 " |

b. 200 Kcs. spacing.

| | | | |
|---|---|---|---|
| Wanted signal | 34 db. | | |
| Attenuation of unwanted signal 100 Kcs. off | 55 " | | |
| | 89 " | | |
| Less 3/1 ratio | 10 " | | |
| Range of quasi-maximum field | 79 " | = | 215 N.M. |
| Add range from wanted signal stations | | | 1400 " |
| Required separation | | | 1615 " |

5. Referring to Tab 3, it may be noted that the on-frequency components of the adjacent channel transmitter are now down in the order of 70db or more. At point "P", 50 Kcs. off, transmitter components are down 40db. New transmitting equipment with output characteristics of the order illustrated would permit use of four channels between 1800 and 2000 Kcs. spaced 50 Kcs. apart with 25 Kcs. guard channels. Such an arrangement should provide adequate rates for all Loran ground facilities that might be contemplated with probably far less inter-channel interference than is experienced with current allocations.

6. It is evident from the foregoing that:

a. Temporarily use of 1700 to 1800 Kcs. is required for Loran in addition to the band now approved from 1800 to 2000 Kcs. if any substantial number of ground stations are to be operated in the immediate future.

b. Reduction of transmitter band width should be accomplished as soon as possible; field replacements to follow thereafter as soon as modernized equipment is available in order that the excessive frequency allocations now required may be relinquished.