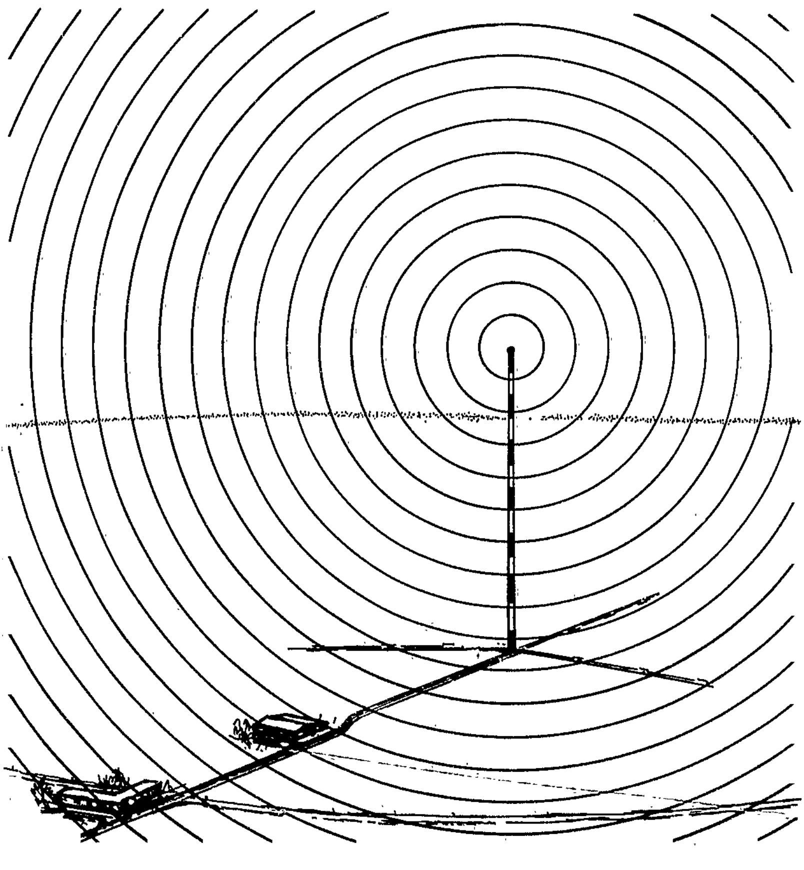
# Omega Navigational Installation

*Report from the Joint Committee on Foreign Affairs and Defence*





# Omega
# Navigational Installation

*Report from the Joint Committee on Foreign Affairs and Defence*

Australian Government Publishing Service, 1975

Printed by the Government Printer of Australia



## *Members of the Committee*

| | |
|---|---|
| Senator the Hon. J.M. Wheeldon . . . | <u>Chairman</u> |
| The Hon. N.H. Bowen, M.P. . . . . | <u>Deputy Chairman</u> until 21 August 1973 |
| The Hon. A.S. Peacock, M.P. . . . | <u>Deputy Chairman</u> from 21 August 1973 |
| Senator J.L. Carrick | |
| Senator A.J. Drury | |
| Senator G.D. McIntosh . . . . . | from 23 August 1974 |
| Senator F.P. McManus . . . . . | until 11 April 1974 |
| Senator C.R. Maunsell | |
| Senator B.R. Milliner . . . . . | until 11 April 1974 |
| Senator C.G. Primmer | |
| Senator J.P. Sim | |
| Mr J.M. Berinson, M.P. | |
| Mr J. Coates, M.P. | |
| Mr D.M. Connolly, M.P. . . . . . | from 23 August 1974 |
| Mr J. Corbett, M.P. . . . . . | from 23 August 1974 |
| Mr M.D. Cross, M.P. | |
| Mr J.S. Dawkins, M.P. . . . . . | from 23 August 1974 |
| Mr G.W.A. Duthie, M.P. . . . . . | until 11 April 1974 |
| Dr the Hon. A.J. Forbes, M.C., M.P. . . | until 17 April 1975 |
| Mr K.L. Fry, M.P. . . . . . | from 23 August 1974 |
| Mr G.O'H. Giles, M.P. . . . . . | from 23 August 1974 |
| Mr D.J. Hamer, D.S.C., M.P. . . . | until 11 April 1974 |
| Mr J.C. Kerin, M.P. | |
| The Hon. D.J. Killen, M.P. . . . . | from 17 April 1975 |
| Dr R.E. Klugman, M.P. | |
| Mr A.S. Luchetti, M.P. . . . . . | until 11 April 1974 |
| Mr P.E. Lucock, C.B.E., M.P. | |
| Mr M.J.R. MacKellar, M.P. . . . . | until 11 April 1974 |
| Mr M.W. Oldmeadow, M.P. | |

Secretary:

D.V. Selth,
The Senate.

## *Terms of Reference*

Foreign Affairs and/or Defence aspects of the proposed Omega navigational installation in Australia and, in particular, the proposed conditions of ownership and control of the installation.

# Contents

## *Preface*

In accordance with the resolution of appointment of the Joint Committee on Foreign Affairs and Defence, the then Minister for Foreign Affairs, the Hon. E.G. Whitlam, Q.C., M.P., referred to the Committee on 23 May 1973 for inquiry and report:

> Foreign Affairs and/or Defence aspects of the proposed Omega navigational installation in Australia and, in particular, the proposed conditions of ownership and control of the installation.

On Tuesday 21 August 1973, the Committee resolved that the full Committee should examine this reference.

The Committee wishes to record that the tabling of this Report, being the first Report presented by the Joint Committee on Foreign Affairs and Defence to the Parliament, has a three-fold significance.

It is the first Report by the Committee since its terms of reference were expanded to include defence matters as well as foreign affairs.

The Omega inquiry is the first during the Joint Committee's 22 years of existence that the full Committee has conducted. All previous inquiries were conducted and reports drafted by sub-Committees.

This is also the first Report of the Committee presented directly to the Parliament. Previously the Committee only reported to the Parliament that the Foreign Minister had been forwarded a Report on a certain matter pursuant to his request; the Foreign Minister had the prerogative of deciding whether or not the Report should be tabled in Parliament. The Committee sees this change as a welcome growth of its independence.

The Committee has held 25 meetings on the Omega Navigational Installation reference. At eight of these, held between 28 August and 6 November in 1973, evidence was heard from 26 witnesses. All meetings, except one deliberative meeting in Melbourne, were held in Canberra. The witnesses who appeared before the Committee included representatives of Australian Government departments and various associations, academics and private individuals. The Committee received 45 formal and informal submissions and letters, in addition to the submissions of the 26 witnesses. The Committee is pleased to note that all evidence was taken in public session. This is only the second occasion on which the Committee has not taken all evidence <u>in camera</u>.

<u>Scope of the Inquiry</u>

Throughout the inquiry, the Committee found that there was widespread misunderstanding about the basic technological features of the Omega Navigational System - what



Omega can do and what it cannot do. For this reason, the Report includes essential information about Omega signals and the Omega transmitting system. As the system will be widely used by civilian craft, the Committee also felt it was necessary to include a section on the benefits of Omega that will be of particular value to non-military craft. The inclusion of this material will enable the foreign affairs and defence aspects of this issue to be seen in perspective.

Some members of the Committee expressed reservations about aspects of the Committee's report. These views are set out in the dissenting report on p.109.

<u>Technical Adviser</u>

Dr J. Crouchley, Reader in Physics of the University of Queensland, was appointed Technical Adviser to the Committee at the beginning of the inquiry. Dr Crouchley's advice has been invaluable and the Committee expresses its appreciation to him.

# I Omega as a Navigational Aid

## A. THE DEVELOPMENT OF OMEGA

### FROM SUN TO SATELLITE

Man has always explored his world - to satisfy his material needs, to ascertain whether danger threatens or merely to satisfy his curiosity.

When his world was limited by the distances he could walk, an ability to recognise the landmarks in his immediate vicinity was sufficient to ensure a safe return. When he began to travel further afield, venturing into unknown territory, the position of the sun in the sky guided him safely home. As his journeys lengthened, he needed navigational aids.

The Phoenicians used a dead-reckoning system to guide them in their ocean crossings as early as 600 B.C. They calculated their direction by observations of the Polaris and other stars, and calculated their speed by measuring the time it took a chip of wood (hence 'log') dropped from the stem of the boat to pass the poop deck. Refinements such as the magnetic needle, the sextant, quadrant and astrolabe appeared in the next 2500 years.

However, it was not until the extensive use of air transport (with an accompanying need for faster and more accurate calculations) that radio and electronic aids were developed. In the 1940s England developed Decca and Radar, the United States developed Loran, and Germany developed Consol. Radar and Decca give greater accuracy than was available previously and can be used in all weather conditions, but they have a range of only about 350 kilometres which restricts their use for ocean navigation. In addition, Decca is expensive and therefore not likely to be available to smaller ships. Loran A (as Loran later became known), a low frequency version - Loran C, and Consol are valuable long-range aids, but are only available in certain areas of the northern hemisphere. Loran C chains were established in 1957 for military purposes, and are in use today by the United States and the Soviet Union.

In recent years a number of other navigation aids have been developed. For instance, the United States' satellite navigation system became operational in 1964. This system allows positions to be fixed anywhere in the world with very great accuracy, although at present the satellites may only be observed at intervals of approximately two hours. The system is therefore not available continuously. It is also expensive.

Omega, however, is the first all-weather world-wide navigation aid that is continuously available at reasonable cost.



## DEVELOPMENT OF OMEGA IN THE U.S.A.

In 1947 Professor J.A. Pierce, of Harvard University, proposed a hyperbolic low frequency navigation system using phase difference techniques rather than the pulse time difference of the Loran system, with which he had also been connected. A system, sometimes known as Radux, using a frequency of about 40 kHz, was investigated experimentally but eventually abandoned in favour of a system operating at lower frequencies. After considerable experimentation during the 1950s a basic frequency of 10.2 kHz was chosen for what is now known as Omega. While the propagation mechanism for transmitting at this frequency is more simple than at higher frequencies, the difficulty of radiating energy at low frequencies, and the consequent need for large and expensive antenna systems, set a lower practical limit on the frequency that can be used. At about the same time the International Telecommunications Union set aside the 10-14 kHz band for radio navigation and radio location.

Experimental transmissions were made between San Diego and Hawaii in 1958 and 1959. In the next few years experimental transmissions were also made from sites in Wales, Norway, Trinidad and the Panama Canal zone. Regular transmission from Forrestport, in New York, began in 1966.

From 1962, considerable experimentation and development of the Omega system took place in the United States under the aegis of the United States Navy, mainly because the Navy was the only government authority in U.S.A. which had facilities for, and experience in, VLF transmission. The U.S. Navy began to place Omega receivers in its surface ships in 1967 (after experimentation in the previous few years had been successful), and it is currently proceeding with this policy. In September 1968, the U.S. Navy decided to proceed with world-wide implementation of an Omega system. In 1972 the first contract was awarded for the installation of receivers in attack submarines, sometimes known as hunter-killer submarines, and in the same year the United States Coast Guard commenced taking over the responsibility for the operation and maintenance of the U.S. transmitters.

## DEVELOPMENT OF A GLOBAL NETWORK

Five transmitters are currently at or near operational status (although some of them are not yet operating continuously or at full strength). A station, which has been built in North Dakota, U.S.A., to replace the experimental station at Forrestport in New York, was the first to become operational on full power (10kW) in October 1972. The station in Norway is now operational. The stations in Japan and Hawaii are testing at present and expect to be transmitting at full power in the near future. The transmitter in Trinidad, which is operating at low power, will be closed and replaced by another in Liberia, which is expected to be operational later this year.

The transmitters which are being constructed in Argentina and Reunion Island are expected to begin testing in the near future, and it is proposed that a transmitter be constructed in the Tasman Sea area. These eight stations would transmit signals that would provide adequate global coverage.



There are three transmitters in U.S.S.R. operating at slightly higher frequencies than the Omega stations are using, or are likely to use. These transmitters are sited in positions that suggest their main aim is to assist Russian vessels or aircraft operating in the Arctic region, but any vessel or aircraft with equipment capable of receiving the Russian signals could make use of them. Similarly, Russian vessels or aircraft capable of receiving the signals from the seven or eight Omega transmitters could use Omega.

## OMEGA IN THE TASMAN SEA AREA

To be useful for navigation the signals received from Omega transmitters must be simple, repeatable, stable and reliable. These criteria rule out the use in Australia, New Zealand and their environs of signals from some of the Omega transmitters.

The signals from Reunion Island are expected to be strong and reliable in the Tasman Sea area. Likewise, signals from Japan are expected to be useful all over Australia, and in the areas north, east and south of Australia. However, there may be some unreliability in the southern Indian Ocean. The signal from Hawaii is expected to be unreliable at night, and at sunrise and sunset. The signal from Liberia is expected to be reliable but the direction of arrival of this signal is similar to that of the Reunion Island signal, and thus the value for Australia of the Liberian station is largely negated. The signals from Norway, North Dakota and Argentina are likely to have only a very limited usefulness for Australia.

Accordingly, only two signals will be sufficiently strong and reliable to be useful in Australia and the surrounding area. Because three signals are necessary to enable a position to be determined accurately, global cover cannot be adequately provided without a transmitter in the Tasman Sea area. Such a transmitter is of prime importance if the system is to be used in this area, and is of either secondary or no importance for the rest of the world.

It was submitted to the Committee by Mr E.N. Armstrong that the Omega Project Office's opinion of the effect on global coverage of the absence of an Australian station was:

> that without a station in Australia the regions to the west of Australia and to the east could suffer a marked degradation in accuracy.
>
> (Ev. p.520)

Evidence was also given by Mr Armstrong that operation in the Antarctic region would not be possible without an Australian transmitter (Ev. p.520).

## THE EIGHTH TRANSMITTER

The United States Government first approached the Australian Government in June 1967, and requested permission for U.S. Navy representatives to discuss with Australian officials the feasibility of building a transmitter in Australia. A similar approach was made to the New Zealand Government in August 1967. A United States survey team visited Australia in



December of that year to explain site requirements to an inter-departmental committee which had been set up under the Chairmanship of the Department of Foreign Affairs. The team also visited New Zealand and requested permission of both countries to seek and recommend possible locations. The then Prime Minister of New Zealand, Mr Holyoake, announced on 29 November that a United States team would visit New Zealand to investigate sites.

At that time it was believed that for economic reasons a deep valley would be necessary for the construction of a valley-spanning antenna; a United States technical team examined a number of Australian sites in May 1968 and recommended two - the Forth River, Tasmania, and the Nattai River, New South Wales. At the same time, it also examined a number of sites in New Zealand and found two - Lake Sumner and Lake Pearson - equally suitable.

In June 1968 opposition to the establishment of an Omega transmitter in New Zealand was expressed by several staff members of the Physics Department of Canterbury University in Christchurch. They stated that the erection of a transmitter would allow ballistic missile submarines to fix their positions with great accuracy, thus contributing to their offensive potential. They also stated that this could invite a nuclear attack on the transmitter to forestall its use by these submarines. This concern generated considerable public discussion and some opposition. Accordingly, the New Zealand Government requested the Royal Society to investigate and report on all aspects of the Omega system. The Royal Society presented its report in August 1968. It did not recommend whether or not an Omega transmitter should be built in New Zealand. Rather the report acknowledged the advantages of Omega, while at the same time it pointed out major disadvantages for New Zealand of a station sited in New Zealand. These disadvantages were that:

(a) the near-zone effect of a station in New Zealand would reduce the usefulness of the station for New Zealand; and

(b) it was possible that experiments in the VLF field, in which New Zealand is particularly active, would be adversely affected by VLF transmission from a local Omega station.[1]

It has been suggested that the Society was also influenced by the realisation that a transmitter in Australia would have greater value to New Zealand than a transmitter located in New Zealand. Furthermore, the Australian Department of Foreign Affairs understands that the expense of erecting the transmitter and constructing the ancillary buildings was more than the New Zealand Government wished to bear (Ev. p.210).

At about this time changes in engineering technology made it unnecessary to use a deep valley for the antenna, and the four sites previously considered the most suitable (two in Australia and two in New Zealand) were no longer proposed. A tower antenna, which does not suffer from the siting restrictions of a valley-span antenna, became economically as feasible as the latter type.

1 Royal Society of New Zealand, Report of the Ad Hoc Committee on the Omega Navigation System (Wellington, 1968), p.5.



Evidence was given that the Prime Minister of New Zealand advised Capt. M. Polk, Advisor on Navigation to the Executive Office of the President of the United States, who had led the investigating team which visited New Zealand in April 1969, that the New Zealand Government was willing to host an Omega transmitter in New Zealand, subject to suitable financial arrangements (Ev. p.514). However, in the following month the United States decided that it preferred Australia as a site. It is believed this change resulted from the decision to build the West Pacific station in Japan rather than the Philippines, and the consequent changes in system geometry caused by this decision. No further investigations were made in New Zealand by the United States, and no request to build an installation in New Zealand was made by the United States.

In April 1969 another U.S. Navy team visited Australia and resumed discussions and exchange of information with the inter-departmental committee that had been set up in December 1967. In April 1970 a formal proposal was received by the Australian Government from the United States that Australia agree in principle to the building of an Omega transmitter (Ev. pp.213-214). In December 1970 the Australian Government expressed its agreement in principle to this proposal (Ev. p.216).

The Australian Prime Minister advised Parliament on 18 March 1971 that the Government had agreed in principle to build a transmitter 'somewhere in the vicinity of Bass Strait' but that a precise location had not been selected (Ev. p.189). Site selection investigations and negotiation with the United States continued, and in June 1971 discussion was initiated between the Australian Government and the states of New South Wales, Queensland, Victoria and Tasmania on the possibility of building a transmitter in one of these states. In August 1972 agreement between Australia and U.S.A. was reached except for minor drafting changes (see pp.52-58). However a conclusive agreement has not been signed.

## B. THE OPERATION OF THE OMEGA SYSTEM

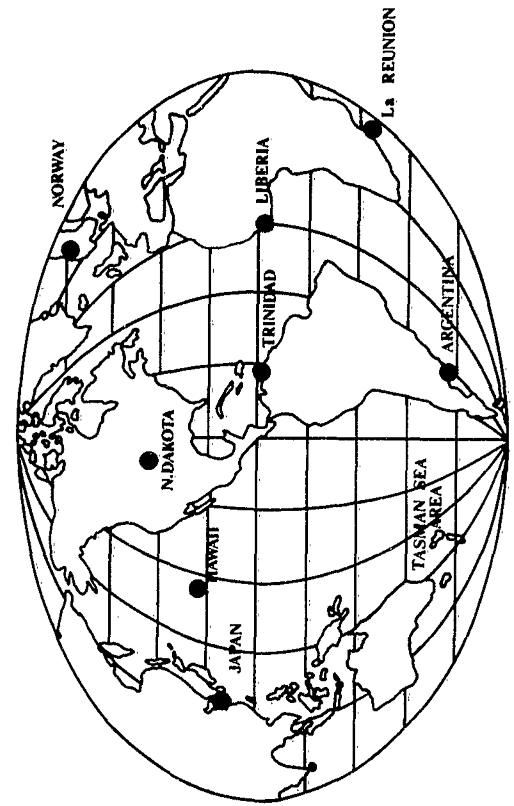
Omega is an all-weather, continuous, world-wide position-fixing system for surface ships, submarines and aircraft. It is one of a family of hyperbolic radio navigation aids; Omega uses radio signals with frequencies located in the Very Low Frequency (VLF) band, between 10 and 14 kHz.

### OMEGA SIGNALS

Signals in this frequency range penetrate the ionosphere to a much lesser extent than signals at higher frequencies. Accordingly, they present very stable and reliable wave fronts at great distances from the transmitter. Therefore, eight Omega transmitters, sited in a suitable global pattern, could provide sufficient redundancy (that is, over-lap of signals) to ensure a continuous reception of at least three reliable signals in virtually all parts of the earth.



PRESENT AND PROPOSED SITES FOR OMEGA NAVIGATION TRANSMITTING STATIONS



Each transmitter emits a basic pattern, repeated at precisely ten-second intervals, consisting of successive approximately one-second intervals of frequencies 10.2, 11.33 and 13.6 kHz separated by intervals of 0.2 seconds. The remainder of the ten-seconds repetition period may be used for transmission of frequencies for special purposes, e.g., GRAN (see p.23), or may not be used at all. The frequency, phase and timing of the transmission is controlled by the use of an extremely accurate frequency standard (Caesium-beam) and a clock driven by this frequency standard. No station can simultaneously transmit two frequencies, nor will the same frequency be transmitted simultaneously by any two stations.

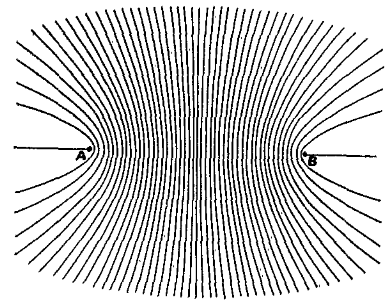
Each of the transmitters is intended to have a signal range of about 12,000 kilometres. This range will require a radiated signal power of 10 kW. However, because a VLF antenna in this frequency range has a low radiation efficiency, the required transmitter power is 150 kW.

## POSITION-FIXING USING THE OMEGA SYSTEM

Radio waves have a finite velocity and hence, if it is possible to measure the time of propagation from a transmitter to a receiver, the separation of the transmitter and the receiver is given by the product of velocity and propagation time. By comparing signals, for example, from two transmitters A and B, a phase difference is measured which represents the time difference for the two signals to reach the receiving point. If a ship moved in such a path that this difference was kept constant, its track would be a line of position (LOP). At

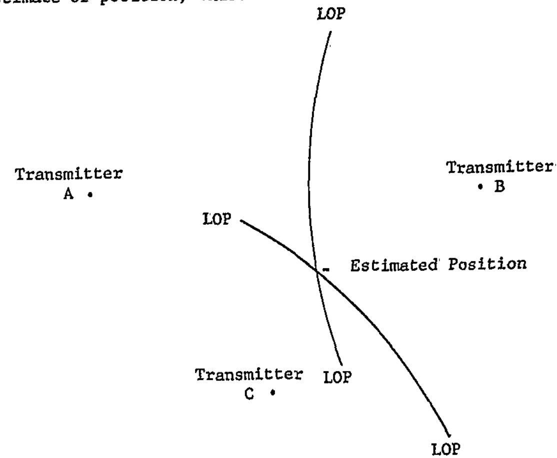


any time therefore a navigator who can receive these two signals can be aware that he is somewhere on the LOP.




The nature of the lines of position when stations are many wavelengths apart. Note the uniform spacing along the baseline, the gradual increase in spacing transverse to the baseline and the marked increase in spacing behind the transmitters (A and B).

By comparing two other signals, for example, from transmitters B and C, a second phase-difference measurement will give another LOP; the intersection of the two LOPs is the estimate of position, thus:




However, the diagram over-simplifies the situation. A position-fix is obtained, not by drawing intersecting lines on a map, but by drawing intersecting bands, with each band making some allowance for errors and deviations from a theoretical centre line. The result is a quadrilateral where the bands intersect, not a point. A navigator can then construct a circle, its centre at the centre of, and its radius derived from, the



lines which bisect the quadrilateral. The length of that radius will naturally depend upon the width of the bands from which the quadrilateral was originally drawn, and therefore upon the errors and deviations for which allowance has to be made. The accuracy of a navigational system relying on Omega signals is commonly expressed in terms of the circular error probable (CEP). If the circle, constructed in the manner specified above, has a radius of 2000 metres, then a CEP of 2000 metres merely means that in 50% of cases the vessel's true position will be somewhere within that circle. (In 95% of cases it will be, statistically, within 5600 metres of the true position.)

The generally-accepted thesis is that a position can usually be fixed within about 2000 metres of the exact position during the day and within about 4000 metres during the night.[1] The diurnal variation arises because of the day-night changes in the ionosphere, which acts as a spherical mirror about 70 kilometres above the earth during the day and about 90 kilometres during the night.

There are certain times and conditions which will allow position-fixing with CEP errors of less than 2000 metres, but the accuracy of Omega is affected by factors that are both unpredictable and beyond control. With further research and

1 The design specifications of the United States Navy's AN/BRN-7 Omega receiver call for achieving a 'daytime navigational accuracy of 1 nm RMS and night-time accuracy of 2 nm RMS'. Department of the Navy, Operational Evaluation of the AN/BRN-7 Omega Receiver in Submarines (Norfolk, Virginia, 1972), p.4-1.

experience it is possible that greater accuracy will be achieved. However, technical opinion appears to be that inherent system limitations will prevent Omega signals from having a CEP of better than 1000 metres, except occasionally under the most favourable conditions. With our present knowledge and under unfavourable conditions it could well be that inaccuracies of as much as 8-10 kilometres will occasionally occur.

It is possible to fix a position by observing signals from only two transmitters if a vessel carries its own Caesium-beam frequency standard, by comparing the incoming signals with those generated by its own Caesium-standard instead of with other incoming signals. However, Caesium-standards cost about $15,000. They are very complex instruments and may need special facilities for repair. Furthermore, if extreme reliability is required it is desirable to carry more than one standard. While the cost and complexity of fitting a Caesium-standard into some naval vessels is not a major obstacle, it is unlikely that aircraft, submarines or small commercial vessels will be able to use the Omega system unless there are three transmitters in the area. Likewise, other factors generally require signals from three transmitters for undersea use. Accordingly, the absence of a station in the Australian area would be of more significance to commercial aircraft and civilian vessels than to service aircraft and vessels.

In certain areas of the world it may be possible to receive signals from more than three transmitters, and it may be possible to receive signals on more than one frequency from one or more of these stations. If this is possible, the accuracy of position-fixing could be improved. It is not known



to what extent this would be so, partly because the system has been in operation for only a brief time but mainly because the inaccuracy varies from time to time and from place to place.

No evidence has been given to the Committee that hyperbolic Omega signals, transmitted above the surface of the ocean under normal conditions, can give a position-fix that is likely to be more accurate than about 1000 metres (half a nautical mile), even if more than three signals are available at more than three frequencies.

## LIMITATIONS ON ACCURACY AND RELIABILITY

Omega signals enable a navigator to fix his position with sufficient accuracy for most purposes, but not with the pin-point accuracy necessary for some purposes. The navigator who receives Omega signals may on occasions be able to fix his position very precisely, or he may be as much as three or four thousand metres in error from his estimated position. He will not know whether his position-fix is accurate or inaccurate. All he will know is that there is a statistical probability, if his CEP is 2000 metres, that his estimate will be within 2000 metres of the actual position in 50% of cases. Therefore, in any given instance, the navigator will not know whether his position-estimate is very accurate, or inaccurate by 1000, 2000, 3000 or 4000 metres, or even more. These features, i.e., limitations of accuracy and probability, are of course common to all navigational systems.

## Near-zone unreliability

The variation of phase and field strength of the signals is unreliable near the transmitter from which the signals originate. Various estimates of the extent of the 'near-zone' in which the signals are unreliable have been made. Some witnesses have suggested that only those signals received in the area within 350 kilometres of the transmitter are likely to be unreliable (Ev. p.72 and 112). Others have claimed that signals are unreliable as far away from the transmitter as 1000 kilometres (Ev. p.411 and 567). Computerized aircraft and submarine receivers automatically ignore signals from transmitters which are less than 700 kilometres distant; it seems likely that this figure is the best estimate that can be given.

## Natural Limitations

In many parts of the world and because Omega is still in the experimental stage, there is too little experimental information on the effect of predictable (as distinct from the random unpredictable) sky-wave variations to allow accurate estimates of position to be made all over the earth. This is particularly relevant to Australia. In the North Atlantic region there is considerable information on the effect of regular ionospheric changes and this can be taken into account when calculating positions, but it will take many years of monitoring, and studying the data, before sufficient information is available to give a better accuracy for hyperbolic Omega than 2000 metres during the day in the Australian region, even if a better figure is appropriate elsewhere at certain times of the day and at certain seasons.



There are also constant changes in the velocity of propagation of signals, depending on latitude and direction of propagation relative to the earth's magnetic field. With more experience of Omega transmissions in the southern hemisphere the effect of these changes could be built into correction charts or tables, but for some years, and until more observational information is available, the accuracy of the system may be significantly less than in regions which have been carefully studied.

## Reception below the surface of the sea

The penetration of radio signals below the surface of the ocean increases as the frequency of the signals is lowered. Far too little experimentation and observation has been carried out to enable maximum useful signal depth to be estimated reliably but it has been suggested that, under ideal conditions, 10 kHz signals from Omega transmitters may be received at a depth of 10 metres and possibly about 15 metres under the surface of the ocean. However, it is uncertain how reliable the signals are at various depths and under adverse conditions. Most authorities believe that reliability is affected by the state of the surface of the ocean. Submarines can certainly receive Omega signals without surfacing or without floating an antenna on the surface, but it is uncertain how valuable the signals will be under different circumstances (see pp.67-72).

The latest advice available to the Committee concerning sub-surface reception is that the Northrop Corporation has developed an Omega receiver for submarine use with the receiver itself having a CEP of about 600 metres, but to this figure must be added the inaccuracies mentioned above, which cause the larger part of the error in position-fixing.

Occasional Limitations

Other factors are also relevant; accordingly, estimates of accuracy in specific cases may be less reliable than suggested by a normal CEP value. Thus, quotation of a CEP figure as an illustration of accuracy should be taken as referring to normal as distinct from abnormal circumstances.

a) Solar x-rays

The emission of solar x-rays causes considerable variations in long-wave transmission, which greatly affect accurate reception - even to the extent of rendering Omega inoperable for some time. The onset of solar disturbances is usually abrupt (five minutes) and the recovery slow (about two hours) but the onset cannot be forecast and therefore it is impossible to know when Omega signals will be affected. In addition, the rate of recovery after solar disturbances is very variable. The navigator of a ship should recognise such disturbances by a sudden shift in apparent position and accordingly realise that the Omega system is temporarily unreliable.

b) Natural Disturbances

Polar Cap Absorption events, whistler-mode signal interference and electron-precipitation events also occasionally disturb the phase of Omega signals to an unknown and unpredictable extent.

c) Nuclear Explosions

A nuclear explosion in the atmosphere makes it



difficult, perhaps impossible, to receive Omega signals in that vicinity for several hours afterwards. Measurements taken after a nuclear test in 1962 suggest that errors of 12-15 kilometres may be caused in some regions of the world.

SPECIAL USES OF OMEGA

Differential Omega

Differential Omega, one form of which is known as Micro-Omega, is the name given to a short-range navigation system that makes use of local corrections to the information given by the basic hyperbolic Omega system. A fixed monitoring station could receive Omega signals and compare the position given by them with its own known position. This comparison yields correction data which could be broadcast to Omega users in that area, thus allowing them to make more accurate estimates of position than would otherwise be possible.

The necessary equipment is simple and inexpensive. The correction data is broadcast on a medium frequency, not at very low frequency, because it will not be useful until the receiver is within a few hundred miles of the transmitter, thus making VLF transmission unnecessary. Correction information should be broadcast at intervals of less than five minutes to avoid degradation of accuracy.

Differential Omega can give greater accuracy than conventional hyperbolic Omega to users within about 300-400 kilometres. The accuracy varies according to the distance of the receiver from the monitoring station, and also according to whether signals are received during night or day, or sunrise or sunset. The usually-accepted belief is that a Differential Omega transmitter can provide a position that is accurate to within about 250 metres at a range of 20 kilometres at night, or within about 750 metres at a range of 200 kilometres.

Differential Omega may be particularly useful for landfall positioning and coastal navigation. The Bass Strait area and the approaches to Torres Strait are regions where Differential Omega installations could be particularly helpful.

While its use for landfall positioning is considerable its use by submerged vessels is impracticable because, apart from the extra errors produced by ocean waves, medium frequency signals do not penetrate the surface of the sea, and the use of VLF transmitters is not feasible for a large-scale coverage. Its use by warships of other nations is most unlikely (both in the case of surface and sub-surface ships) because Differential Omega is only available within a few hundred miles of the correction transmitter, where restraint of movement and the possibility of detection are both unacceptably high.

## Precision Omega

Precision Omega is the name given to a suggested position-fixing system which would use a combination of satellite observations and Omega signals. Because the observation of satellites gives an extremely accurate position-fix it is possible to correct any error in a position calculated by Omega signals if at the same time the position is ascertained by the



observation of a satellite. By applying this correction to Omega signals received subsequently an accurate position-fix may be maintained for some time. Some estimates suggest that above the sea a position could be fixed within about 300 metres under optimum conditions during daylight hours for up to one hour after obtaining an accurate position by satellite observation if the vessel's position has been affected only by drift, and that the inaccuracy may be about 500 metres after travelling ten knots in an hour.

## Global Rescue Alarm Net

The establishment of a Global Rescue Alarm Net (GRAN) system, using Omega as its basis, is actively being developed. GRAN will be based on the ability to fix the position of a vessel immediately help is needed, without the survivors having to do more than press a switch on a piece of equipment which it is estimated will cost no more than $200 or $300. The proposal is that a life-boat or a life raft will be equipped with a transmitter-receiver which receives signals from Omega stations within range and retransmits the raw data from those signals via a satellite to a ground receiving station. There, a computer will automatically calculate the life-boat's position, and alert the appropriate rescue organisation. This will save lives and considerably reduce the expense of the search-and-rescue operations.

The Inter-Governmental Maritime Consultative Organisation (IMCO) is the United Nations agency dealing with maritime safety and efficiency in navigation. In January 1972, the Sub-Committee on Radiocommunications of the IMCO Maritime

Safety Committee held its ninth session, to which Australia and eighteen other nations sent representatives. At this session the sub-Committee drew up a set of proposals on a future maritime distress system which included the recommendation that as a matter of urgency 'the development and implementation of a satellite based distress system for alerting and position indication such as the Global Rescue Alarm Network (GRAN) be completed.'[1] Consideration of this recommendation, however, has been deferred pending the future development of the Omega system.

## TRANSMITTING STATION

The transmitting antenna may be either a vertical conductor suspended by a horizontal wire strung across a deep valley or fiord or a guyed-mast radiator about 400 metres in height. The guyed-mast type, which is now preferred, supports at its head 16-20 radial wires spaced symmetrically and extending over an area of about 300 hectares, that is, an area with a diameter of about 1850 metres. In addition, in order to reduce power losses in the ground, a radial system of conducting wires forms an underground 'mat' below the antenna system out to a radius of about 450 metres. The ground would be restored after the mat is implanted to make good any environmental damage. For safety and security purposes it would be necessary to install fences around the base of the mast and the guy anchorages. A building of about 20 metres by 15 metres is necessary near the

1 Sub-Committee on Radiocommunications, Report to the Maritime Safety Committee (of IMCO) COM IX/12 (1972), ANNEX II, p.3.



base of the mast to house the antenna coupling equipment, the main part of which is a cylindrical helix coil about 1½ metres in diameter and 10-12 metres in height. Another building of about 20 metres by 25 metres is necessary about 450 metres from the base of the mast to accommodate the transmitters and ancillary equipment, offices and staff amenities. An adjacent building of about 15 metres by 20 metres accommodates the emergency power plant and workshops, and provides general storage space. The total power requirement for the transmitter and all auxiliary purposes, e.g., a stand-by transmitter, cooler, etc., is about 500 kW. This would be supplied from the local grid.

## THE PRODUCTION OF OMEGA RECEIVERS

Omega receivers are being produced by at least 27 firms in at least six different countries. The cost ranges from $3000 for basic receivers to about $40,000 for receivers incorporating small computers which give a direct read-out of position, course to steer and other refinements. It is expected that the cost will be reduced if widespread use of the system causes greater production.

The receivers are freely sold to anyone who enquires. In fact, witnesses spoke of purchasing receivers in the same manner as one might speak of purchasing grocery items: 'Go to AWA, and they will get you one in 6 weeks for $2,500' (Ev. p.652).

Since speed of operation and simplicity are essential in fast-moving aircraft, the use of a receiver which incorporates a small computer is virtually essential. Therefore the receiving equipment in aircraft is more complex and more expensive than the equipment necessary for ships.

## C. LIFE EXPECTANCY OF OMEGA

There was a wide divergence of opinion on the question as to how long an Omega system would be necessary or useful. Witnesses submitted estimates that varied from ten to one hundred years.

A technical working party drawn from various Departments of the Australian Government considered the question of likely life-expectancy in 1969, and concluded that 'the system would be maintainable for at least twenty years' (Ev. p.211). Mr G. Unkles, of the Department of Transport, suggested that Omega would have a useful life 'very likely as long as 50 years' (Ev. p.56). Commodore (now Rear-Admiral) G.J. Willis, of the Department of Defence, thought 'possibly 50 or 60 or even 100 years' (Ev. p.109). Dr J. Crouchley, of the University of Queensland, suggested that 'it might be 20 or 30, maybe more, years' (Ev. p.159). On the other hand, Dr D.R. Hutton, of Monash University, claimed that 'Omega will be outdated in 1980 or thereabouts' (Ev. p.322). Mr A. Langer thought that Omega would 'be usefully operational for no more than fifteen years' (Ev. p.431). Mr D.S. Graham, of the former



Department of Civil Aviation, could foresee a lifetime of 'probably 25 years' (Ev. p.474). Captain K.A. Urry, representing the Australian Chamber of Shipping, expected 'a lifetime in excess of 20 years, possibly to 50 years' (Ev. p.478).

Mr Langer and Dr Hutton, who believed that the life-expectancy of Omega was short, claimed that a satellite navigation system would replace it in the near future.

Some witnesses claimed the reverse - that Omega would replace satellite navigation, and would therefore have a much longer life than is currently anticipated. A paper by F.M. Foley was quoted to suggest that Omega is likely to be more widely used than satellites.[1] Captain S.L. Horscroft, Lecturer in Navigation and Seamanship at Sydney Technical College, stated: 'There is a great debate as to whether satellite navigation will eventually make Omega redundant. I do not think it will. And I would also think that it might be the other way round' (Ev. p.497). Captain Horscroft also suggested that Omega is 'the most likely (navigation) system to survive any rationalisation process' (Ev. p.486). Dr J. Crouchley, of the University of Queensland, wondered whether 'so many satellites will be put up ... if Omega turns out to be as useful as people hope it will be' (Ev. p.159). Others conceded the great accuracy of satellites, but pointed out that the cost of installing satellite receivers would make it impossible for small vessels

1 'Ship Navigation - The Means and the End', a paper presented to the Royal Institute of Navigation, and published in the Journal of Navigation (July 1972), p.305.

to install them. A number of witnesses also forecast that some nations would be most reluctant to rely on satellites that were entirely controlled by another nation. Therefore, it seems most unlikely that a satellite navigation system would cause Omega to be out-moded in the near future.

While it is impossible to predict accurately the life-expectancy of Omega, the Committee is of the opinion that Omega will be a useful navigation aid for the foreseeable future.

## D. THE BENEFITS OF OMEGA

Certain advantages of the Omega navigation aid will be of particular assistance to civilian craft, especially commercial ships, although defence craft will also benefit. The most important of these advantages are:

a) Comparative inexpensiveness

The comparative inexpensiveness of an Omega receiver makes it possible for virtually all ships to use Omega. It is unlikely that small fishing vessels, for example, could afford any other navigation aid of comparable accuracy.

b) Greater safety

Greater safety will be possible in making landfalls and in avoiding hazards, particularly in adverse weather



conditions when navigation aids currently in use may be inoperative. A navigator approaching land requires accurate and continuous position-fixing, which Omega gives, rather than periodic fixes with greater accuracy which a satellite would give, or dependence on more conventional aids which may be affected by weather or other natural phenomena.

c) Reduction in running costs

There will certainly be a reduction in voyage time, estimated to be about 2% (Ev. p.406), with a consequent reduction in the running costs for commercial shipping, including a decrease in fuel consumption and costs. This will be achieved by more accurate course-plotting which will also enable a better prediction of arrival time. This saving will probably be greatest for vessels using dangerous passages such as Torres Strait. In these waters, large vessels need to be able to calculate accurately the time of arrival at the entrance to the Strait in order to take maximum advantage of tidal flow, thus ensuring that they will have the full depth of water. Mr G. Unkles, of the Department of Transport, informed the Committee:

> We have been engaged and are still engaged in considerable studies of the Torres Strait problem. There is a growing amount of traffic going through Torres Strait, which is a hazardous piece of water and in particular is limited as to depth. We have completed a study of the western approach limiting factor which is Gannet Passage. We have completed a study over 12 to 13 months to establish precisely what is the depth of water and what is the behaviour of the bottom of Torres Strait, which was showing a peculiar sand wave phenomenon. We are now about to engage in a full tidal study

> so that we can ... put vessels through, taking maximum advantage of the maximum water. This, of course, will be critical in the time frame. It will therefore be critical to a vessel, let us say, eastbound through Torres Strait. His time of arrival at the gateway will be critical if he is to take advantage of the full depth of water that we can predict for him and thus have his maximum possible draught.
>
> (Ev. p.52)

d) Ability to plan docking arrangements

Further time and cost savings should result from the consequent ability to plan docking and cargo handling arrangements in ports that are becoming increasingly congested. Both the shipping company and the shore-based transport industry will benefit, leading to lower prices for the consumer, and also quicker mobilisation in time of national emergency. It has been suggested that a container ship which was forced to cross the Indian Ocean by dead-reckoning could be 'as much as 100 miles' in error in its position by the time it reaches Australia (Ev. p.60). Thus the navigator's estimated time of arrival could be most inaccurate, with consequent disabilities in all the shore-based industries required to move passengers and cargo to their ultimate destinations. Mr Unkles illustrated this point:

> I would, for example, point to the Indian Ocean passage. Once a container ship rounds the Cape, en route let us say to Fremantle, he will take his departure off the Cape and that could very easily be the last positive position fix he gets until he comes within range of a couple of lighthouses on the western Australian coast because, if the conditions are overcast all the way, he will have no system other than celestial navigation for fixing his position. He will be on dead reckoning, and he could be as much as 100 miles out in his position by the time he finishes his crossing.
>
> (Ev. p.60)



e) The speeding-up of rescue operations

The establishment of a Global Rescue Alarm Net (GRAN) system has been proposed, using Omega as its basis. A Department of Transport officer suggested that $282,000 would have been saved by the use of GRAN in eleven search-and-rescue incidents investigated by that Department (Ev. p.50). The inability to locate the survivors after the foundering of the 'Blythe Star' in 1973 is an example of a tragedy which would have been avoided if GRAN could have been used.

f) Advantages for aircraft

Like inter-continental shipping, long distance, inter-continental and reconnaissance aircraft will gain the advantages of a reduction in running costs and improved safety.

g) Advantages for prospectors

The advantages of accurate position-fixing for prospectors in distant outback areas and at sea could be considerable.

h) International standards for navigation aids

It is desirable that the maritime states of the world designate international standards for navigation aids. IMCO has set up standards for ship construction and ship equipment but not yet for navigation aids. The Omega system is the only immediate prospect for a standard international long-range navigation aids. At present a mariner can be confronted on a voyage which entails trading with, say, three nations with the need to carry three different sets of sophisticated navigation equipment and personnel trained to use them.

i) Weather-routing

Weather-routing will be facilitated, allowing ships to either take advantage of favourable weather patterns or to avoid unfavourable weather.

j) Rendezvous needs

Rendezvous needs (for instance, between the mother vessel and its fishing fleet, or an oil tanker refuelling a ship at sea) will be facilitated by Omega.

Overall, Omega is a considerable improvement on conventional methods of ship navigation; its continuous availability, low cost and world-wide coverage, rather than extreme accuracy, are its most important features, especially for commercial shipping.



A.E. Fiore, of the National Maritime Research Center in New York, quotes from the (U.S.) National Plan for Navigation : 'In the high seas environment the U.S. *commercial* mariner would be satisfied now and for at least 20 years in the future with a position-fix accuracy within 4 n.m. 95% of the time.'[1] There is no doubt Omega will meet this requirement.

## E. THE COST OF AN OMEGA STATION

### COST OF CONSTRUCTION

The cost of constructing an Omega transmitter and the ancillary buildings depends partly on the characteristics of the site. However, an estimate which was accepted by most of the witnesses in 1973 was $8,000,000 - $10,000,000.

As previously stated, Australia and the United States reached a tentative agreement in 1972 that Australia would only be required to meet a comparatively small proportion of the total cost of erecting a transmitter, because many nations would gain an advantage from it. It was tentatively agreed that Australia would provide the land and up to $500,000 towards the cost of construction, of which $200,000 would be set aside to

1 A.E. Fiore, 'Navigation Requirements of the Maritime Community', Proceedings of the National Radio Navigational Symposium 1973 (Institute of Navigation, Los Angeles), p.20.

overcome possible interference to open-wire trunk line telephone systems in the vicinity of the transmitter. The United States agreed to provide the electronic equipment, the component parts for the antenna system, and the cost of construction not covered by the Australian responsibility. Thus, the United States' contribution to the construction cost would be considerable.

The willingness of the United States Government to meet these financial responsibilities will remain in force until 30 June 1976. If an agreement has not been reached by that date the question of the availability of United States funds will have to be re-opened.

COST OF OPERATION

The cost of operating a station in Australia was estimated in 1969 to be about $525,000 per annum. As already noted, in the draft agreement negotiated in 1971 and 1972 the Australian Government agreed to pay half the cost of operating and maintaining the station.

Thus, while the cost of constructing the station would be borne to a large extent by the United States, the actual cost of operating and maintaining the station would be shared equally by Australia and the United States. This is similar to the agreements reached between the United States and most of the other nations hosting Omega stations, although the details vary (Ev. pp.208-209).



CUMULATIVE COST

The Australasian Airline Navigators' Association estimated that the cumulative cost for the entire Omega system would be $120 million by the end of the century, compared with the cost of $1,050 million for the Loran A and C networks (Ev. pp.506-507).

RECOUPING THE COST

The Department of Transport submitted to the Committee details of a cost/benefit study which it had carried out, and concluded that the savings to ships operating in Australian trades which would be affected by the use of Omega would be far greater than the cost. The Department calculated that if the Government appropriated from the industry, by way of charges for the use of the aid, half the benefits, and that if the Australian Government met the full cost of establishing the station, without taking into account the benefit to Australian coasting operations or the benefit to vessels not touching Australia, the cost/benefit ratio would be 2.4 at 7% discount rate and 1.9 at 10% discount rate.

However, it is stated in the tentative agreement negotiated in 1972 that the Government will not be required to meet all the costs (see pp.53-55), and since there would be some benefits to ships in the coasting trade and ships passing close to Australia, it seems possible that the Government would appropriate some benefits from the industry. The real cost/benefit ratio is therefore likely to be much greater than the Department has forecast. It is possible that the Australian Government could charge a user fee for Omega whereas the Government must pay a user fee for Loran A aids. Furthermore the Australasian Airline Navigators' Association has given evidence that there would be a considerable saving for Qantas if Omega was adopted. These benefits would to some extent offset the cost of operating the station.

## F. *THE SITE OF AN AUSTRALIAN STATION*

The desirability or otherwise of building a transmitter in Australia is partly influenced by whether Australia's environs will receive usable signals from at least three stations. Because the usefulness of the signals which are received in some parts of Australia from an Australian transmitter is strongly dependent on the location of the Australian station, the site of the station needs to be considered.

The choice of a site for an Omega transmitter depends on both the requirements of the Omega system and the specific characteristics of the possible sites, e.g., ground electrical conductivity of the possible sites.

### TECHNICAL REQUIREMENTS

Ideally a station should be sited to give optimum cover over the region in which its signals are required. Thus



one should take into account near-zone effects, the geometry of lines of position (LOPs) in the regions of interest, and any propagation effects, including disturbances to propagation.

### Near-Zone Effects

Very close to the transmitter, and possibly up to a radius of 250 kilometres, the so-called ground-wave will dominate and phase values may be expected to be stable and hence useful. From about 250 kilometres to about 700 kilometres there will be a mixture of ground-wave and waves which have been reflected from the ionosphere. Accordingly, phase values may be unstable and markedly dependent on position. Thus, for example, while a shift of about 1500 metres normally causes a phase shift in a single signal of about 5 microseconds there *may* be regions in the near-zone where the phase shift associated with a displacement of 1500 metres is up to ten times the normal value. The phase value in this (250-700 kilometres) region will also be much more susceptible to ionospheric disturbance. The detailed behaviour in this near-zone probably depends on the latitude of the station and the direction of propagation. No detailed comprehensive study has been made (see p.18).

It *may* be possible to use a local monitoring station in some parts of the near-zone to increase accuracy over a limited region - much in the same way as for Differential Omega. However, if the corrections from such a local monitor are used outside the region of applicability they may cause a serious degradation of, rather than an improvement in, accuracy. Any attempt to use such a system would be very much on a trial and error basis.

## The Geometry of Lines of Position

For position determination it is desirable that lines of position produced by one pair of transmitters should cut the lines of position produced by another pair of transmitters at as near a right angle as possible. This is because there is always some uncertainty in a line-of-position - it might possibly better be called a band-of-position in a practical situation - and the region of uncertainty is less when the lines of position cross at right angles than it is for a crossing at other angles.

The shape of a line of position is that of a hyperbola, with the exception that at the centre of the base line, i.e., at the centre of the direct line joining the two transmitters, it is a straight line perpendicular to the base line. Near a transmitter the curvature of the LOPs is marked and behind a transmitter (that is, roughly in the direction of the extension of the base line) the LOPs are not only more widely spaced but also may be nearly parallel, rather than perpendicular, to the base line (see diagram p.13). For this reason station siting which gives 'good' geometry in regions away from the transmitter may give 'bad' geometry, and therefore a corresponding serious decrease in the accuracy of a position-fix, in the vicinity of a transmitter.

## Propagation Effects

Beyond the approximate 700 kilometres radius of the near-zone it is usual to regard the propagation as being of a waveguide type. The propagation will in general be more complex at say 1500 kilometres than at 5000 kilometres due to the



presence of more than one waveguide mode. The complexity also depends on the latitude of the transmitting station, the direction of propagation and the time of day. Propagation is more complex when part of the path is in darkness than when there is full daylight along the entire path. Complexity seems to be the greatest for a signal propagating westwards, particularly from a low latitude station at night.

At a distance of about 10,000 kilometres on the western side of a transmitter it is possible for the signal travelling around the long-path (that is, starting eastwards at the transmitter) to be comparable in strength with the primary signal at some times of the day. Such complex signals may, if repeatable, be usable for navigation purposes, but would probably be more variable and less reliable than simple signals. Again, this short-path/long-path interference is more pronounced for signals travelling at low latitudes than for signals propagating at higher latitudes, and is not likely to be of significance for paths which are roughly north-south.

Disturbances to propagation due to solar x-rays are less pronounced for paths at higher latitudes, whereas Polar Cap Absorption effects are most pronounced above geomagnetic latitude $65^{o}$ and extend down to about geomagnetic latitude $60^{o}$, or lower for severe disturbances.

## SITE REQUIREMENTS

The Omega Project Office, Washington, D.C., U.S.A., has supplied to the Australian Department of Transport some criteria relevant to the selection of a possible transmitter site. Such criteria apply to an ideal site but in practice compromises clearly have to be accepted, e.g., Reunion Island is subject to very strong winds and Norway is subject to snow and ice. Among the more important criteria are:

(a) high conductivity soil;
(b) reasonable proximity to a centre of population;
(c) access to electric power (a load of 600 kVA);
(d) an adequate fresh water supply (35 gallons per minute) for cooling;
(e) reasonable access to roads and power, or the ability to provide these facilities;
(f) a flat open area with no snow and only light winds;
(g) a distance of at least 30 kilometres, but preferably not an excessive distance, from airports and air routes; and
(h) a separation of at least 30 kilometres between transmitter and monitor.

## A BRIEF ASSESSMENT OF SOME AUSTRALIAN SITES

### North-East Australia

Any Omega transmitter which was sited in the Australian region ought to be south of the major shipping and airline routes to Australia, since there is a marked decrease in accuracy behind a transmitter, i.e., on an extension of the line joining two transmitters (see diagram p.13). If a transmitter



was located near Brisbane, for example, there could be considerable error south of Brisbane, i.e., in a region of high traffic density, when using signals from this transmitter. In addition, it is desirable that the site be located as far east in Australia as possible to give the best LOP lattice-geometry for the south-west Pacific. Therefore, a site in the south-eastern part of Australia is required.

### Norfolk Island

Since Norfolk Island is approximately 1500 kilometres from the Australian coast any near-zone effects would become apparent in an ocean area, thus creating fewer problems than if the uncertainty was in a coastal zone. However, Norfolk Island is a small island with probably insufficient distance between the transmitter and the monitor. In addition, modal troubles at night appear to be most pronounced for east-to-west propagation from a transmitter at a low latitude. Accordingly, a low latitude station to the east of Australia, e.g., Norfolk Island, would probably give undesirably complex signals over the east coast of Australia at night.

### The Murray Valley

This area would meet most of the site, as distinct from system, requirements but near-zone effects would affect most of the South Australian, New South Wales and Tasmanian coasts, and all of the Victorian coast. A Differential Omega station (or possibly more than one) for use in restricted regions of Bass Strait would be desirable if an Omega transmitter was built in the Murray Valley. There would proably also be night-time modal effects for signals received in the Great Australian Bight from a transmitter in such a location.

Severe inaccuracies are likely along much of the eastern and south-eastern coasts of Australia from the use of stations in Japan, Reunion Island and the Murray Valley. If Hawaii can also be used (at times of full daylight along the path) accuracy would be acceptable but when Hawaii cannot be used accuracy may be inadequate, especially for aircraft use.

Tasmania

A site in Tasmania has some minor limitations from the point of view of the LOP system geometry, and a site in Tasmania would probably also create near-zone effects along the coast of Victoria and over Bass Strait. However, a site in Tasmania, particularly in the south of Tasmania, would give far better and more reliable coverage for the south east of Australia than a site in the Murray Valley, and would present no logistic disadvantages.

When discussing possible sites for an Australian transmitter, the Department of Transport made it clear that its 'preference is strongly favouring Tasmania' (Ev. p.31), but no field investigations have been carried out in that state to determine the most suitable site. The then Department of Civil Aviation, while expressing a preference for Macquarie Island, added: 'The next best choice would be Southern Tasmania, where the near-field effects would be confined to SE Australia which is well served by existing navigation aids' (Ev. p.457).



Macquarie Island

From a propagation and geometrical point of view a location on Macquarie Island has pronounced advantages. Propagation over Australia would be south to north which is certainly to be preferred to propagation from east to west; near-zone effects would not affect the Australian coast and the region of worst geometry is displaced southwards from normal sea and air routes. The only propagation disadvantage appears to be a greater susceptibility to PCA effects. The frequency of occurrence of PCA events is not well documented; the occurrence rate depends on the path of the 11-year Solar Cycle. Signals from Macquarie Island to Australia should be relatively immune from the effects of PCA events, unlike signals from Argentina. A phase deviation of more than 10 micro-seconds except for the most severe disturbances is unlikely.

There are obvious and very severe logistic problems associated with a transmitter at Macquarie Island, not the least of which are transport and communications. Likewise, the cost of building on Macquarie Island would obviously be greater than on the mainland of Australia; so would the maintenance and staffing costs. However, since Australia's share of construction costs is expected to be limited to $500,000 (see p.53), this may not be a relevant factor.

Strong opposition to building a transmitter on Macquarie Island has been expressed by the Department of Transport because of the difficulty of recruiting and retaining specialist staff, the difficulty of transporting stores and equipment to the island, the possible effect of local climatic conditions, the poor conductivity of the rocky soil, the cost of constructing and maintaining ancillary facilities, e.g., a road system, the impossibility of using air transport for importing heavy construction equipment, the adverse effect on the ecological balance of the island which is a major flora and fauna sanctuary, and the difficulty of supplying sufficient electrical power. The Department, which will be responsible for operating any transmitter that is established, asserted that the difficulties presented by locating a transmitter on Macquarie Island were so great that 'an Australian Omega station is beyond the limits of practicability' if Macquarie Island is the only siting option.[1] In contrast, the then Department of Civil Aviation expressed a preference for Macquarie Island, as mentioned above (Ev. pp.457 and 466).

No examination of Macquarie Island has been made by the Omega Project Office, or (we believe) by any other organisation.

While not wishing to make a firm recommendation on where an Omega station should be located in Australia, it became obvious to the Committee that any station should be located as far south-east in Australia as is feasible.

---

1 Department of Transport, Omega Navigation System: Supplementary Submission No.3 to Parliamentary Joint Committee on Foreign Affairs and Defence (Melbourne, October 1973), p.7.



## SUMMARY

Omega is a navigational system making use of signals in the VLF radio band. Its main advantages are its inexpensiveness, continuous availability and world-wide coverage with moderate accuracy. The accuracy depends on the global position of the receiver, the time of day, and a number of other factors. The use of Omega in special ways over restricted regions may give a greater accuracy.

Advantages available to all nations using Omega are increases in safety and economy. In particular, the Committee is impressed by the possibility of developing a global rescue and alarm system.

The absence of an Omega station in the Tasman Sea area would leave Australia, New Zealand, Antarctica and the surrounding ocean areas without adequate Omega coverage. To be of maximum benefit to Australia, an Australian station should be sited on the east of the continent and as far south as is feasible.

While it is impossible to forecast the useful life of the system the Committee believes that Omega will be a valuable aid to navigation for the foreseeable future.

# II Control and Ownership

The Omega navigation system will be comprised of eight transmitting stations, each of which is under the operational control of the nation on whose territory it is situated, but which collectively function according to a format which has been agreed by each of the host nations.

Therefore, any consideration of the control of the Omega navigation system must take into account not only the method by which each host-country can control the operation of its own transmitter, but also the international agreements which concern the operation of the system as a whole. We examine these two different aspects below:-

## CONTROL OF THE TRANSMITTING STATION

*The Committee is of the unanimous opinion that* any Australian transmitter which is erected should be controlled by the Australian Government. This view was strongly submitted by most witnesses, and in fact the Department of Foreign Affairs made it clear that no other possibility had been contemplated:

> On the question of ownership and control of any installation in Australia, there has never

> been any doubt that the station would be controlled by the Australian Government.
>
> (Ev. p.261)

Control of an Australian transmitter by the Australian Government would be possible because in the Omega system each station is independent of the others; there is no master-slave relationship between individual stations as exists in some other navigational systems. Some witnesses believed that there would be a master-slave relationship between a 'system controller' and the individual transmitters and that the Omega system could therefore be used for whatever purpose the 'controller' wished, without the consent and perhaps even without the knowledge of the various stations. This was the case before 1965 when the experimental Omega transmitters, using quartz crystals, were forced to operate in a master-slave relationship, but such a relationship became unnecessary with the development of the very high precision frequency standards which are now used. There is no such relationship in the Omega system as it is now being implemented, and accordingly Australia could control its own transmitting station.

Each of the Omega stations now operating is controlled by an agency of the host nation. In Japan, for example, the operation of the station is the responsibility of the Electronic Navigation Aids Division of the Maritime Safety Agency; the Norwegian station is staffed by the Norwegian Telecommunications Administration.

An Omega transmitter cannot be used to transmit messages without the knowledge of the operators of that



transmitter, and if an Australian transmitter is controlled by the Australian Government there can be no possibility that the transmitter will be used by any nation as a communications base without the agreement of the Australian Government. This was acknowledged by some witnesses who opposed the erection of a transmitter in Australia. Dr A.P. Roberts, of Monash University, was asked if he could 'see Omega as sending command signals under any specific circumstances?' He replied:

> This possibility in my opinion was completely done away with, when it was finally arrived at that the corrections of synchronisation only needed to be made about once a week or something like that, so this possibility of surreptitious communication in my opinion simply has not been on.
>
> (Ev. p.589)

There is no control of the signal that is emitted, except by the operators of the station and with their knowledge. It is not possible to send even a simple one-letter coded message through a transmitter without the knowledge and co-operation of the local operators. Commodore (now Rear-Admiral) G.J. Willis of the Department of Defence, advised the Committee:

> There is no outside control of the signal that is emitted, and no signal - communications or navigation - can be emitted from that station without the knowledge of the people who are operating the station.
>
> (Ev. p.106)

Similarly, any attempt to 'juggle' the system surreptitiously to provide an advantage for one side during a war, for example, would be impossible. Any change of normal procedures by one or more stations would be immediately obvious to the others who could then either discontinue operating their station, or add their own 'juggling' which would cause the system to break down for all operators - including those who initiated the malpractice.

The fact that any alteration in the format which has been accepted by the host nations can only be made by manual operations, and cannot be made without the knowledge and co-operation of the operators of each individual station, gives each host nation complete responsibility for the signals emitted by its own transmitter.

CONTROL OF THE SYSTEM

It is generally accepted that a directorate, or international policy committee, comprised of representatives of countries where transmitters are situated, will be established to co-ordinate the signals of the transmitters, and regularly notify the officers in charge of the transmitters of any need to adjust the timing of the signals to ensure complete synchronisation. This body will also be responsible for the preparation and printing of charts, and for technical and logistics support for station operators. Advice that synchronisation was needed would be sent through normal communication channels from the directorate to the transmitter; for example: 'Observations indicate your synchronisation one micro-second late'. The



appropriate phase correction could then be made by and monitored at the transmitter, and presumably monitored at other transmitters also. The Committee accepts that notification of this nature would not in any way compromise Australia's control of its transmitter.

It is expected that there will be an Australian member of the directorate, and the Committee recommends that such membership be required by the Australian Government as a condition of Australia's participation in the system.

The Department of Transport recommended to the Committee that 'ultimate "internationalisation" of the system should be an accepted objective in principle' (Ev. p.39). This could best be done by the recognition of Omega as an international standard aid to navigation by the Inter-Governmental Maritime Consultative Organisation (IMCO), the United Nations agency (with 86 member-nations) which deals with maritime technical and safety questions. The Committee endorses the principle recommended by the Department, but stresses that this suggested internationalisation refers to the operation of the system - not to the control of individual stations which should remain entirely subject to the authority of the governments of the host nations.

OWNERSHIP OF AND CONDITIONS FOR ESTABLISHING AN AUSTRALIAN STATION

Witnesses who commented on the matter agreed that the Department of Works (now the Department of Housing and

Construction) should be the constructing authority, that the Department of Transport should be the operating authority, that maximum use be made of Australian resources, and that all operations of the station should be in the hands of Australian employees of the Australian Government. The Committee endorses these views. There has not been any suggestion that these stipulations would be unacceptable to the United States Government, and in fact there are already similar arrangements in some of the other nations.

In 1972 the Governments of the United States and Australia tentatively reached agreement that a transmitter should be built at a site in south-eastern Australia agreed by the two governments, in accordance with technical and design information provided by the United States Government. The text of the proposed agreement is set out below:

DRAFT

EXCHANGE OF NOTES ON THE ESTABLISHMENT OF AN OMEGA NAVIGATION STATION IN AUSTRALIA

Excellency,

I have the honour to refer to recent discussions between representatives of the Government of the United States of America and the Government of the Commonwealth of Australia concerning the establishment in south-eastern Australia of an OMEGA Navigation system capable of being used by any suitably-equipped ship or aircraft, for the purpose of improving the navigational efficiency of mariners and aviators of all nations.

In the light of those discussions I have the honour to propose that an OMEGA Station be established, operated and maintained, as an Australian station, by the Australian



Government acting through the Department of Shipping and Transport and that, to this end, an agreement between our two governments be concluded in the following terms:

1. The Australian Government shall construct an OMEGA Station at a site in south-eastern Australia to be agreed upon by the two governments.

2. The construction of the OMEGA Station shall be in accordance with the technical and design information provided by the United States Government.

3. The Australian Government shall be responsible for the following:

(a) the construction of station facilities and installation of the antenna array and ground system, including supervision, administration and inspection;

(b) adaptation of United States Government facility designs to accommodate local construction materials and methods; and

(c) installation of electronic and related equipment made available by the United States Government and their initial adjustment with the assistance of United States technicians.

4. The Australian Government shall provide the necessary land for the station and an amount not to exceed $A500,000 towards the cost of the work set forth in paragraph 3 (a), (b), and (c) above. The cost of that work will include the costs incurred by the Post Master-General's Department in the form of new works to overcome possible interference with its open-wire trunk line carrier system by the OMEGA Station. The two governments shall consult on those telephone interference mitigation efforts that need be undertaken as a result of the establishment and operation of the station.

5. The Australian Government shall set aside from the total amount it will contribute to the construction of the station $A200,000 as a notional amount to cover the cost of new works to overcome possible interference with its open-wire trunk line carrier system. It shall restore to the main fund the part of the $A200,000 remnant after the full costs of the mitigation works have been defrayed.

6. Costs for the work set forth in paragraphs 3 (a), (b) and (c), and 4 above in excess of the financial limitation of the Australian Government as set forth in paragraph 4 above shall be borne by the United States Government, which shall make periodic advance payments to the Australian Government to cover projected expenditures.

7. The United States Government shall make available without cost to the Australian Government the following United States equipment, materials and services for the construction of the OMEGA Station in Australia.

(a) component parts for one complete antenna array and ground system, construction drawings and antenna erection procedures;

(b) all electronic equipment necessary to transmit OMEGA navigation signals in phase with the worldwide OMEGA system;

(c) normal initial spares for the equipment referred to in (a) and (b) above;

(d) lists of standard test equipment needed, together with all special test sets needed for OMEGA Station operation and maintenance;

(e) five (5) sets of all applicable technical documents related to the foregoing equipment at the time of delivery of the equipment;

(f) construction drawings and specifications of the North Central United States OMEGA Transmitter Station and Monitor Station facilities;

(g) delivery of the foregoing equipment and materials to an Australian port of entry to be agreed upon by the appropriate authorities of the two governments; and

(h) all other technical assistance as may be agreed between the authorities of the two governments to be necessary for the establishment and construction of the station and its facilities.



8. The two governments shall exercise all reasonable endeavours to complete the construction and equipment of the OMEGA Station within two years from the date of entry into force of this Agreement.

9. The two governments shall share equally the cost of operating and maintaining the station.

10. Any payments incurred as a result of legal liability under Australian laws for damage to property or injury to persons arising out of the construction, operation or maintenance of the station shall be regarded as a part of the cost of operation and maintenance.

11. To the extent that participation by the United States Government in the establishment, operation and maintenance of the station is dependent upon funds to be appropriated by the Congress of the United States, it shall be subject to the availability of such funds. If the necessary funds are not appropriated by the Congress of the United States, the Australian Government shall not be bound to carry out its obligations under this Agreement.

12. Title to all equipment made available in accordance with paragraph 7 above shall remain in the United States Government.

13. The United States Government may remove without restriction any equipment no longer required for the operation of the station.

14. The equipment, parts, materials and supplies made available by the United States Government for the OMEGA Station shall be exempt from customs duties and taxes in accordance with Australian laws, regulations and procedures. These exemptions shall extend to equipment and materials brought temporarily into Australia by either government in connection with construction of the station.

15. No equipment and materials brought into Australia for the OMEGA Station may be disposed of in Australia except upon conditions agreed upon by the two governments and in accordance with the laws of Australia.

16. At all stages in the establishment, operation and maintenance of the station the maximum practicable use shall be made of Australian resources.

17. Upon the request of the Australian Government its personnel required for the operation of the station shall be trained by the United States Government without charge to the Australian Government. The Australian Government shall pay the transportation and accommodation and living expenses of such personnel.

18. When construction and equipment of the OMEGA Station is completed:

(a) the two governments shall make final adjustments and arrangements for beginning the regular transmission of signals by the station as a part of the world-wide OMEGA system;

(b) the Australian Government shall use its best endeavours to ensure the continuous operation of the station without interruption in phase with the world-wide OMEGA system.

19. All OMEGA navigation system developmental and evaluation data gathered by the United States authorities shall be made available upon request to the appropriate Australian authorities.

20. The Australian Government shall be granted access to and use of rights and data owned by the United States Government and pertaining to the development or manufacture of OMEGA shipborne and airborne equipment.

21. The Australian Government may participate together with the other countries operating OMEGA Stations in the management of the overall OMEGA system. The United States Government and the Australian Government will use their best endeavours to bring about the establishment of an international body to this end.

22. The appropriate authorities of the two governments may make additional arrangements for the effective implementation of this Agreement.

23. The cooperating agencies for the purpose of this Agreement shall be the Australian Department of Shipping and Transport and the United States Navy.



24. At any time after this Agreement has been in force for a period of ten years either Government may give notice in writing of its intention to terminate the Agreement. The Agreement shall terminate one year after the notice has been received by the other Government.

I have the honour to propose that, if the foregoing is acceptable to the Australian Government, my Note and Your Excellency's reply to that effect shall together constitute an Agreement between our two governments which shall enter into force on the date of Your Excellency's reply.

Annex 1

## UNITED STATES NOTE NO.181
## OF 25 AUGUST 1972

No. 181

The Embassy of the United States of America presents its compliments to the Department of Foreign Affairs and has the honor to refer to the draft Agreement for the establishment and operation of an Omega Navigation Station in Australia attached to the Department's Note 694/7/50 of June 6, 1972. The United States authorities have considered the draft Agreement and have made the following suggested revisions:

Paragraph 6 - Should be reworded to read:

'Costs for the work set forth in paragraphs 3 (A), (B) and (C) and 4 above in excess of the financial limitation of the Australian Government as set forth in paragraph 4 above shall be borne by the United States Government. The balance of the Australian Government's financial contribution after the set-aside referred to in paragraph 5 above will be held in escrow account. The balance of that set-aside remnant will be added to the escrow account after the full costs of the mitigation works referred to in paragraph 5 have been defrayed. Timely payment for all work accomplished under paragraphs 3 (A), (B) and (C), and 4 above will be made by the Australian Government out of the escrow account. The United States Government will promptly reimburse the escrow account on a current basis for actual expenditures so incurred by the Australian Government thereby maintaining an escrow balance until final settlement. If at the time of final settlement, expenditures have been made from the escrow account in an amount equal to or greater than the Australian Government's deposits therein, the remaining balance in that account shall then be transferred to the credit of the United States Government. If, however, at the time of final settlement total expenditures from the escrow account have been in an amount less than the Australian Government's deposits therein, the difference between the amount so expended and the Australian Government's deposits shall be refunded to the Australian Government from the escrow account before the remaining balance of that account is transferred to the credit of the United States Government.'

Paragraph 19 - Should be reworded to read:

'All Omega navigational system developmental and evaluation data owned by either the Australian or United States Governments mutually shall be available to the respective authorities upon request.'

Paragraph 20 - Should be reworded to read:

'The Australian and United States Governments mutually shall be granted access to and use of rights and data pertaining to the development or manufacture of Omega shipborne and airborne equipment owned by the respective Governments.'

Paragraph 23 - Complete by adding word 'Navy' at end.

All of the other changes in the draft Agreement suggested by the Government of Australia are acceptable to the U.S. authorities. If the revisions above are acceptable to the Government of Australia, the Embassy hopes that this Agreement may be concluded soon.

Embassy of the United States of America
Canberra, August 25, 1972



## Additional Conditions

The Committee is of the opinion that the agreement between the United States and Australia to build a transmitter should specify, in addition to the conditions set out above, that:

(a) Omega signals from an Australian station should be used only for navigation, search and rescue operations, and if deemed desirable by the Australian Government for time dissemination, but not for any communications function;

(b) The Australian Government should control the station and will determine what staff should be employed;

(c) Australian-manufactured components, as well as Australian resources, should be used wherever practicable;

(d) The participating countries should be encouraged to accept a commitment to maintain standards of accuracy and reliability through conventions concluded under the auspices of IMCO and ICAO;

(e) Australia should be able to influence policy directly in respect of the operational functions of the system, and therefore must have a representative on the international controlling body (see p.51);

(f) The words 'railway control, signalling and communications systems' should be inserted after the words 'trunkline carrier system' in paragraph 5 of the draft agreement (see p.53);

(g) Paragraph 7 (e) should read 'five (5) sets of all applicable technical documents including detailed and complete circuit diagrams of all equipment to be installed at the transmitting and monitoring stations at the time of delivery of the equipment' (see p.54);

(h) An additional section, 18 (c), should be added specifying that the Australian Government reserves the right to cease transmitting from the Australian Omega station if the Australian Government judges this to be desirable in the national interest (see p.56).

The Committee is adamant that any Omega station must be completely controlled by the Australian Government. The conditions set out above, in the opinion of the Committee, would ensure this.



## SUMMARY

The Committee believes that an Australian station can and must be under the control of the Australian Government, and that such control would ensure that an Australian station would function only in the ways that the Australian Government deems to be desirable.

The Committee believes that pro-tem an international policy committee for overseeing the Omega system (as distinct from the individual stations) should be established and that Australia and all other nations hosting stations must have a representative on the policy committee. However, it is hoped that ultimately the Omega system will be brought under the auspices of the United Nations' Inter-Governmental Maritime Consultative Organisation (IMCO), or some other appropriate international agency.

In a draft agreement, tentatively reached in 1972, Australia's share of the cost of establishing an Omega station was limited to $500,000, and the provision of the required land. In the same agreement it was proposed that Australia would be responsible for half of the station's operating costs.

# III The Relevance to Australia's Defence

INTRODUCTION

Much of the opposition to the proposal to build an Omega transmitter which was expressed to the Committee was based on the belief that the erection of a transmitter in Australia could lead to a nuclear attack on Australia. These witnesses feared that Australia's participation in an Omega system could contribute to the offensive potential of nations operating ballistic missile submarines and that the erection of a transmitter could result in an Australian Omega station being attacked or used as a hostage in the event of a nuclear war.

These witnesses did not accept assurances given by other nations, especially the United States of America, that Omega receivers will not be installed in ballistic missile submarines. They emphasized that Omega signals could be received below the surface of the sea and argued that there was a requirement by ballistic missile submarines for such a navigation aid, particularly for the strategic operations of such submarines.

However, the Committee and most witnesses accepted the assurances that were given, particularly as the technical evidence suggested very strongly that Omega signals could not give ballistic missile submarines the accuracy that they require for position-fixing. The assurances and the technical evidence are examined below.

## ASSURANCES THAT BALLISTIC MISSILE SUBMARINES WILL NOT USE OMEGA

### United States

The United States Government has advised the Australian Government that 'OMEGA receivers will not be installed in United States ballistic missile (FBM) submarines. The Omega system does not possess sufficient accuracy for these ships, nor in fact does it have any uniquely military application' (Ev. p.259). In addition, the United States Department of Defense has stated on several occasions that Omega receivers will not be installed in U.S. ballistic missile submarines.

A similar assurance was given to the New Zealand Government by the United States Ambassador to that country on 9 July 1968, in response to an enquiry by the New Zealand Government (Ev. p.529).

The Australasian Airline Navigators' Association submitted that a similar assurance was given to its officers on 7 September 1973 by Dr M. Polk, Expert Advisor on Navigation and Navigation Policy to the Executive Office of the President; Commander R. May, Executive Head of the Naval Systems Section, and Deputy Chief, Naval Operations Warfare; Commander J. McDonnell, Director, Ocean Surveys Programme; and



Commander J. Richardson, Executive Head, Omega Project Office, Naval Electronics Command (Ev. p.530).

On 17 April 1970 during the U.S. Department of Defense Appropriations hearings the following testimony was given by Rear-Admiral B.H. Andrews, Vice Commander of the U.S. Naval Electronic Systems Command:

> Mr Mahon: How does transit and timation navigation satellite systems fit into this picture? Are we going to provide our surface fleet with both Omega and these navigation satellite systems?
>
> Admiral Andrews: All ships will be equipped with the Omega navigation systems. Selected users including the SSBN's, CVA's, and hydrographic survey ships will also be provided with the transit system ...[1]

This reply by Admiral Andrews has been quoted by many opponents of Omega as an indication that ballistic missile submarines will be fitted with Omega receivers, despite assurances to the contrary. The Committee feels that it is probable (even if a stronger view cannot be taken) that Admiral Andrews' first sentence was answering the specific question he was asked - whether <u>surface</u> ships would be equipped to receive Omega signals - and that after the first sentence of his answer he was no longer talking about Omega.

---

1 United States. House of Representatives, <u>Department of Defense Appropriations for FY 1971</u>. <u>Hearings before a sub-Committee of the Committee on Appropriations</u> Pt.5, p.641.

The submission of the Australasian Airline Navigators' Association supports this view:

> Dr M. Polk, Expert Advisor on Navigation and Navigation Policy to the Executive Office of the President of the United States, in discussion with the Association, explained that until the period when Admiral Andrews answered the question on Omega he, Dr Polk, had given the testimony concerning Omega before Appropriation Committee Hearings.
>
> Dr Polk emphasised that evidence before the same committee in 1970 stating that Omega was not a strategic weapons system should be read in conjunction with Admiral Andrews' testimony. Dr Polk understood the testimony to be saying that all surface ships would be fitted with Omega. The reference to Omega was then complete. The remainder of the testimony simply referred to the transit system stating that not only surface ships will be provided with the Transit but so will other selected users such as SSBN's and CVA's. [1]
>
> (Ev. p.531)

Some submissions to the Committee appeared to confuse Admiral Andrews with Admiral Zumwalt. The latter visited Australia in 1971 and stated at a Press Conference on his arrival on 25 May 1971 that in theory Omega could be used in Polaris submarines but there were no plans to do so.

1 Dr Polk, in fact, gave this evidence on 19 May 1969 before a sub-Committee of the U.S. House of Representatives Committee on Appropriations (See U.S. House of Representatives, Department of Defense Appropriations for FY 1970. Hearings before a sub-Committee of the Committee on Appropriations Pt.3, p.679.)



Thus there are clear assurances that the United States does not intend to fit its ballistic missile submarines with Omega receivers.

Great Britain

The Committee has also received an assurance from the British Ministry of Defence that 'there is no plan to fit Omega in British SSBNs'. [1]

Other Nations

The Committee has not received (or sought) assurances from France or U.S.S.R. that these countries will not fit Omega receivers in their ballistic missile submarines, but the technical evidence is such that the Committee has no reason to believe that the constraints that limit Omega's use by U.S.A. and Britain will not also apply to France, U.S.S.R. and any other nation.

## THE ACCURACY OF OMEGA SIGNALS IS NOT SUFFICIENT FOR BALLISTIC MISSILE SUBMARINES

The opinion that Omega allows accurate position-fixing by submerged vessels appeared to be the strongest factor motivating those who expressed opposition to the proposal to build a

1 Advice received by the Committee from the Australian Department of Foreign Affairs in a letter dated 29 October 1973.

transmitter. However, evidence received by the Committee indicated that there are significant limitations on the accuracy of the signals.

These limitations were discussed in Chapter I Section B of the report. In this section the Committee drew attention to the fact that under normal conditions above the surface of the sea the CEP of an Omega position-fix is about 2000 metres by day and about 4000 metres by night. While under certain favourable conditions a greater accuracy may be expected, under other conditions a less accurate position-fix would result. For instance, within about 700 kilometres of a transmitter the signals received from that transmitter are unreliable; constant changes in the velocity of propagation signals and sky-wave variations decrease general accuracy; and there are occasional limiting factors such as solar x-rays, Polar Cap Absorption events, whistler-mode signal interference and electron-precipitation events which further reduce Omega's reliablity.

In addition to these factors, there are other factors which further increase both the unreliability and the inaccuracy of signals received below the surface of the sea, thus making Omega less useful for submarines than for surface vessels.

## Depth

The depth at which Omega signals can be received influences the extent to which Omega can be used. Most submissions claimed that Omega signals could be used 15 metres below the surface of the sea, but the Committee has not received any



confirmation that signals can be received reliably below 10 metres.

In fact, Mr E.N. Armstrong claimed that the Omega Project Office in Washington, D.C., had discovered by experiment that 10 metres is the maximum depth at which reliable signals can be received, and that if twice the power is used to transmit Omega signals the effective depth would only be increased by one metre (Ev. p.548). In addition, Commander J.D. Richardson, Project Manager of the Omega Navigation System in the United States in 1973, advised the Committee that:

> fifteen feet antenna depth is the typical reception limit experienced ... at the prevailing power levels ... Increasing the power to ten kilowatts ... will theoretically increase reception depth by ten feet. [1]

This figure for reception depth is supported by the United States Navy report <u>Operational Evaluation of the AN/BRN-7 Omega</u> Receiver in Submarines (see footnote p.15).

However, Mr R.J. Cooksey, Lecturer in International Relations at the Australian National University, claimed that 'the importance of Omega is for the patrol activities, while at 1,000 to 2,000 feet, of the ballistic-missile submarines' (Ev. p.668). But any estimate that Omega is useful at an antenna depth greater than 10 metres is certainly in error. Consequently, a submarine would have to have a cable towing an

---

1 Letter to the Committee, 17 December 1973.

antenna floating 1000 to 2000 feet above the submarine. The length, strength and weight of such a cable would be far too great to be practicable. In addition, it would be impossible for a submarine 1000 feet below the surface to ensure that it was maintaining its antenna at a depth of between three and 10 metres below the surface. Accordingly, it is clear that signals could not be received when a submarine was at a depth of 1000 feet.

Surface of Water

All the above estimates are based on an assumption that there is a calm flat surface of water. It is probable that only in conditions of dead calm will there be the same reliability and accuracy of signals below the surface as there is at the surface. Even in moderate seas there is likely to be a significant degradation of position-fixing.

Waves on the surface of the sea cause the head of water above the antenna to vary, and as phase measurements are made at different times on different stations there will be errors introduced by the different heads of water for the different observations. Because the same frequency is never transmitted simultaneously by any two stations, and because no station ever transmits two frequencies simultaneously, there is a minimum time of at least one second between the start of transmission from one station and the transmission of the same frequency by another. By selection of station pairs the time difference may be minimised, but it is still of the order of two seconds. A further problem which arises is caused by the fact that the head of water can change significantly during the one second period of observation, thus either increasing or decreasing slightly the



frequency of the received signal. Consequently, weak signals from distant stations can become unusable; the maximum depth at which the system may be used is reduced; and the effect of atmospheric noise on the signals is increased. While the third consequence may be minimised by use of a computer, the others will remain to affect unfavourably the accuracy that can be achieved by using signals while submerged.

It is not easy to estimate accurately the effect of waves on underwater Omega reception. It is, however, difficult to see how the effect, even using multiple frequencies, can be less than a random error of 500-600 metres CEP in moderate seas. Such an additional error, while not significant if the error at the surface is 2000 metres, would be extremely important in any system which was seeking minimum error. Accordingly, inaccuracy caused by rough weather is a vital factor in estimating the importance of Omega for submarines.

Reliable reception of Omega signals cannot be assured

A basic feature of a deterrent force is the reliability of its operation, as well as its command and control. Limitations of the accuracy of position-fixing using Omega signals have already been outlined. However, the Committee believes that the unreliability and the impossibility of predicting the extent of inaccuracy is even more important than the degree of inaccuracy. As there are occasions when solar eruptions and consequent ionospheric disturbances could render the system completely inoperable, a deterrent force could not rely on Omega as a navigation aid.

It is undeniable that Omega signals can be received by submerged submarines, but the errors in position would be unacceptably large for certain military purposes. Because a Commander-in-Chief could not be aware of all the various relevant circumstances on the other side of the world at any given time it is difficult to believe that he would regard Omega signals as a reliable means whereby his submarines could exactly ascertain their position. In addition, it is possible that one or more host nations would close their transmitter in time of war, or at any other time they believed it desirable to do so. Accordingly, it is most unlikely that submarines guided principally by Omega would be a crucial part of a deterrent force.

## THE GREATER ACCURACY OF OTHER NAVIGATION AIDS

Some of those who claim that Omega signals will be used for aggressive purposes base their argument on acceptance of the theory of 'multiple redundancy' in military systems. This theory, it is asserted, will lead nations to use all possible means of accomplishing their aims, even if some of those means will increase the likelihood of success only marginally. The Committee accepts the validity of the 'multiple redundancy' concept of modern warfare, but the submissions which emphasised this concept failed to emphasise the significant increases in the accuracy of SINS in the last 10 years, the very accurate position-fixing devices such as Loran C and underwater sonar, and that the satellite navigation system will almost certainly be developed in the next decade so that it will provide continuous very accurate position-fixing.



Those submissions which claimed that Omega signals could endanger world peace by allowing submerged ballistic missile submarines to determine their position accurately have failed to evaluate fully the importance and availability of other means of position-fixing which are used by ballistic missile submarines. All of these methods of position-fixing are more accurate and more reliable than Omega. They are therefore more likely to be attractive to those responsible for any nation's offensive or defensive potential, and conversely more abhorrent to those who oppose all offensive activities.

We examine these methods below.

### The Ships Inertial Navigation System (SINS)

The Ships Inertial Navigation System (SINS) is a self-contained dead-reckoning device which provides a continuous indication of position by using sensitive gyroscopes and accelerometers to keep continuous and accurate account of a ship's movement from a known initial position. Devices of this nature may be fitted in any vehicle or craft but the version fitted in a ballistic missile submarine is much more elaborate, accurate and costly than other versions because of the need of such submarines for invulnerability and the associated requirement of minimal exposure at the sea's surface. It is believed that the two or three SINS that are used in each ballistic missile submarine together with the computer that accompanies them cost about $2 million. Periodic position checks are necessary to remove the errors which gradually accumulate, but continuous refinements and improvements to the SINS in submarines over the past decade now enable the navigator to determine his position with great accuracy and with relatively infrequent (perhaps once per day or less often) reference to external aids.

The process of correcting for accumulated errors is referred to as up-dating the SINS. All man-made methods of up-dating the SINS are potentially vulnerable in time of war. (The only navigational method which is completely invulnerable is SINS itself, and even that is probably vulnerable to a nearby explosion). Hence there has been and probably still is every reason to improve the SINS as much and as rapidly as possible, in order to minimise the need for up-dating. The ideal situation, from the point of view of a ballistic missile submarine, is one in which its SINS does not need up-dating at any stage during its spell of duty. It is most unlikely that such a stage has currently been reached, as this would require gyros with error rates of the order of 0.00001$^{o}$/hour. Work has however been in progress for more than 10 years on so-called laser gyros (non-mechanical) which have a theoretical (as distinct from achieved) limiting error rate of less than 0.000001$^{o}$/hour.

A wide range of inertial navigation systems are made with accuracies depending on the purpose and complexity of the system and also on the quality of the components. Thus, for example, a compact aircraft system using gyroscopes with drift rates of about 0.01$^{o}$/hour has an error rate of about one nautical mile per hour and costs about $100,000. A SINS made in the mid-1960s used gyroscopes with a drift rate of around 0.001$^{o}$/hour and had an error rate of one nautical mile per day. Several different laboratory-type gyroscopes with drift rates of the order of 0.0001$^{o}$/hour were described in the scientific and technological literature in the early and mid 1960s. One of



these, the electrostatic gyroscope, is now available in a commercial form. As well as these developments, there have been dramatic improvements in electronic and computer technology in the last decade, and sophistication of electronic control which would have been difficult or impractical in 1960 has become readily available since 1970. For these reasons, the accuracy of SINS is undoubtedly far greater than it was in the early 1960s. Thus it is highly unlikely that the error rate of the present day SINS is greater than 30 metres per hour and indeed it could be only a fraction of this figure.

The United States journal <u>Electronics</u> commented on the latest developments in SINS for use in submarines:

> The Autonetics division of North American Rockwell Corp. is hard at work on inertial navigation systems for the upcoming Trident class of missile-firing submarines. Sea trials of an advanced-development model of an Autonetics inertial unit that uses electrostatic gyros will begin in January or February aboard the USS Compass Island, a Navy test ship. Both Autonetics and Honeywell Inc. in St. Petersburg, Fla., have Navy funds to develop electrostatic gyros and run the sea trials.
>
> An Autonetics source says that, to avoid detection, the new inertial units in the Trident subs will have <u>to be able to run for weeks without any updating</u>. Autonetics also supplied the Ships Inertial Navigation System (SINS), <u>which runs for days without updating, aboard today's Polaris and Poseidon subs</u>. A source says the initial Trident boats could carry either the new inertial units with strapdown electrostatic gyros or an updated version of the SINS for the Polaris/Poseidon boats. Autonetics is updating its SINS units,

which use conventional gimbeled gyros, to be ready for either eventuality.[1] (our underlining)

Loran C

It is incorrect to claim that Omega is unique in providing signals which allow a submerged vessel to calculate its position accurately. Loran C signals give an accuracy within about 150 metres of the true position at a distance of about 2000 kilometres from the transmitting station.[2] These signals can be received while submerged. Both Loran C and Omega can only be received if an antenna connected to the submarine is close to the surface (within about three metres for Loran C; within about 10 metres for Omega). Loran C signals are only available in certain areas of the world, but these areas are the main operational areas for ballistic missile submarines.

Transit Satellite Navigation System

Probably the most precise and most common method of navigation for a ballistic missile submarine is to up-date its SINS at intervals by making use of positions determined from the

1 Electronics 45,26 (18 December, 1972), p.26.

2 A recent paper claims that Loran C has a potential accuracy of 14 metres at a range of 1400 kilometres from the furthest transmitter. (L.F. Fehlner and T.A. McCarthy, 'How to Harvest the Full Potential of Loran-C', Navigation 21,3 (1974) p.223.) Funds for improving the Loran C system installed in ballistic missile submarines were approved several years ago. It is therefore possible that the figure of 150 metres is much too great.



Transit satellite navigation system, which was specifically implemented for the use of United States ballistic missile submarines. SINS can then be used for navigation alone, or with occasional reference to Loran C, until the next satellite fix can be made. The Transit system is of little use to civilian aviation but successful experiments on its use in anti-submarine patrol aircraft, which fly lengthy missions, were conducted in 1969. To determine a position it is necessary for the submarine to expose an aerial about one metre long above the sea, but it is not necessary for the submarine to surface.

Operational use of the Transit system by United States ballistic missile submarines began in 1964, and civilian use became available in 1967. The system is solely under United States control, whereas Omega signals will be controlled by seven nations.

Transit gives extremely accurate position-fixes. All evidence suggests that an accuracy of less than 100 metres is possible, and some witnesses suggest that the accuracy may be within 20 metres. However, there may be an interval of up to two hours between successive observations.

Navstar Global Positioning System

At present a satellite system incorporating some of the features of various other proposed systems (including Timation) is being developed by the U.S. armed forces and Department of Defense. The Navstar Global Positioning System is intended to meet the needs of the U.S. Army, Air Force and Navy and ultimately a small receiver as light as one kilogram may be available for the use of the individual soldier. This system will give continuous position-fixes and also altitude with great accuracy, probably within tens of feet, and will therefore remove the disadvantage that Transit satellite information is not continuously available. A further advantage of this system is that precise knowledge of a vessel's velocity is not required.

The Committee does not accept that Omega signals are necessary to allow ballistic missile submarines to maintain their positions with great accuracy in the intervals between satellite observations. However, even if it was necessary now, it is clear that Omega would not be required for this purpose when the Navstar system is available. This system may be available with a limited capability by 1978, and is expected to be fully operational by 1984.

## Sub-surface position-fixing aids

There are a number of very accurate under-sea position-fixing aids available for submarine use. Several of these, such as sub-loran, deep-ocean transponders and sonar, make use of acoustic waves as distinct from radio aids which utilise electromagnetic waves.

Details of relevant sonar work are classified, but U.S. Congressional hearings make it clear that considerable development work on sonar systems for ballistic missile submarines has taken place in recent years. The United States Department of the Navy requested $38.9 million for the development and testing of the fleet ballistic missile system in FY 1972. This amount



included a request for $11.4 million for fleet ballistic missile system sonars. [1]

One position-fixing system using three acoustic beacons claims positional accuracy of five metres within an area of several square kilometres. Another single-beacon system claims a navigational accuracy of six metres when directly above a beacon, the signals from which can be acquired at a range of eight kilometres. This positional accuracy is more than adequate for up-dating a SINS.

A member of the U.S. Naval Ships Command has indicated the relevance and feasibility of such devices for the navigation of ballistic missile submarines: 'In some of the systems that we used in the early days for Polaris we had transponders that operated for 6 years with lead acid batteries.' [2] Clearly, ballistic missile submarines have been able to use extremely accurate sub-surface position-fixing aids for some years.

## Stellar Observations

In clear weather submarines may fix their positions by stellar observations; this method was probably used for up-dating the less accurate SINS that were available in about 1960. It is known that in 1964 periscopes used on ballistic missile

1 U.S. Senate, Department of Defense Appropriations for FY 1972. Hearings of a sub-Committee of the Committee on Appropriations Pts 3-4, p.907.

2 The Journal of Navigation 27,3 (1974), p.362.

submarines were aligned optically to have an error of less than 0.2 seconds of arc, an extremely small error. On land it is possible to determine a position to within about 16 metres by stellar observation. At sea, using a stable platform, the error is probably about 100 metres.

## In-Course Guidance Systems

The accuracy of ballistic missile strikes is a factor related to the arrival of the missile at the target, rather than its departure from the carrier. If a missile cannot receive external in-course guidance its targeted accuracy at the moment it is launched is vital, but if its course can be corrected after it is launched there is no need for accuracy of position at the moment of launching. Recent experimentation and development of mid-course and terminal guidance systems makes it at least possible that such systems will be available in the near future to ensure the complete targeting accuracy of missiles, even if the position of launch is not accurately known. Radiometric area correlators, which enable missiles to home onto a target even at night and in adverse weather are being developed by the U.S. Air Force's Avionics Laboratory for operational use in 1977. Stellar inertial guidance systems have been used by the Russians for some time, and similar systems are being developed in the United States. Such systems are believed to have a targeting accuracy of about 400 metres CEP.

There seems no doubt that, given the accuracy of position-fixing of the navigation aids discussed above, Omega would be neither necessary nor helpful for ballistic missile submarines. In any case, the development of in-course missile



guidance systems will remove the need for precise position-fixing for these submarines.

## THE DIFFICULTY OF DETECTING SUBMARINES

Most of the witnesses who believed that Omega signals could be used improperly by enabling submarines to determine their position accurately without surfacing claimed that submarines would not be able to avoid detection if they surfaced, and that Transit observations could therefore be made only occasionally or irregularly.

It was alleged on a number of occasions that, because of the risk of detection, ballistic missile submarines cannot afford to float even an antenna on the surface in order to take a satellite fix. Consequently, it was argued that the ability to receive signals while submerged is of crucial importance to ballistic missile submarines and that Omega is therefore essential to their operation. However, evidence given at U.S. Congressional hearings on numerous occasions makes it apparent that the Transit navigation system is already being used by the United States ballistic missile submarines which are thus required to surface from time to time.

However, as several witnesses pointed out, even if a searching aircraft happened to be in the vicinity of a submarine when it floated its aerial on the surface, the possibility of distinguishing the aerial from other surface flotsam in even moderate wave conditions would be most unlikely. The Department of Defence witnesses claimed that the dangers of detection have been greatly exaggerated, even if the submarine surfaced as often as it wished. Both the difficulty of distinguishing an aerial from other flotsam and the immense area of ocean which would need to be kept under surveillance militate against detection.

The ballistic missiles carried by the submarines have a range of up to 4000 kilometres. Accordingly, a ballistic missile submarine with any target in mind would have millions of square miles of ocean in which to conceal itself. It is impossible to keep such an area of ocean under surveillance. The need for a submarine to surface for a very brief period in such a vast area is not likely to place it in a situation of risk.

It was pointed out by Commodore (now Rear-Admiral) G.J. Willis that a submarine's ability to detect vessels or aircraft in its vicinity is greater and faster than the ability of such vessels to detect the submarines.

Q: Would you say that a conservatively operated submarine intent on evasion ... would have no real operational difficulty in taking Transit fixes as frequently as it reasonably needed to?

A: I think none whatever.

(Ev. p.88)

Q: There would be little chance of (an aerial) being detected ...?

A: Even ... if (the aerial) was left exposed continuously, the chances would be remarkably slim ...

Q: It would be quite impracticable to have ... surveillance of a large stretch of ocean.



A: It would be totally impracticable ... This is taking it to the ridiculous.

(Ev. p.103)

If these views are correct, ballistic missile submarines could if necessary surface in order to fix their position by Transit observation (to within about 50 metres of the true position) every few hours and could maintain adequate accuracy by using their SINS in the meantime. However, as indicated above, frequent up-dating of the SINS used by ballistic missile submarines is probably unnecessary.

In time of national emergency, there is the possibility that a large number of 'decoy' aerials could be dropped over various parts of the world's oceans, if it was considered necessary to mislead aircraft searching for submarines, thereby making it virtually impossible to detect the real aerial.

On the evidence, therefore, there appears to be very little risk in a submarine surfacing to observe satellite or other above-surface signals.

## THE USE OF AN AUSTRALIAN TRANSMITTER FOR BALLISTIC MISSILE SUBMARINES

Even if the Omega system was essential to the operations of ballistic missile submarines, the Australian transmitter would not be. No submarine-launched missile attack upon the United States, the Soviet Union or China is possible from any ocean area in which Omega reception would depend upon an Australian transmitter.

Any American submarine missile launch against the Soviet Union or China would have to take place from waters in which a submarine would find transmissions from Japan, Reunion Island, Liberia, the United States or Norway entirely adequate for its Omega reception. Any Soviet launch against the United States would be from waters where, equally, Australian transmissions are not essential.

It was suggested to the Committee that submarines in the northern area of the Indian Ocean would depend on the Australian transmitter if the Liberian and Reunion Island signals could not be received because the Liberian and French authorities decided to close their transmitters. In this event, however, the Australian Government could - if it wished to do so - close its transmitter.

In any case if, say, the United States was planning to use the Omega system for military purposes with the Soviet Union as its principal target, as several witnesses suggested, it would be a simple matter to build transmitters on Guam and Samoa, thus giving an excellent coverage of the Indian and North Pacific Oceans from where its missiles would be launched. No negotiations with foreign nations would be necessary, and yet all suggested U.S. military aims could be achieved.

## THE USE OF OMEGA IN ATTACK SUBMARINES AND SURFACE VESSELS

The United States has since 1966 consistently stated that it does not intend to fit Omega into its ballistic missile



submarines; it has also stated that it does intend to equip its attack submarines and all of its surface vessels capable of independent operation with Omega. For submarine use a multi-frequency receiver incorporating a computer which can also accept inputs from other navigational devices is proposed. Such a receiver (the AN/BRN-7) was tested in a submarine in the latter part of 1971 and was considered to satisfy operational requirements.[1] For use in surface vessels about 500 of the AN/SRN-12 single frequency Omega receivers had been ordered by 1972.[2,3]

Omega signals can be used by surface and sub-surface vessels of all nations. Other navigation aids which are also available for submarines include SINS, Loran A, Loran C, the Transit satellite system, Doppler sonar, optical observations, gyro-compass and electro-magnetic log.

The most recently constructed United States attack submarines are fitted with SINS (although possibly a less accurate version than is fitted in ballistic missile submarines) and use satellite position-fixes for up-dating their SINS, with Loran as a 'back-up' system. Loran A, which has been in

---

1 See footnote p.15

2 Operational Logistics Support Plan for Omega Receiving Set AN/SRN-12 (Naval Electronic Systems Command), Introduction.

3 A 1973 report stated that there were then at least 1000 Omega receivers in non-military vessels, and that the number was increasing rapidly. F. Schneider and J.N. Wilson, 'Civilian Maritime Use of the Omega System: Growing Pains', Proceedings of the Radio Navigational Symposium 1973 (Institute of Navigation, Los Angeles), p.135.

operation for more than 30 years, will be discontinued in the next few years, and Loran C is not available in all parts of the world. Accordingly, the United States is gradually replacing Loran as a 'back-up' aid in its attack submarines with Omega, which will be available virtually world-wide. [1]

Attack submarines may be used in the conventional way against enemy naval and merchant shipping, or for the specific purpose of attempting to 'shadow' and, in the event of hostilities, destroy an enemy ballistic missile submarine. The ballistic missile submarine would launch its missiles against fixed land-based targets, possibly thousands of kilometres away, and thus would need to know its geographic position with extreme accuracy. On the contrary, the attack submarine attempts to deal with local targets which are within sonar, visual or radar range, possibly up to 40 or more kilometres away. Accordingly, it is the position of the attack submarine relative to its target that is of consequence at times of attack, rather than its exact position at sea. Therefore the navigation system of the attack submarine is required only to direct the vessel to its operating area, whereas the navigation system of the ballistic missile submarine must be able to locate the vessel very precisely, i.e., with the accuracy requisite for the launching of its missiles.

Some attack submarines are diesel powered and were built as early as the 1940s; others are nuclear powered and have

1 Current advice is that Omega receivers have been installed in five U.S.N. attack submarines.



been built at various times since the 1950s. Because each submarine's navigation system will depend on the time of commissioning and of subsequent refitting(s) and on the operational function of the submarine, there will be a considerable variation of sophistication of equipment and accuracy of navigation in the vessels of the attack submarine fleet.

The United States Government's statements on the need for Omega receivers to be installed in attack submarines comment on the cost-effectiveness of Omega and on the need to replace Loran receivers with Omega receivers. In addition, two other factors relevant to the mode of operation of attack submarines (but not relevant to the operation of ballistic missile submarines) may have influenced the decision to install Omega receivers in attack submarines. Attack submarines sometimes work in packs and thus each may need to know its position with respect to other submarines in the pack, i.e., like surface vessels, these submarines may on occasions require a high rendezvous navigation accuracy, and may need to maintain accurately separations of a few kilometres from one another. Omega signals can be used above the sea for establishing <u>relative position</u>, i.e., with respect to one another, with an accuracy of about 400 metres (if the vessels are within about 40 kilometres), although this figure may be degraded considerably for under-surface use. The ballistic missile submarines, which operate alone, have no need to establish relative positions and thus no need to use Omega signals for this purpose. Also, attack submarines must be able to operate in more restricted areas than ballistic missile submarines, e.g., in shipping lanes rather than in the vastness of the ocean. Therefore the possibility of an attack submarine being observed if it surfaces, though still remote, is greater than it would be if a ballistic missile submarine surfaced. The ability to receive navigation signals while submerged, i.e., Loran C or Omega signals, could therefore be an advantage to attack submarines.

To summarise: the navigational requirements of an attack submarine are essentially to guide it to its operational area and not to assist in the firing of its weapons; however, the navigation system of the ballistic missile submarine is an integral part of its missile-firing system. A statement that Omega receivers will be used in attack submarines operating in a particular mode does not suggest that Omega will also be used by ballistic missile submarines operating in a completely different mode.

While the above discussion has made specific reference to vessels of the United States Navy because criticism of that country was made to the Committee and because information about the United States navigation systems are known, the same general principles apply to naval vessels of all nations. Omega signals are usable by any country that buys or manufactures Omega receivers. Omega is not restricted in its availability and is of more use to vessels with simpler and thus cheaper navigation aids than it is to those carrying more sophisticated devices.

## THE USE OF OMEGA IN AIRCRAFT

Various papers in technical journals have described the experimental use of Omega in aircraft. It is probable that aircraft will use the same type of multi-frequency receiver



that is proposed for submarines. The use of such a receiver in an aircraft may permit the use of a less accurate inertial navigation system, e.g., with an error-rate of 10 nautical miles per hour instead of one nautical mile per hour, in a so-called hybrid system. This would lead to savings in cost which may be significant in the commercial sector.

It is believed that the United States Government intends to equip 1000 of its military transport planes with Omega receivers, at a cost of about $15,000 each. These are expected to remain in use until Navstar becomes available (see p.77). The advantage of Navstar to aircraft will not only be that it will give extremely accurate position-fixes, but that it will give accurate estimates of altitude.

## THE USE OF OMEGA BY AUSTRALIA'S DEFENCE FORCES

Evidence was given to the Committee that signals from a transmitter in Australia would be used by the Royal Australian Navy and the Royal Australian Air Force.

It is proposed that Omega receivers will be fitted in surface and sub-surface vessels and long-range reconnaissance aircraft. In addition to Omega's use for position-fixing, the Navy and the Air Force could use Omega to establish more accurately the positions of naval and air units relative to one another in maritime operations, including search and rescue operations.

Australian vessels and aircraft would be able to use Omega signals in any part of the world where they were required to operate, but they would obviously 'derive most benefit if there were good Omega coverage in the ocean environs of Australia' (Ev. p.86).

SUMMARY

The Committee accepts assurances that have been received from the United States of America and Great Britain that Omega will not be used in ballistic missile submarines, particularly as these submarines have a number of superior, more accurate and more reliable navigation aids that make Omega irrelevant to their operation. Accordingly, the Committee believes that there is no likelihood of a transmitter in Australia being attacked to prevent it sending Omega signals to ballistic missile submarines.

United States attack submarines, some surface vessels and some military aircraft are being fitted or will be fitted with Omega receivers to assist their navigation needs, which are different from the needs of ballistic missile submarines. The Committee assumes that the navies of many other nations will also equip their attack submarines and surface vessels with Omega receivers.

Signals from an Australian Omega station will be used by the Royal Australian Navy and the Royal Australian Air Force.



# IV The Impact on Australia's Foreign Relations

The effect on Australia's foreign policy and foreign relationships of a decision to build, or not to build, an Omega transmitter in Australia will be determined on the one hand by the response of other nations to any decision we make to build a transmitter here and on the other hand by the effect (if any) on the independence of our foreign policy.

## THE REACTION OF OTHER COUNTRIES

No evidence was presented to the Committee to suggest that the foreign relations of any other countries that have built a transmitter have been adversely affected.

There has also been no evidence of any ill-will towards Australia arising from the proposal that a transmitter should be built. No nation or international organisation has expressed any opposition, directly or indirectly, to the Australian Government because of the possiblity that Australia may build a transmitter. In addition, there appears to have been no adverse effect on international relationships or international policy in other nations where a transmitter has been built.

## Japan

It was suggested to the Committee that there had been opposition expressed in Japan to the building of an Omega transmitter in that country, but Mr W.H. Hartley, who inspected the transmitter in Japan during its construction in 1973, advised the Committee that:

> There has not been a high degree of interest in the subject in Japan.
>
> (Ev. p.632)

As Japan has built its own Omega transmitter, she would surely welcome the construction of a transmitter in Australia which would enable her to make full use of the Omega system.

## New Zealand

There was some controversy in New Zealand when it was suggested that a transmitter might be built in that country, but much of this controversy was based on assumptions with which the Committee has dealt in this report. Evidence was given that the New Zealand Government was willing to erect a transmitter but the United States Government believed that a site in the south-east of Australia would be preferable, and therefore did not seek formal approval to erect a transmitter in New Zealand (see pp.7-9).



## The Indian Ocean Nations

It was suggested to the Committee that countries bordering the Indian Ocean may regard unfavourably a decision by Australia to build an installation here. The Committee cannot forecast what reaction there would be, except to repeat that it does not know of any protest, ill-will or resentment against Australia as a result of the possibility of building a transmitter.

## China

The Department of Foreign Affairs, in response to an enquiry by the Committee, advised that it was not aware of any reaction (either favourable or unfavourable) in China to the Omega system, or to the proposal to construct a transmitter in Australia.

## The U.S.S.R.

It was suggested to the Committee that it is not our opinion of Omega's role or usefulness, but the opinion of other nations such as the Soviet Union, that is significant. It was suggested that Russian authorities may believe that an Omega transmitter in Australia would be designed to help United States submarines aim ballistic missiles at Russian targets, and that therefore the Soviet Union may destroy the Omega transmitter to prevent this, or in retaliation for its use.

The only evidence offered to support the view that an Omega transmitter might be the object of nuclear retaliation was an article published in 1964 in the Soviet publication, International Affairs, in which it is stated:

> Naturally, countries on whose territory the various installations, associated with the use of nuclear-missile weapons in general and submarine missile carriers in particular are being built, would draw nuclear retaliation onto their territory. [1]

However, this quotation refers to 'stations transmitting orders and navigation instructions' to U.S. ballistic missile submarines, and is part of an article which forecasts reprisals against nuclear missile weapons systems, and against support facilities for vehicles capable of launching such weapons. Omega, which was being developed in 1964, is not mentioned in the article. Because an Omega station cannot transmit instructions and because the Committee believes that Omega signals will not be used by ballistic missile submarines, it does not believe that Mr Shvedkov's article is relevant to Omega.

In fact, it was suggested by Dr (now Professor) H. Gelber that an Omega transmitter was not relevant to considerations of nuclear warfare:

> The role of Omega in all this is at best marginal and probably irrelevant. Even assuming that one side wished to strike at the command and control systems of the other,

1 Y. Shvedkov, 'Bases in Pentagon's Strategy', International Affairs 5 (Moscow, 1964), p.60.



> there would be no point in striking at Omega transmitters, since no side relies on them or would have its operational capabilities crippled by their destruction.
>
> (Ev. p.448)

The Committee endorses this opinion - that Omega is not a part of any strategic system of warfare and that Mr Shvedkov's opinion, even if correct in respect of communications bases, *is not relevant to the Omega navigational system.*

'Krasnaya Zvezda', the newspaper of the Defence Ministry of the Soviet Union, published the only adverse comment by the U.S.S.R. about Omega that came to the Committee's attention. In an editorial comment on 4 October 1973 it was alleged that the construction of Omega stations runs counter to the recent trends towards international detente:

> The Pentagon continues the construction of a system of long-range radio-navigation, the so-called 'Omega', designed to provide co-ordinates for American strategic nuclear attack forces-- missile carrying submarines and strategic bombers. At present stations of this system have already been built not only on the continent of the United States and on the Hawaii Islands, but also in Norway and Trinidad. As much as 26 million dollars were spent for the construction of these four stations during the five years between 1967 and 1972 alone. Construction of another station of the system is nearing completion now on Tsushima Island, belonging to Japan, which is expected to be put into operation in the current year. The Americans have not stopped at this and intend to build such stations on the Territory of South America, on islands in the Indian Ocean and in Australia.

> Thus, as is noted in the Foreign Press, the matter concerns the setting up of a Global Navigation System using the territory of a number of countries. The public and peoples of these countries are aware of the fact that this system is meant by far not for peaceful purposes and justly point out that the construction of stations of this system would threaten the security of the countries on whose territories they are planned to be built. Sober appeals for disassociation from these dangerous plans can be heard in many countries today.
>
> The construction of 'Omega' stations runs counter to the international detente taking shape of late and evokes the protests of the peaceloving public. For example, a 'Stop the Omega Committee' was set up in Australia. It enjoys the support of broad sections of the country's public. At the Labor Party conference held last July the question regarding the construction of the 'Omega' station in Australia became a subject of sharp discussions.
>
> The United States has also conducted preliminary talks with the Government of New Zealand regarding the possibility of building an 'Omega' station on the latter's territory. However, according to Foreign Press Reports New Zealand has rejected the American proposals.
>
> The plans of building foreign military installations on other countries' territories in any case contradict the cause of consolidating peace and the security of nations.
>
> (Ev. pp.658-659)

The Committee understands that 'Krasnaya Zvedza' is a paper of some status, and that an editorial in this paper would not be out of step with the Soviet Union's official policy. However, the article's basic premise is that Omega is to be used



'to provide co-ordinates for American strategic nuclear attack forces'. The Committee has already expressed its opinion that Omega is not a part of a strategic system of warfare (see p.84). In any case the fact that signals from an Australian station are not needed by submarines or aircraft within range of U.S.S.R. weakens the force of the Russian argument. In addition, there is no evidence of other comment, which one would expect if there was strong concern in the U.S.S.R.

The Committee emphasizes that the U.S.S.R. is developing its own system of three Omega-type stations. The Committee has also received evidence that the U.S.S.R. has purchased a number of Omega receivers geared to the Omega system of which an Australian station would be part. Therefore it is possible that the U.S.S.R. would wish to see an Australian station built, so that its vessels would be able to receive Omega signals throughout the world.

<u>THE INDEPENDENCE OF OUR FOREIGN POLICY</u>

It was suggested by several witnesses that an Australian decision to build an Omega station here would compromise our wish to be, and to be seen by others as, an independent nation. Some extended this argument to advocating the rejection of the proposal in order to demonstrate that we are independent.

Some witnesses accepted that the proposal would not play a significant role in our foreign policy, but believed that it was undesirable because of its symbolism: 'The Omega proposition should be seen as more psychological than anything else' (Ev. p.611). They claimed that even if the danger to Australia caused by transmitting Omega signals was very slight, or even non-existent, a refusal to build the station would demonstrate that we are an independent nation.

However, the Committee believes that Australia's independence is best demonstrated by making decisions which are based on our own interest, but which also take into account the needs and attitudes of other nations. It is the Committee's view that the establishment of an Omega transmitter on Australian territory would not jeopardize our independence.

<u>Alignment with U.S.A.</u>

Several witnesses regarded the Omega station as a military base controlled or substantially controlled by the United States Government, such as the North West Cape, Pine Gap and Narrungar bases. They argued that the construction of a transmitter here would indicate an undesirable association with United States military policy.

Some examples demonstrating this attitude are quoted below:

> Omega is primarily a military installation for the benefit of the greatly unloved US Navy.
>
> (Mr A. Langer: Ev. p.412)

> The Omega Navigation System would ... tie us even closer to the instantaneous war potential of the United States.
>
> (Mrs P.D. Mitchell: Ev. p.279)



> While more serious and drastic steps should be taken in relation to the alliance with the United States ... the refusal of the OMEGA project would appear a first logical step.
>
> (Mr W.H. Hartley: Ev. p.613)

A leaflet forwarded as part of the submission of the Campaign Against Foreign Military Bases in Australia advocated: 'For an Independent Australia' 'Stop Omega' 'Oppose all U.S. bases'. Another leaflet from the same source bore the heading '$mash U.$. Imperialism' and referred to political prisoners in Vietnam and the bombing of Cambodia, and alleged that '33 U.S. military installations operate on Australian soil and now the U.S. want to build an Omega submarine navigation installation'.

The newspaper of Macquarie University, <u>Arena</u>, published an article in which it stated:

> The bases are also an integral part of the US policy of domination of the world's resources. Just as the US made war on Asia, they can use their Australian bases to wage war on any country that challenges their imperial domination.[1]

However, in contrast Dr (now Professor) H. Gelber said:

> The countries involved in this proposed world-wide Omega network include such countries as

1 <u>Arena</u> 6, 7 (14 June 1973), p.5.

> Japan, Norway and Liberia, which is a member in good standing of the Organisation for African Unity. It may be that all these countries are in some sense beguiled into becoming tools of some military system of whose particular character they are not wholly aware. I find it hard to believe that that is so.
>
> (Ev. p.397)

It is certainly true that Omega was proposed and developed in the United States. However, it is not accurate to describe Omega as a system controlled by the United States. Such a description is misleading in that it suggests an operation in which each of the stations is, or can be, controlled by one nation for any purpose determined by that nation. The proposal is for eight transmitters, controlled by seven different nations, to operate in an agreed mode for mutually-determined purposes.

In fact, Omega has a number of key features which ensure the independence of the host nations. Omega signals may be used by anyone who has a receiver. No patent rights have been sought by the United States to protect the Omega receiver. Technical information concerning Omega is readily available. Many nations, including the Soviet Union, have purchased receivers. The installations are to be situated in seven different countries, some of which are not allies of the United States. The directorate responsible for co-ordinating the signals of the eight transmitters will include representatives of each of these seven nations. Each transmitter is completely controlled by the government of the host nation.



If an Omega station is constructed in Australia, it will not be constructed, controlled, operated or staffed by military personnel. In addition, all operating personnel will be appointed by and responsible to the Australian Government, and all directions will stem from the Australian Government (except insofar as co-ordination of signals will be supervised by a multi-national directorate, on which Australia will be represented). Accordingly, the Committee rejects the suggestions that an Omega station will be a military base, that it will be influenced or controlled by the United States Government, that it is in any way part of a United States military system, and that its construction here will compromise our independence by increasing alignment with the United States.

## INTERNATIONAL CO-OPERATION

Several witnesses suggested that positive advantages in international co-operation would stem from Australia's participation in an Omega system. For instance, there are many reasons for welcoming the prospect of technicians from Omega projects in other nations serving a term of duty at the Australian station and Australian technicians serving in other countries.

Furthermore, Australia's participation would be well regarded by countries engaged in or dependent on international shipping. In particular, it is the opinion of the Department of Foreign Affairs that south-east Asian countries would regard it as an advantage if a station was built. An Omega system will soon cover most of the world; it would handicap ships and aircraft approaching Australia to lose the advantage of a system that is available elsewhere. It is likely that other nations, which would benefit from having an Omega station here, would be disappointed by an Australian decision not to proceed with the proposal; to that extent our foreign relations could suffer.

A decision by the Australian Government not to proceed with building a transmitter in Australia may also be regarded by the other countries participating in the project as an implication that Australia believed these countries were parties to a military project.

The establishment of a complete Omega system would assist international navigation by providing a basis for achieving uniform procedures. Rejection of the proposal may, indeed, make it difficult for Australia to take further part in international co-operative measures on navigation and maritime safety. Consequently, rejection could contradict that aspect of Australian foreign policy which stresses international co-operation.

The IMCO Sub-Committee on Radiocommunications is working towards establishing GRAN, which is based on Omega (see pp.23-24). This sub-Committee includes representatives of the United States (Chairman), the Soviet Union (Vice-Chairman), Australia, 16 other nations, the United Nations and eight specialised agencies and non-government organisations, including the International Confederation of Free Trade Unions (ICFTU). In addition eleven nations including the Soviet Union sent representatives to the international Omega Symposium in Washington, D.C., in November 1971. These two examples show



that there is already considerable international co-operation in discussing matters related to Omega. The Committee hopes that such co-operation will increase, and that Australia will play an active role.

Advice was received from the Department of Foreign Affairs in 1973 that the establishment of an Omega station in Australia would not affect any Australian treaty or arrangement (Ev. p.260). The Department subsequently advised the Committee that the proposal was not contrary to the SALT accords or to any other international agreement or treaty.

Although the Australian station would be entirely controlled by the Australian Government and operated by Australian technicians, the Committee draws attention to the desirability of furthering international co-operation which would be made possible by a decision to build a transmitter here.

# V Conclusions

The Committee now draws together the main conclusions it has reached as a result of considering the submissions and the evidence it has received.

1\. a. The control of an Australian station

It will be possible for the Australian Government to control every aspect of the operation of any Omega station built in Australia, and to ensure that such a station will not be used for communication purposes.

b. The control of the Omega system

The operation of the world-wide Omega system will be controlled by a policy committee (or directorate) comprised of representatives of Australia and the other six host nations. The Committee advocates the eventual transfer of control of the system (but not the station) to an international agency.

2\. The defence aspects

The absence of an Omega station in the Tasman Sea area will leave Australia, New Zealand, Antarctica and the surrounding ocean areas without adequate Omega coverage, thus depriving the Royal Australian Navy and the Royal Australian Air Force of full use of the system.

The Committee accepts the explicit statements that have been made that the United States and the United Kingdom will not install Omega receivers in their ballistic missile submarines.

The following conclusions reached by the Committee support those statements:

(a) There are a number of other navigation aids available and currently used by ballistic missile submarines which individually or in combination provide position-fixes with greater accuracy and reliability than Omega gives.

(b) There is virtually no risk of detection when a ballistic missile submarine surfaces in its normal area of operation - the less frequented areas of the oceans. Therefore, the more accurate navigation aids which require a submarine to expose an antenna above the surface (such as Transit) can be and in fact are being effectively used by ballistic missile submarines; hence Omega is not necessary for the effective operation of these submarines.

(c) In the event of a nuclear war the Omega system, with transmitters in seven different countries and subject to the effects of ionospheric disturbances caused by nuclear explosions as well as natural disturbances, would be too uncertain a navigation aid (from the points of view of reliability, availability and accuracy) for use by vessels requiring precise navigation.

As the purpose of the Omega system is well known, the Committee concludes that there is no likelihood that an Omega



transmitter built in Australia will be attacked because of a belief that its signals assist ballistic missile submarines.

Australia could close down its transmitter in time of war.

Omega signals could be received by the attack submarines of various nations, subject to restrictions of depth and the surface state of the sea, but this would not increase their existing offensive capabilities.

## 3. The foreign affairs implications

There is no evidence of any ill-will from other nations towards Australia arising from the possibility that an Omega transmitter may be built. No nation or international organisation has expressed any opposition, directly or indirectly, to the Australian Government due to the possibility that Australia may build a transmitter. Furthermore, there has been little protest against Omega by the citizens of other countries (including those which are already building a transmitter) to the national governments of those countries.

There is some disquiet in Australia that the building of a local transmitter may have adverse effects, but the Committee hopes that its thorough investigations and the availability of its findings will allay these fears.

The Committee believes that Australia's participation in an Omega system which includes seven nations of diverse interests in six different continents should be regarded as an example of international co-operation appropriate to an independent nation.

Participation in this project should enable us to continue to play a useful role in various United Nations and other international bodies, and should not harm our relations with any other nations. In fact, our participation appears likely to be viewed favourably.

John Wheeldon
Chairman

May 1975



## *Dissenting Report*

In presenting this minority report, we acknowledge the undeniable navigational value of Omega. However, we hold some doubts about its true cost/benefit and relative effectiveness to commercial shipping and, in particular, we believe that the Committee's Report implies excessive enthusiasm for the establishment of an Omega station in Australia.

DEFENCE IMPLICATIONS

It is unfortunate that many of the opponents of Omega have over-stated their case, which has only served to weaken any genuine arguments against it. To portray Omega as being in the same category as the United States communication base at North West Cape is not correct.

The evidence presented to the Committee does show that the Omega system is not vital to nuclear ballistic missile submarines, though this does not necessarily mean that it may not be of some value as a back-up system to other navigational aids, now or in the future.

However, the evidence shows that Omega is an important navigational aid to hunter-killer submarines, surface naval vessels and military aircraft.

Thus, Omega necessarily has defence implications because of its value to vessels which are designed for, and could be involved in, hostile acts. A judgement must then be made as to whether it is any more justifiable to say that Omega could be used for hostile acts than it is to ascribe a similar usefulness to lighthouses or the stars.

It is unrealistic to make the simple assertion, as the Committee's Report does, that Australia could close down its transmitter in time of war. In the event of a nuclear war, the armed forces of other countries could have made use of an Australian Omega station for military purposes without the knowledge or control of the Australian Government, even before a decision could be made to close down the transmitter.

Because of these military implications, it cannot be assumed that Omega stations would not be military targets.

FOREIGN AFFAIRS IMPLICATIONS

It would seem that some countries, particularly the United States, would be pleased if an Omega transmitter were to be established in Australia. However, the attitude of other countries which may take a contrary view, must be taken into account. For example, the official Soviet publication, Red Star, has claimed that an Omega installation would be part of a world-



wide United States military system.

It follows from this that, even though the Soviet Union may be mistaken in this view, the fact has to be recognised that rightly or wrongly it does hold this view. Therefore, in the event of a conflict between the Soviet Union and the United States, we have no guarantee that Australia would not be in some danger of attack by the Soviet Union because of the presence of an Omega station.

OWNERSHIP AND CONTROL

If a decision is made to proceed with the establishment of an Omega station in Australia, we strongly believe that internationalisation of the system must be a prerequisite, rather than, as the Report advocates, a desirable future objective. Sponsorship of Omega by one nation is not judged to be a satisfactory situation.

Ownership and control of an Australian station must always reside with the Australian Government, but internationalisation of sponsorship and of co-ordination of the system would overcome to a large degree reservations about the attitude of other countries to the system and to Australia's being part of it. If Omega is primarily of use to civilian navigation and without any effect on the offensive capability of any military vessels which would use it, then there can be no objection to internationalisation as a prerequisite. It would have the added advantage of allaying some of the other suspicions which may be held by individuals and other nations.

In proposing internationalisation, we do not express firm views about detail. Under international sponsorship, day-to-day operation and co-ordination of the system would be controlled by a committee of representatives of all host nations, with each retaining ownership and ultimate control of its own station. We believe that, not only should plans to establish such a committee be a condition of Australian participation, but that the existence of the committee should be a prerequisite or, at least, co-incidental with commencement of construction of any Australian transmitter.

To achieve international sponsorship, Omega could be established as a system under the auspices of the United Nations. This would presumably involve a multilateral agreement, rather than the bilateral one between Australia and the United States which has been proposed in the Committee's Report. The implications of such a change may include a different funding arrangement. However, if Omega is a truly international system, there is no reason why the United States should bear the major cost of its construction and half the operating cost. Financing of an Australian station in an international system could be by Australia itself as a major maritime nation, by the U.N.O., or by a system of contributions from all those nations -- or private shipping companies, for that matter -- which it is claimed will benefit from Omega.

SITING

There is another aspect of an Australian Omega station which we wish to raise, and that is its siting. It appears that,



if the proposed Omega transmitter for this region is sited in Australia, there will be a reduction in the benefit to Australian shipping, both international and coastal. The near-zone effect means that a station some distance from Australia would be of greater benefit to Australia. An island well to the south of Australia or New Zealand would be almost the only suitable place from this point of view but would present so many disadvantages and contrary arguments when the other factors are taken into account as to make it impossible. Any site in Australia diminishes the value of Omega as a navigational aid to ships approaching the eastern Australian coast or engaging in the coastal trade. Tasmania as a site would rule out reliability in the whole Bass Strait area; the Murray Valley as a site would also rule out reliability as far north as Brisbane. This raises doubts as to the value of Omega to commercial shipping in eastern Australian waters.

| | |
|---|---|
| Senator G.D. McIntosh | Mr J. Coates, M.P. |
| Senator C.G. Primmer | Mr J.S. Dawkins, M.P. |
| Senator the Hon. J.M. Wheeldon | Mr K.L. Fry, M.P. |
| | Mr M.W. Oldmeadow, M.P. |

# Appendix I Witnesses

The following witnesses made submissions and also appeared before the Committee:

| | Date of Appearance | Hansard Page Reference |
|---|---|---|
| ARMSTRONG, Mr E.N., appearing for the Australasian Airline Navigators' Association | 16/10/73 | 498 |
| BELL, Mr J.A., appearing for the Australian Quaker Peace Committee | 25/9/73 | 275, 283, 322 |
| BROGAN, Mr B.W., Secretary, Victorian Stop-Omega Committee and Senior Lecturer in Economics, Monash University | 25/9/73 | 275, 287, 322 |
| COOKSEY, Mr R.J., Lecturer in International Relations, Australian National University | 6/11/73 | 654 |
| CROUCHLEY, Dr J., Senior Lecturer in Physics, University of Queensland | 18/9/73 | 125 |
| FLOOD, Mr P.J., appearing for the Department of Foreign Affairs | 18/9/73 | 183 |
| GELBER, Dr H., Reader in Politics, Monash University | 9/10/73 | 392, 440 |
| GRAHAM, Mr D.S., appearing for the Department of Civil Aviation | 16/10/73 | 453 |

| | Date of Appearance | Hansard Page Reference |
|---|---|---|
| HARTLEY, Mr W.H., appearing for the Victorian Trade Union Anti-Vietnam and Conscription Committee | 23/10/73 | 609 |
| HOLMES, Mrs M., appearing for the Women's International League for Peace and Freedom | 9/10/73 | 387, 438 |
| HORSCROFT, Captain S.L., Lecturer in Navigation and Seamanship, Sydney Technical College | 16/10/73 | 482 |
| HUTTON, Dr D.R., Senior Lecturer in Science Education (Physics), Monash University | 25/9/73 | 300, 322 |
| JONES, Mr D.G., appearing for the Australian Quaker Peace Committee | 25/9/73 | 275, 283, 322 |
| KEAYS, Dr R.H., appearing for the Australia Party | 25/9/73 | 300, 322 |
| LANGER, Mr A., appearing for the Stop Omega Campaign Research Groups | 9/10/73 | 359, 410 |
| LAW, Mr F.M., Editor 'Sea Spray' | 23/10/73 | 636 |
| MATHAMS, Mr R.H., appearing for the Department of Defence | 11/9/73 | 82 |
| MITCHELL, Mrs P.D., appearing for the Moorabbin Peace Action Committee and the Congress for International Co-operation and Disarmament | 25/9/73 | 275, 278, 287, 322 |
| O'KEEFFE, Mr H.B., appearing for the Department of Civil Aviation | 16/10/73 | 453 |
| ROBERTS, Dr A.P., Senior Lecturer in Physics, Monash University | 23/10/73 | 555 |
| STROHFELDT, Mr M., appearing for the Department of Transport | 28/8/73 | 2 |



| | Date of Appearance | Hansard Page Reference |
|---|---|---|
| SUTER, Mr K., appearing for the Stop Omega Committee in Sydney | 9/10/73 | 379, 434 |
| UNKLES, Mr G., appearing for the Department of Transport | 28/8/73 | 2 |
| URRY, Captain K.A., appearing for the Australian Chamber of Shipping | 16/10/73 | 474 |
| WALKER, Mr P.A., appearing for the Department of Foreign Affairs | 18/9/73 | 183 |
| WILLIS, Commodore G.J., appearing for the Department of Defence | 11/9/73 | 82 |

## *Appendix II Written Submissions*

In addition to the witnesses who gave evidence before the Committee, the following organisations and academics gave the Committee written submissions:

AMALGAMATED ENGINEERING UNION (Innisfail Branch)

AMALGAMATED WIRELESS (AUSTRALASIA) LIMITED

ANDERSON, Mr R., Instructor on Communications, Electronics and Electronic Navigational Systems, Royal Melbourne Institute of Technology

AUSTRALIAN FISHING INDUSTRY COUNCIL

AUSTRALIAN LABOR PARTY (Bragg Sub-Branch)

AUSTRALIAN LABOR PARTY (East Glenelg Sub-Branch)

AUSTRALIAN LABOR PARTY (Mitcham Sub-Branch)

BARRETT, Mr H.D.

BENDIX INTERNATIONAL

BERTRAND RUSSELL PEACE FOUNDATION (Queensland Branch)

BRIGGS, Dr B.H., Reader in Physics, and other Members of the Staff of the Physics Department of the University of Adelaide

BURNS, Prof. A.L., Research School of Sciences, Australian National University

BURTON, Mr. N.

CAMPAIGN AGAINST FOREIGN MILITARY BASES IN AUSTRALIA (Mr A. Langer) of Mount Waverley (Vic.), Norwood (South Australia) and Monash University

CARN, Mr T.L.

CHAPMAN, Mrs E.G.

CHRISTIANSEN, Prof. W.N., Professor of Electrical Engineering, University of Sydney

COUNCIL OF AUSTRALIAN HUMANIST SOCIETIES

CROMPTON, Captain K.C.

DARLING, Mrs J.L.

DENILIQUIN OMEGA INVESTIGATION COMMITTEE

FINNERTY, Mr K.

FLAHERTY, Captain C.I.

GALVIN, Mr P.

GARDNER, Mr G.D., Senior Lecturer of Applied Physics Department, Ballarat Institute of Advanced Education

GENTLE, Mrs E.

GRAF, The Rev. J.

GREBLE, Mr E.StJ.

HORN, Mr J.

JONES, Mrs C.

KING, Mrs J.

KLASS, Mr P.J., Editor, Aviation Week

QUEENSLAND PEACE COMMITTEE FOR INTERNATIONAL COOPERATION AND DISARMAMENT

RAMSDEN, Mr B.



REBER, Mr B.

RESIDENTS OF COHUNA SHIRE

RIVERINA STOP OMEGA COMMITTEE

STURT, Captain P.

SYDNEY UNIVERSITY ASSOCIATION FOR INTERNATIONAL CO-OPERATION AND DISARMAMENT

THE AUSTRALIAN INSTITUTE OF NAVIGATION

THE AUSTRALIAN NATIONAL LINE

THE COMPANY OF MASTER MARINERS

TRADE UNION VIETNAM COMMITTEE

UNION OF AUSTRALIAN WOMEN

WHITAKER, Mr J.P., Triad Reports Correspondence