PN-AAH-532

THE FEASIBILITY OF SURVEILLANCE AND MONITORING OF FISHING VESSELS WITHIN THE DECLARED FISHING ZONE OF PAPUA NEW GUINEA

Prepared For

Reimbursable Aid Programs
Office of Reimbursable Development Programs
U. S. Agency for International Development
Washington, D.C.

January 1980

Resources Development Associates, P.O. Box 239, Los Altos, CA 94022
(415) 961-7477

ACKNOWLEDGEMENTS

This study has been prepared by Resources Development Associates for the United States Agency for International Development and the Government of Papua New Guinea under Indefinite Quantity Contract No. AID/SOD/PDC-C-0025, Work Order No. 2. Mr. Robert W. Campbell, Project Manager, directed the project and was responsible for the analyses of satellite systems and remote sensing data. Mr. Keith W. Cox, Senior Fisheries Scientist, provided guidance and input on the fisheries and fishing industry of Papua New Guinea. Mr. Kenneth B. Craib, RDA Director of Operations, was responsible for the analyses of airborne sensor systems and alternative maritime surveillance aircraft. Mr. Charles D. Matthias, PDC/RDP, served as technical monitor for USAID/Washington.

The project could not have been completed without the interest and assistance of several key persons and offices, both in the United States and in Papua New Guinea. These people include Mr. Peter T. Wilson (Director, Fisheries Division, PNG) and his staff, various agencies and ministries within the PNG Government including the Defence Force, The Flying Unit, and the Surveillance Committee.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

1.0 EXECUTIVE SUMMARY

On March 30, 1978, the Independent State of Papua New Guinea issued the Offshore Seas Proclamation 1978. This proclamation put into effect certain features of the National Seas Act 1977 defining the "offshore seas" of the State. In essence, this proclamation declared waters within 200 miles of the State to be under the control of the State with regard to certain matters, among them, fishing. The offshore seas became synonymous with the Declared Fishing Zone (DFZ) of PNG. The State declared its rights to control all fishing activity within this zone and to defend these rights by force, if necessary. Figure 1 shows the boundary of the offshore seas (Declared Fishing Zone) of PNG.

The Fisheries Division of the Ministry of Primary Industry is charged with the responsibility for regulating fishing activity within this zone, and, with the assistance of the Defence Force, for enforcing its regulations. The Fisheries Division has enacted a licensing procedure by which fishing vessels, both domestic and foreign, may purchase a license to fish these waters. The cost of this license is based on a percentage of the value of fish that a vessel of a particular type and size should be able to catch.

The waters within Papua New Guinea's DFZ are some of the richest in the world, and boats from several nations fish here with a variety of gear. In addition to vessels legally licensed, a large number of unlicensed foreign vessels fish these water for tuna, prawns, clams and other fish and shellfish. Estimates of the number of such illegal vessels vary widely. A reasonable estimate is 150 vessels per year. This level of uncontrolled fishing activity creates a substantial direct loss of revenue to Papua New Guinea.

In response to a request from the Fisheries Division of the Government of Papua New Guinea, the United States Agency for International Development initiated a project to determine the feasibility of various techniques for surveillance and monitoring of high seas fishing vessels in the DFZ of Papua New Guinea.

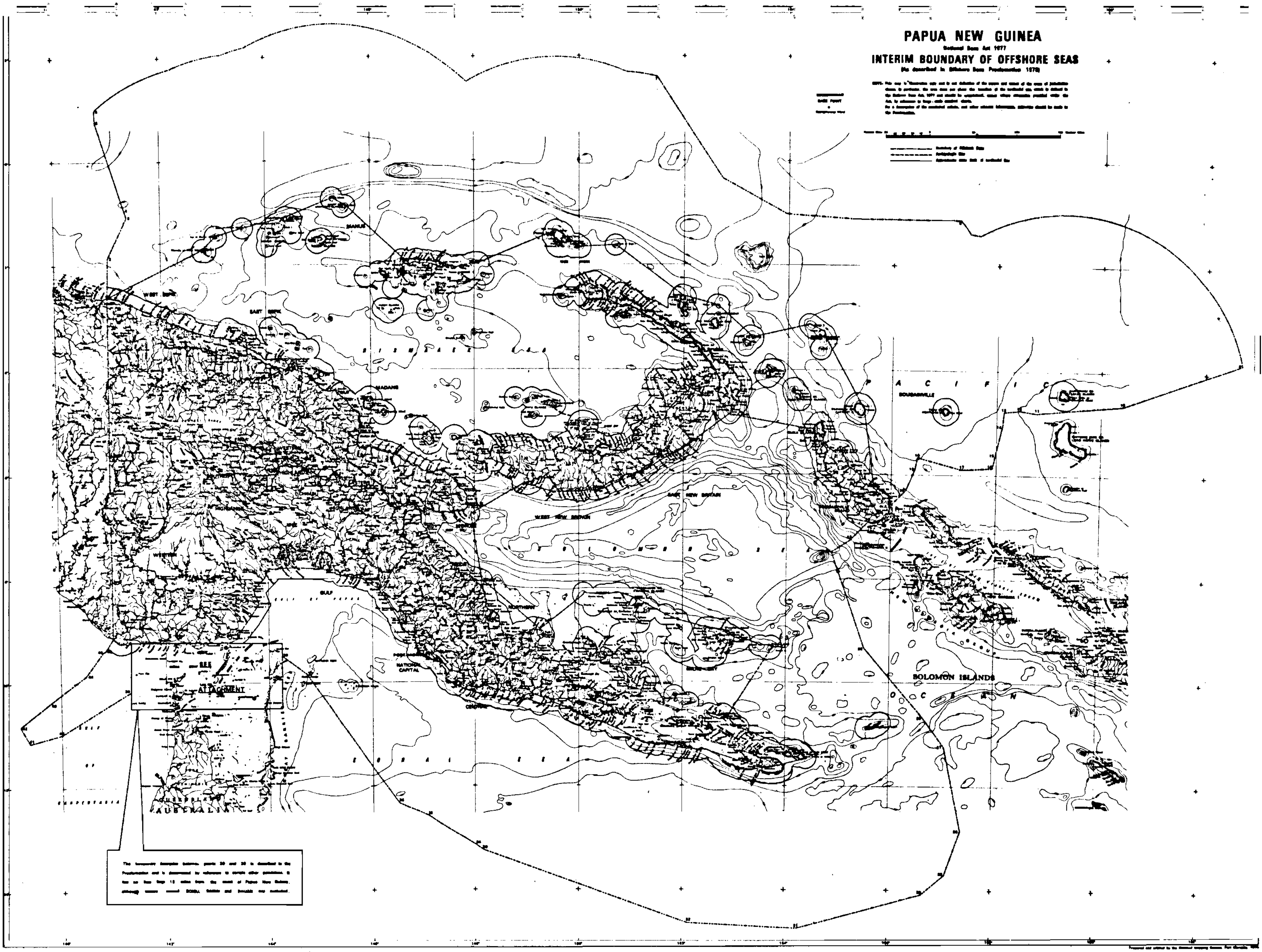


Figure 1: PAPUA NEW GUINEA INTERIM BOUNDARY OF OFFSHORE SEAS

BEST AVAILABLE COPY

BEST AVAILABLE COPY

Resources Development Associates (RDA) was chosen to perform the study.

The RDA project team consisted of Mr. Robert W. Campbell, a specialist in satellite technology and resource development, Mr. Keith W. Cox, a specialist in fisheries development and fishing technology, and Mr. Kenneth B. Craib, a specialist in remote sensing and resource economics. Prior to traveling to PNG, the team collected data on the state-of-the-art of reconnaissance technology. The team then traveled to PNG where several extensive briefings were held for PNG officials. Information regarding PNG capabilities and requirements was compiled and reviewed. After leaving PNG, the team visited New Caledonia to consult with the South Pacific Commission regarding its views on a regional approach to surveillance and monitoring of high seas fishing activity.

This study has concluded that an operational system employing a combination of satellite and aircraft reconnaissance technology is both possible and practical for surveillance and monitoring of fishing activity within the 200-mile Declared Fishing Zone of Papua New Guinea. Such a system could also provide urgently needed data regarding growth and movement of the basic fish stocks throughout the western Pacific region. The total acquisition cost for this system, including a suitably-modified special purpose aircraft, is estimated at less than U.S. $4 million. As outlined in this report, an operational plan should be developed and a "pilot" project implemented.

Papua New Guinea's declaration of the DFZ increased its jurisdiction by an estimated 750,000 square miles. Several well-established pelagic fisheries operate within this area; e.g., the Japanese purse seine, longline, and long-distance pole-and-line fisheries, small Taiwanese longliners, as well as the PNG-based pole-and-line fishery.

In 1978, 308 Japanese fishing vessels were granted licenses. Of these, 11 were purse seiners, 274 longliners, and 23 long-range pole-and-line vessels. One U.S. purse seiner applied for and was granted a license. Also, an unknown number of (unlicensed) Taiwanese boats operated in the DFZ. Estimated catches for purse seiners and longliners were 3,500 and 9,000 tons respectively. Japanese pole-and-line vessels did not fish the DFZ and estimates for the Taiwanese catch are unavailable. Foreign tuna vessels based in PNG harvested nearly 50,000 tons of skipjack in 1978, but PNG received only a small percentage of the full value of this catch.

About 1,400 species of fish are found in Papua New Guinea waters, approximately 5,000 species of molluscs and about the same number of crustaceans. However, no more than 100 of these species of fish, molluscs and crustaceans are caught in any quantity. Skipjack and yellow fin tuna are the main species caught in PNG waters.

While the full extent of the tuna stocks in the western Pacific has yet to be properly assessed, experts agree that the western Pacific has the largest tuna fisheries resource in the world. Forty-five percent of the world tuna harvest is taken from this area, twice as much as is taken from the eastern Pacific, and four times as much as is taken from the Atlantic. Within PNG's 200 mile fisheries zone, as much as 100,000 tons of tuna has been harvested in a year's time. In the United States' tuna market, this raw tonnage has a value of U.S. $100 million; fully processed as canned tuna, its value would come to some U.S. $250 million.

The occurrence of poor tuna fishing years may put a restraint on the expansion of the PNG tuna fleet. The year 1978 was an exceptionally good one for skipjack catches world-wide resulting in depressed prices and, consequently, a financially poor year for the fishing companies. This presented a major problem for PNG at the time as it appeared to be not whether its fleet should expand and improve its total catches, but whether it was economically possible to do so. Worldwide demand for tuna has doubled during the past ten years and the current accelerated demand indicates this trend will continue. The available stocks of the eastern Pacific and Atlantic are, for the most part, being fully utilized; therefore, the increased world demand for tuna will cause a continuing upward movement in fish prices. Distant water fishing nations and large tuna processing companies are looking to the undeveloped, rich fishing areas in the western Pacific as a new source of tuna to meet the world's growing demand for tuna.

Papua New Guinea is now working toward the development of a cost-effective surveillance and enforcement system. The costs and problems of detecting and apprehending vessels in such a large area are indeed formidable. With the assistance of the United States, Papua New Guinea is examining the feasibility of establishing a combined satellite and aircraft surveillance system in the southwestern Pacific, developing an effective enforcement capability, improving fisheries data collection and research, and increasing the coordination between national and provincial fisheries agencies. The Government will have total control over fishery resources, but will encourage participation and cooperation of the provincial governments.

The Fisheries Division of the Ministry of Primary Industry is charged with enforcement of the fishing laws. It is assisted in both surveillance and enforcement by the military arm of the Government, the Papua New Guinea Defence Force. The Fisheries Division maintains its own seaborne capability. Its fleet consists of two vessels, a confiscated Japanese longliner, "Der Yang", and a 45-foot double decker. The Papua New Guinea Defence Force operates a fleet of five armed patrol boats and three Nomad patrol aircraft.

The operational surveillance task facing the PNG Fisheries Department is first one of detecting fishing vessels scattered among other ships over an extremely large area, second, of unambiguously identifying these vessels and separating licensed from unlicensed ships, third, of precisely locating their geographic position, and fourth, if warranted, directing and assisting surface vessels to intercept illegal traffic.

The presently existing PNG capability to accomplish this task is marginal at best. Over the past seven years, approximately 30 vessels have been caught and fined for illegal fishing, for an average of slightly more than four per year. Most of these have been small vessels.

Surveillance systems may be tailored to suit a wide variety of purposes and applications. Design of an appropriate and effective surveillance system requires definition of specific detection and monitoring parameters and restrictions placed on the system.

A detection system must be capable of not only detecting fishing vessels but also of differentiating them from other likely targets in the area, such as merchant vessels. The system must provide accurate location of the target. Required accuracy of the system can be on the order of a few nautical miles. A frequency of location of four hours would seem reasonable if it could be achieved. This would prevent deep incursions into the waters and severely limit fishing time for shallow incursions.

The total number of vessels which the system can handle; i.e., system capacity, must be flexible enough to provide for location of up to 1,000 vessels. The surveillance system must have a capability to provide information in real time or close to real time.

It is highly desirable that certain types of peripheral data be gathered concomitant with the identification and location of the vessel. This data might include: daily catch by species, water temperature, pH, salinity, total dissolved solids, total organic carbon, atmospheric pressure, or other parameters.

The total surveillance system must be capable of detecting and monitoring the location of cooperative and non-cooperative targets. A cooperative target is a vessel, presumably licensed and acting within the law, which will cooperate with the surveillance system. Such cooperation might require, as a condition of licensing, the installation of an electronic device which would aid the surveillance system in tracking the vessel. A non-cooperative target is one which might intentionally intrude into PNG waters unknown to any authorities and which might take definite efforts to do so surreptitiously.

The detection, surveillance, and monitoring system requires that the position of a vessel must be determined remotely. There are at least five feasible methods by which one may do so. They include photographic and imaging methods, radio determination methods with a data relay, remote radio determination methods, doppler shift satellite methods with a data relay, and remote doppler shift satellite methods. All will allow a remote observer to monitor the movement of a vessel. Each has its advantages and disadvantages from the standpoint of effectiveness and cost.

The applicability of various techniques falling into each of these categories has been evaluated. Table 1 summarizes this evaluation.

Alternative Techniques	Capability to Identify Vessel	Capability to Locate Vessel	Frequency of Location	System Capacity	Surveil-lance Rate	Real-Time Data	Peripheral (Oceanographic) Data Gathering Capability	Cooperation Required	Capital Cost* Range of Total System
Visual (from aircraft)	Yes	Yes	Dependent on # of aircraft (infre-quent)	Unlim-ited	Low	Yes	No	No	High**
Aerial Photography	Yes	Yes			Low	No	Yes	No	High**
Aerial Imaging	Yes	Yes			Low	Yes	Yes	No	High**
Satellite Imaging	No	No	N/A	N/A	Medium	Pos-sible	Yes	No	Very low - very high
OMEGA with Data Relay	Yes	Yes	As often as desired	Unlim-ited	High	Yes	Yes	Yes	Medium
Passive RF Direction Finders	Possible	Yes	As often as desired	Unlim-ited	High	Yes	No	Vessel must be actively transmitting	Medium - High**
Surface Search Radar	No	Yes	As often as desired	Unlim-ited	High	Yes	No	No	Medium - High**
Imaging Radar	No	Yes	Dependent on # of aircraft	Unlim-ited	Medium	No	Limited	No	High**
TRANSIT with data Relay	Yes	Yes	As often as desired	Unlim-ited	High	Yes	Yes	Yes	Medium
TIROS-N ARGOS	Yes	Yes	4 Hours	400 vessels	High	Yes	Yes	Yes	Low

* Low = < $500,000
Medium = $500,000 - $2,000,000
High = > $2,000,000

** Including cost of surveillance aircraft

Table 1: SUMMARY CHART

The ARGOS Data Collection System of TIROS-N appears to be the most appropriate system for monitoring the location of <u>cooperative</u> vessels from both technical and cost standpoints. The only drawbacks to implementation of this system are the present uncertainties regarding permission to use the system and the possible limitations of system capacity should it be implemented on a regional (multi-nation) basis. The latter drawback can probably be overcome with ingenious modifications to the operation of the system and to the design of the transmitters. Accordingly, we recommend that the Government of Papua New Guinea proceed with appropriate actions to secure permission to use the system. Should these efforts fail, it may be necessary to fall back to the second recommended system for cooperative targets, the TRANSIT/OMEGA system.

Implementation of the ARGOS DCS will require each cooperating vessel to install a government-supplied Platform Transmitter Terminal (PTT). In addition, the government must install and operate a satellite receiving station for the ARGOS data. It is estimated that a single receiving station will provide more than sufficient coverage for all of the waters of PNG's DFZ. Figure 2 illustrates expected range of the system.

A wide variety of environmental sensors may be interfaced with the PTT. Several types of sensors are commonly provided as accessories with the PTT's manufactured in the U.S. They include sea surface temperature, air temperature, barometric pressure, and internal battery voltage. These and other parameters may provide information valuable to the fishery management community. Other parameters may include pH, salinity, dissolved oxygen, and total organic carbon. Ideally, any sensor installed with the PTT should be automated such that no manual operation or calibration is required.

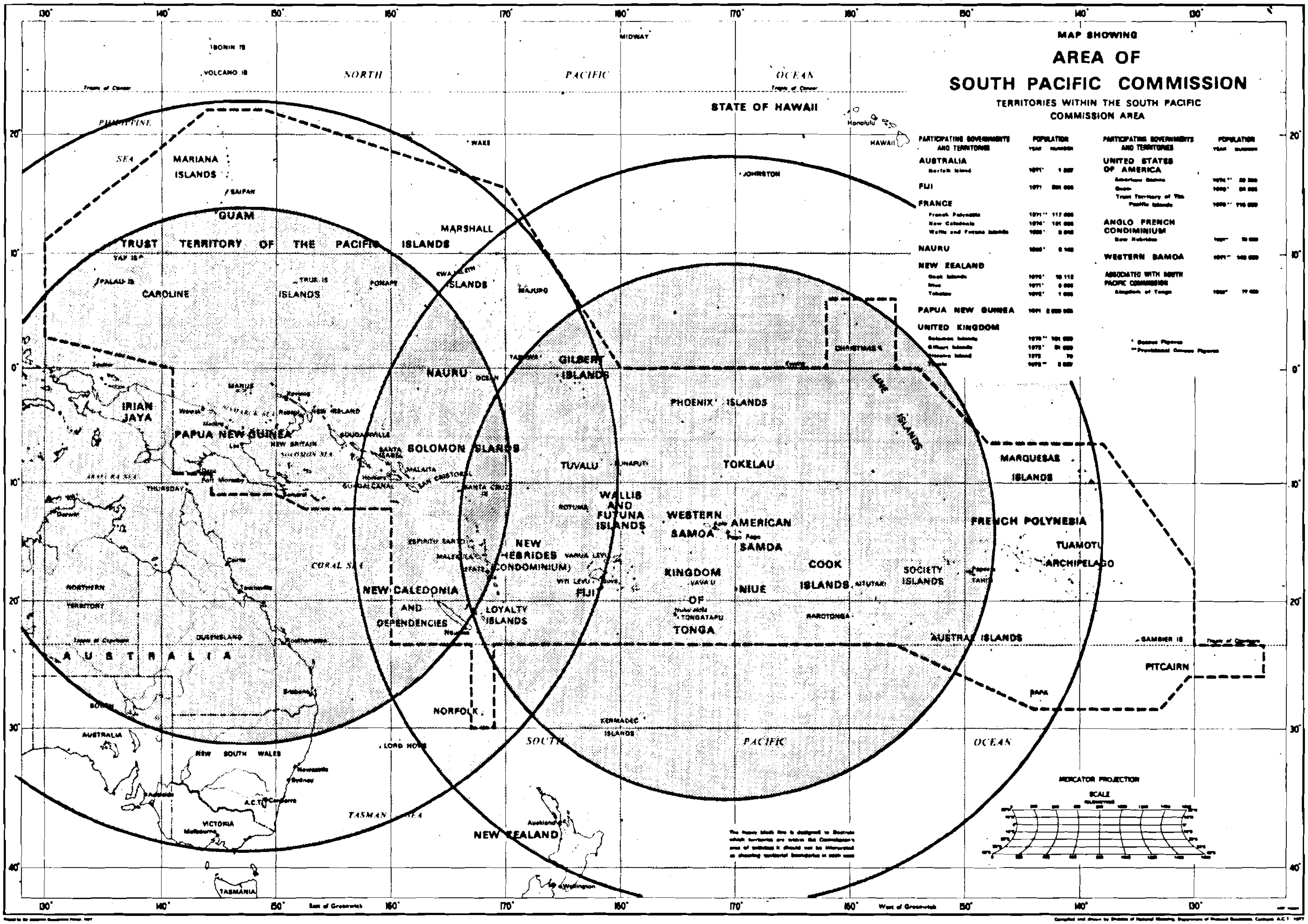


Figure 2: EXPECTED RANGE OF ARGOS SYSTEM

BEST AVAILABLE COPY

Certain types of data must be manually input. Catch data is one such type. Digital thumbwheel switches can be installed on the exterior of the PTT container. These switches can be used to input tons of fish caught, number of fish caught, schools chummed, schools fished, buckets of bait, sea condition, number of baskets, number of hooks, and species of fish (by code).

The ARGOS system will provide a continuous monitoring of all cooperative vessels. Approximately seven times per day, it will update locations of all vessels and will relay oceanographic data from each. This system will thus effectively monitor all cooperative fishing activity in the DFZ and may be expanded to provide regional coverage of much of the South Pacific.

Surveillance of non-cooperative targets will require an airborne capability. A dedicated aircraft should be outfitted with special surveillance sensors and used, in conjunction with the reaction capabilities of the Defence Force patrol boats, to detect and apprehend violators of PNG's waters.

Two primary surveillance systems are recommended for the PNG program - sea surveillance radar, and an electronic intelligence (ELINT) detection system. These units are both compatible and complementary. Although the systems themselves would appear to represent advanced technology, they have been well-tested for years in other applications and are available as "off-the-shelf" hardware.

Certain airborne surface search radar systems have been specifically designed and optimized for maritime surveillance and detection of small targets in high sea states. These systems in general feature higher output power, a physically larger antenna and narrower beam width than found in weather radar systems, multiple pulse widths and PRF rates to maximize resolution at short, medium, and long ranges, and various electronic techniques to decrease sea return clutter and enhance the signal-to-noise ratio, thus improving target detectability. These systems are normally mounted in a radome or pod carried below the aircraft and scan through a full 360 degrees.

Two such sea surveillance radar systems presently available are the Litton AN/APS-504(V)-2 and the AIL (Cutler-Hammer) AN/APS-128. Performance of these systems is similar in many respects and choice between them, or others, should be based on the particular program requirements.

Since the radar horizon or area of possible electronic surveillance increases with altitude, the search aircraft should operate at as high an altitude as possible, consistent with target detectability. As reflected in Table 2, detection range for the smaller 20 square meter targets decreases markedly above about 2,000 feet altitude, whereas most of the larger targets can be seen as well or better at 10,000 feet. This would indicate that two separate types of surveillance missions might be appropriate - a high altitude regional sweep for the larger and more economically important targets, and a low altitude patrol over selected areas against the less "expensive" but more locally destructive illegal "clam boats".

ELINT systems, passive receivers listening for transmissions from vessel radar systems, have several unique advantages over radar for maritime surveillance. The principal advantage is target detection range. Effective range for any radar system is primarily limited by 1) the line-of-sight horizon and 2) the strength of the return signal, or radar echo. Thus, typical radar systems on fishing vessels or maritime patrol boats will have a maximum range of 30 to 50 nautical miles, limited by the height of the antenna above the sea surface, while sea surveillance radar carried on aircraft will have a maximum range of 50 to 100 miles for various targets, limited by the strength of the radar return. ELINT reception is limited mainly by the line-of-sight horizon. Radar transmitters of the type commonly found on commercial fishing and marine vessels can be detected

Radar Target Area (m^2)	Aircraft Altitude (ft)			
	1,000	2,000	5,000	10,000
20	30 nm	30 nm	10 nm	10 nm
150	40 nm	50 nm	60 nm	55 nm
300	40 nm	55 nm	70 nm	70 nm
1000	40 nm	55 nm	85 nm	95 nm

Table 2: RADAR DETECTION RANGE (nm) UNDER SS2 CONDITIONS

and tracked at ranges of 200 to 300 nautical miles from moderate altitudes, or at up to ten times the effective range of radar.

With the combination of advanced sea surveillance radar and ELINT systems recommended here, search aircraft can operate efficiently in the 10,000 to 25,000 foot altitude range. At an altitude of 10,000 feet, the radar coverage area increases to 31,400 square nm, or more than 140 times that possible at 3,000 feet. When combined with ELINT capability, the instantaneous area coverge increases to 196,350 square nm, nearly 900 times the standard radar coverage at low altitude. This increased efficiency means that 100% of the DFZ can now be covered in less than one-third the time otherwise required to cover only 40% of the area. A typical pattern is presented in Figure 3. If the operational altitude is increased to 25,000 feet, then, as shown in Figure 4, 70% of the total DFZ might be covered in a single flight of approximately eight hours.

The principal requirements for aircraft selected for non-military maritime surveillance activities are (in order of importance): range or endurance on station, payload, speed and altitude capability. Ease of maintenance, repair, commonality of equipment and availability of support services are other factors that together with systems' cost will define the specific aircraft or combinations of aircraft that offer the most cost-effective soluion to any nation's maritime surveillance problem.

There are several relatively small turboprop aircraft available whose size, performance and price would seem to make them viable candidates for the sea surveillance role. Six of

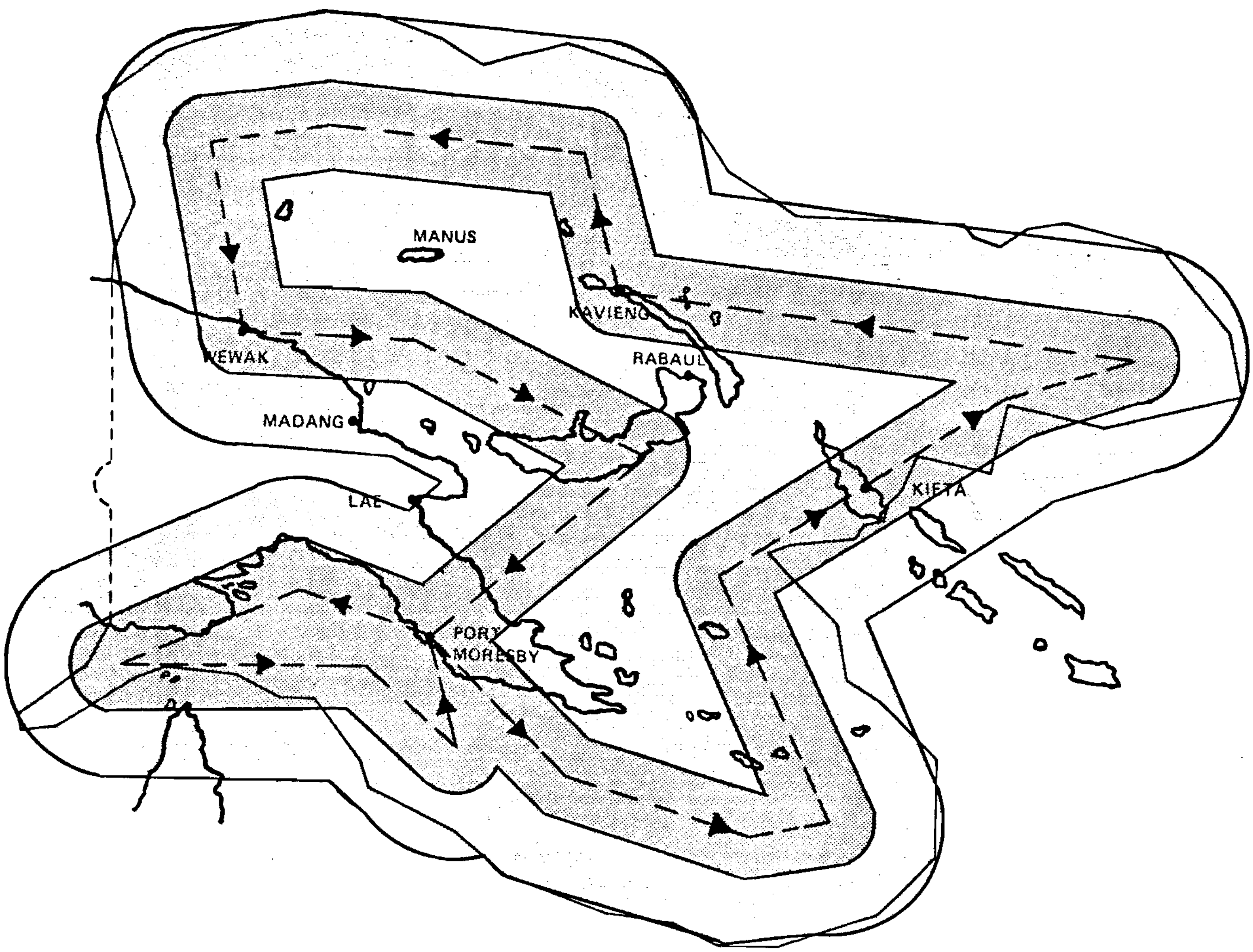


Figure 3: SEARCH PATTERN AND AREA COVERAGE
(150 m^2 target; 10,000 foot altitude; 24 search hours)

RADAR

ELINT

100% of the DFZ

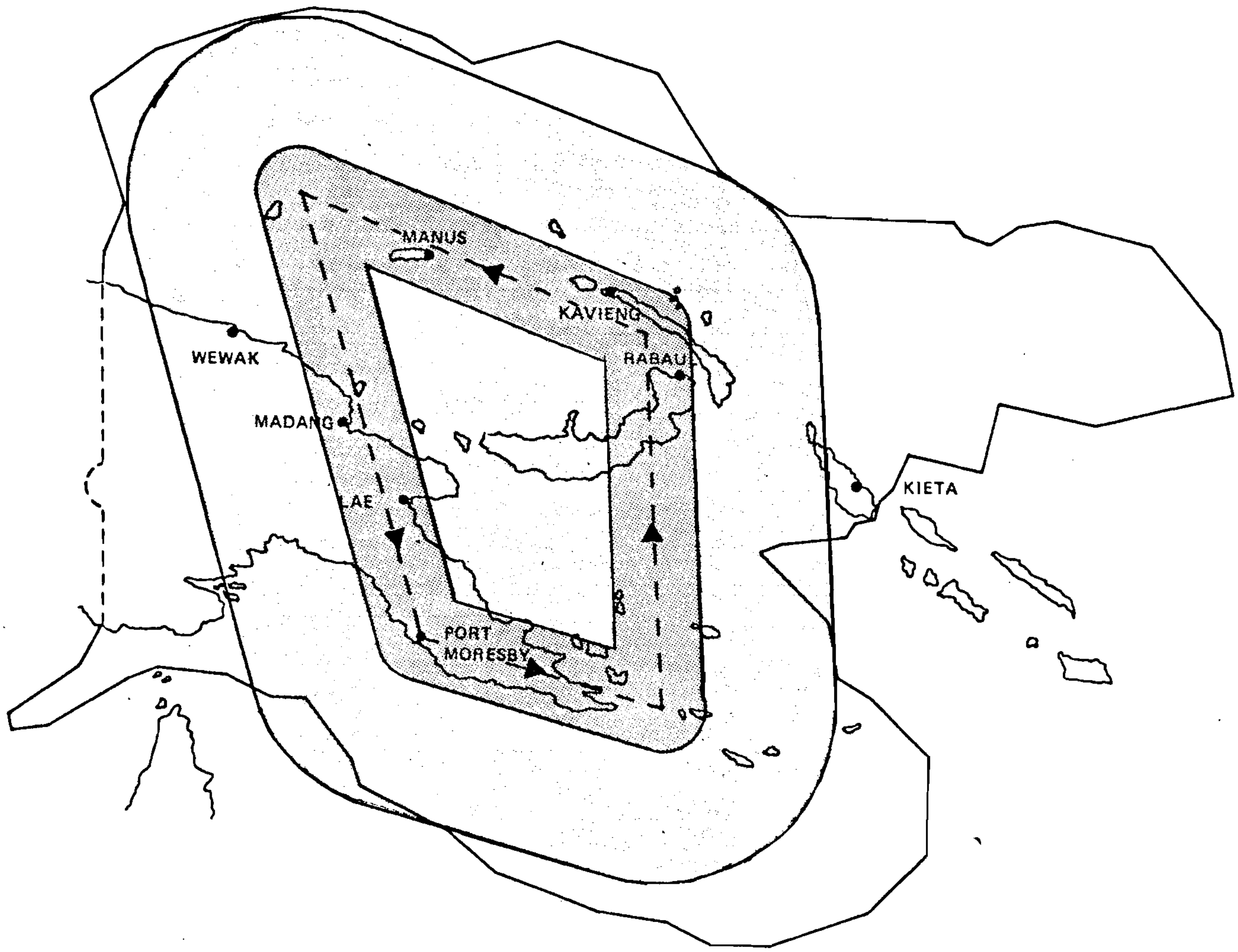


Figure 4: MAXIMUM RANGE SINGLE FLIGHT COVERAGE
(150 m^2 target; 25,000 feet altitude; 8.2 search hours)

RADAR

ELINT

70% of the DFZ

these, together with two jet aircraft included for comparison purposes have been evaluated. They include the Westwind I, the Citation I, the Merlin IVA, the Super King Air, the Marquise, the Conquest, the Turbo Commander 690B, and the Cheyenne II.

Beech and Cessna would appear to be the leading contenders for the maritime surveillance aircraft role, as both have built and modified such aircraft. The Rockwell Commander and Mitsubishi Marquise should definitely be examined in more detail, if only because of their high-wing design. Final selection between these aircraft should be delayed pending decision regarding the specific surveillance systems to be carried, power requirements, number of crew stations and similar considerations.

The Nomad 22B presently operated by the PNG Defence Force is not recommended for the primary sea surveillance role. With extra fuel tanks installed, the aircraft does not have sufficient remaining payload capacity to accomodate the recommended surveillance systems, operators, observers, air conditioning, and similar equipment. This does not, however, mean that the present Nomad 22B fleet should not be used in sea surveillance mission support. The aircraft could play a very useful role in low altitude sweeps against targets such as the illegal "clam boats", which do not carry radar and are difficult to detect from high altitude. Similarly, if a vessel seen to be illegally fishing within the DFZ moves beyond the 200-mile limit before intercept, the doctrine of "hot pursuit" will only hold if the vessel has been followed and kept under constant observation by the surveillance aircraft. Under these conditions, multiple aircraft may be required to maintain a rotating watch on the vessel until it can be intercepted and boarded.

This feasiblity study has concluded that surveillance of Papua New Guinea's Declared Fishing Zone using advanced technology is both possible and practical within present system constraints and budget limitations. Potential advantages of such surveillance include protection of the country's national interest, more efficient enforcement of national laws, more effective management of the country's fishery resources, increased revenues from licensing agreements, and expansion of the scientific data base.

Various techniques are applicable to the surveillance problem. Cooperative vessels may be monitored with use of the TIROS-N ARGOS Data Collection System. An alternative to this technique is the TRANSIT/OMEGA navigation system with a SSB digitial data relay. Detection and surveillance of non-cooperative vessels will require an airborne capability. A dedicated maritime surveillance aircraft with surface search radar and an ELINT capability is recommended.

Maintenance of a reaction or enforcement force is a necessity if the overall system is to work. Detection alone will not suffice. There must be a capability to pursue and capture offenders. The surveillance system will assist in logical and efficient deployment of the reaction forces and will guide these forces to specific offenders.

The technology recommended herein is of proven off-the-shelf design. However, considerable specific design will be necessary to properly tailor the available hardware to the application. This is true for all aspects of the system, including the PTT's, the oceanographic sensor interfaces, the receiving station, the airborne sensor selection and interface, and aircraft modifications. An operational design study should be completed prior to any hardware purchase. This study should provide detailed operational specifications for all systems. These specifications could be directly input to future purchase documents or requests for bids.

Rather than proceeding directly to a full-scale surveillance system monitoring location of all fishing vessels in PNG's waters, it is recommended that PNG proceed first with a Pilot

Project on a smaller scale. This Pilot Project could outfit perhaps 30 vessels with PTT's, establish the recommended reference transmitters, and instrument some rafts. The Pilot system should then be operated for perhaps one year to iron out any operational difficulties which may arise. After that time, the system would become fully operational.

In addition to assisting the Government of PNG in protecting its natural resources, the proposed system will also directly benefit the cooperative fishing industry and foreign vessels operating in PNG waters. At present, PNG and other nations in the western Pacific establish license fees based on the amount of fish a particular vessel "should" be able to catch. These fees are paid whether a vessel catches fish or not. The new system proposed here would allow PNG to do away with this license fee entirely, and instead calculate a fee based on actual catch. Thus, vessels would be free to enter PNG waters and fish at any time with no economic risk to themselves. If nothing was caught, there would be no fee. This system could easily be expanded to include the waters of other nations in the western Pacific. If this were done, fishermen of any nation would be free to follow the schools, paying only for what they actually take.

Second, regional data collected by the system such as water temperature and the location and movement of fish could be made available to cooperative vessels. This would directly assist in effectively locating fish and decrease unproductive time spent in search operations.

Finally, inclusion of an emergency locator switch in the PTT unit will assist in any search and rescue operation. Safety at sea is always a prime concern. This feature should enhance that safety.

2.0 INTRODUCTION AND BACKGROUND

On March 30, 1978, the Independent State of Papua New Guinea issued the Offshore Seas Proclamation 1978. This proclamation put into effect certain features of the National Seas Act 1977 defining the "offshore seas" of the State. In essence, this proclamation declared waters within 200 miles of the State to be under the control of the State with regard to certain matters, among them, fishing. The offshore seas became synonymous with the Declared Fishing Zone (DFZ) of PNG. The State declared its rights to control all fishing activity within this zone and to defend these rights by force, if necessary. Figure 5 shows the boundary of the offshore seas of PNG. It contains over 1.2 million square miles of area, 750,000 of which is ocean.

The Fisheries Division of the Ministry of Primary Industry is charged with the responsibility of regulating fishing activity within this zone, and, with the assistance of the Defense Force, of enforcing its regulations. The Fisheries Division has enacted a licensing procedure by which fishing vessels, both domestic and foreign, may purchase a license to fish these waters. The cost of this license is based on a percentage of the value of the fish which it is estimated that a vessel of a particular type and size should be able to catch. Thus, estimated catch rather than actual catch governs this calculation.

The waters within Papua New Guinea's DFZ are some of the richest in the world, and boats from several nations fish here with a variety of gear. As one example, 310 Japanese fishing vessels including purse seiners, longliners and pole-and-line boats purchased licenses to fish in PNG waters in 1978. In addition to vessels legally licensed, a large number of unlicensed foreign vessels fish these water for tuna, prawns, clams and other fish and shellfish. Estimates of the number of such illegal vessels vary widely, but 150 vessels per year seems a reasonable figure. At any time, there may be 200 or more vessels actively fishing within PNG waters. Some estimates place this figure at nearer 500. Thirty percent of these vessels, or from 60-150, are believed to be illegal.

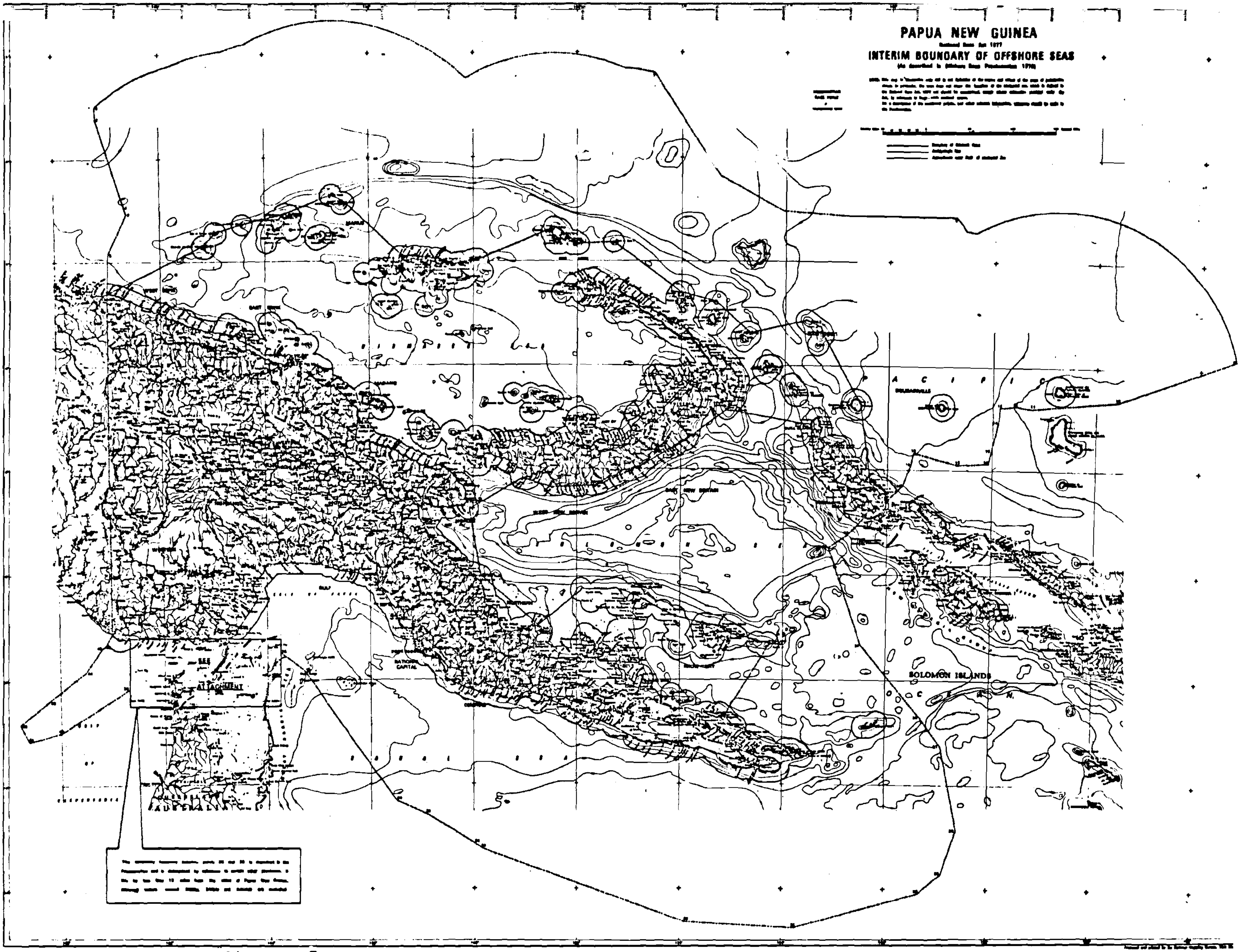


Figure 5: PAPUA NEW GUINEA INTERIM BOUNDARY OF OFFSHORE SEAS

BEST AVAILABLE COPY

BEST AVAILABLE COPY

Estimates of the value of the PNG fisheries resource that is lost each year to illegal fishing operations are not available, but this lost revenue is believed to be substantial. In some cases, the social cost may be well above the market value of the resource lost. The economy and livelihood of villages in outlying areas and small islands may depend entirely upon the resources of a single reef. An illegal "clam boat" can completely strip such a reef, destroying in a matter of hours a renewable resource that would have continued to support an entire village for years. Given the low estimate of 150 vessels per year fishing illegally in PNG waters and the average of slightly more than four per year that are apprehended and fined, then 97% of all vessels escape detection at the present time. With the high profits possible in today's market for fish products, these risks must seem relatively small to many open-water fishermen.

2.1 Project History

In response to a request from the Fisheries Division of the Government of Papua New Guinea, the United States Agency for International Development initiated a project to determine the feasibility of various techniques for surveillance and monitoring of high seas fishing vessels in the Declared Fishing Zone (DFZ) of the waters of Papua New Guinea. In previous discussions with various technical individuals, Mr. Peter Wilson, Director of Fisheries for Papua New Guinea, was briefly introduced to the possibilities of using satellite and aircraft remote sensing and communication procedures to detect and monitor the activity of domestic and foreign fishing vessels within PNG's 200 mile limit. Since the United States is in the forefront of such technology, he approached USAID for possible assistance. The Office of Reimbursable Development Programs (RDP) agreed to finance a feasibility study. One of RDP's stated purposes is to encourage foreign investment in or purchase of U. S. technology.

Resources Development Associates (RDA) was chosen to perform the study. RDA is an acknowledged leader in the fields of remote sensing technology and fisheries development. A four-month contract was awarded under RDA's Indefinite Quantity Contract for natural resources inventory and remote sensing assistance.

2.2 Project Goals and Objective

As stated in the Statement of Work, the principal objective of this project was "to undertake a study to determine the feasibility and costs of a surveillance and monitoring system covering the high seas fishing vessels in the extended economic zone of Papua New Guinea."

Three specific tasks were outlined in the Statement of Work. The requirements of each were as follows:

> Task I: Would consist of the initial collection and compilation of performance data for several candidate satellite and aircraft systems. Comparative examples and data samples would be prepared to illustrate to PNG officials the performance potential and limitations of available alternative systems.

> Task II: A team consisting of a senior fisheries specialist, a senior resources economist, and a senior resources analyst will visit Papua New Guinea to review PNG plans and information requirements, evaluate existing infrastructure and support resources, and discuss possible alternatives with PNG officials. Data samples and examples would be presented and discussed in light of current and foreseeable PNG problems and requirements.

> Task III: On returning to the United States, the team would complete collection of any additional data required regarding alternative systems, establish cost and delivery constraints for equipment or special-purpose transponders that may be required, and prepare a detailed report with illustrative examples.

The RDA Project Team consisted of Mr. Robert W. Campbell, a specialist in satellite technology and resource assessment, Mr. Keith W. Cox, a specialist in fisheries development and fishing technology, and Mr. Kenneth B. Craib, a specialist in remote sensing and resource economics. Prior to traveling to PNG, the team collected data on the state-of-the-art of reconnaissance technology. Various U.S. Government agencies, including NASA, NOAA, and the USCG, and commercial firms were visited.

The team then traveled to PNG where several extensive briefings were held for PNG officials. Information regarding PNG capabilities and requirements was compiled and reviewed. On leaving PNG, the team visited New Caledonia to consult with the South Pacific Commission regarding its views on a regional approach to surveillance and monitoring of high seas fishing activity.

3.0 THE FISHERIES OF PAPUA NEW GUINEA

Papua New Guinea's declaration of the 200-mile Declared Fishing Zone (Figure 6) in March 1978 increased its jurisdiction by 750,000 square miles. Several well-established fisheries operate within this area; e.g., the Japanese purse seine, longline, and long-distance pole-and-line fisheries, small Taiwanese longlines, and the PNG-based pole-and-line fishery.

About 1,400 species of fish are found in Papua New Guinea waters, approximately 5,000 species of molluscs and about the same number of crustaceans. However, no more than 100 of these species of fish, molluscs, and crustaceans are caught in any quantity. Skipjack (Katsuwonis pelamis) and yellow fin (Thunnus albacaras) tuna are the main species caught in PNG waters (see Figure 7).

There are a number of fishery resources within the Gulf of Papua. A growing trawl fishery is supported by stocks of penaeid prawns (Penaeus meguiensis, monodon and Metapenaeus ensis), by the annual migration of the tropical spiny lobster (Panulirus ornatus), and by an increasing utilization of the associated "trash fish" taken by the prawn trawlers. The principal inland fresh water resources include the barramundi (Lates calcarifer), which undergoes a seasonal migration from inland to coastal waters and Tilapia ssp. Tilapia has a short history in Papua New Guinea. Only recently introduced in the Sepik River system, it is rapidly assuming importance as it spreads and establishes its dominance in many of the fresh water systems. A potential domestic consumption of 20,000 - 30,000 tons of Tilapia may exist, which would make it increasingly significant in the local economy.

Approximately 70% of the world tuna harvest is taken from the Pacific Ocean; 20% from the Atlantic Ocean and 10% from the Indian Ocean. While the full extent of the tuna stocks in the western Pacific has yet to be properly assessed, experts agree that the western Pacific has the largest tuna resources in the world. Forty-five percent of the world tuna harvest is taken from

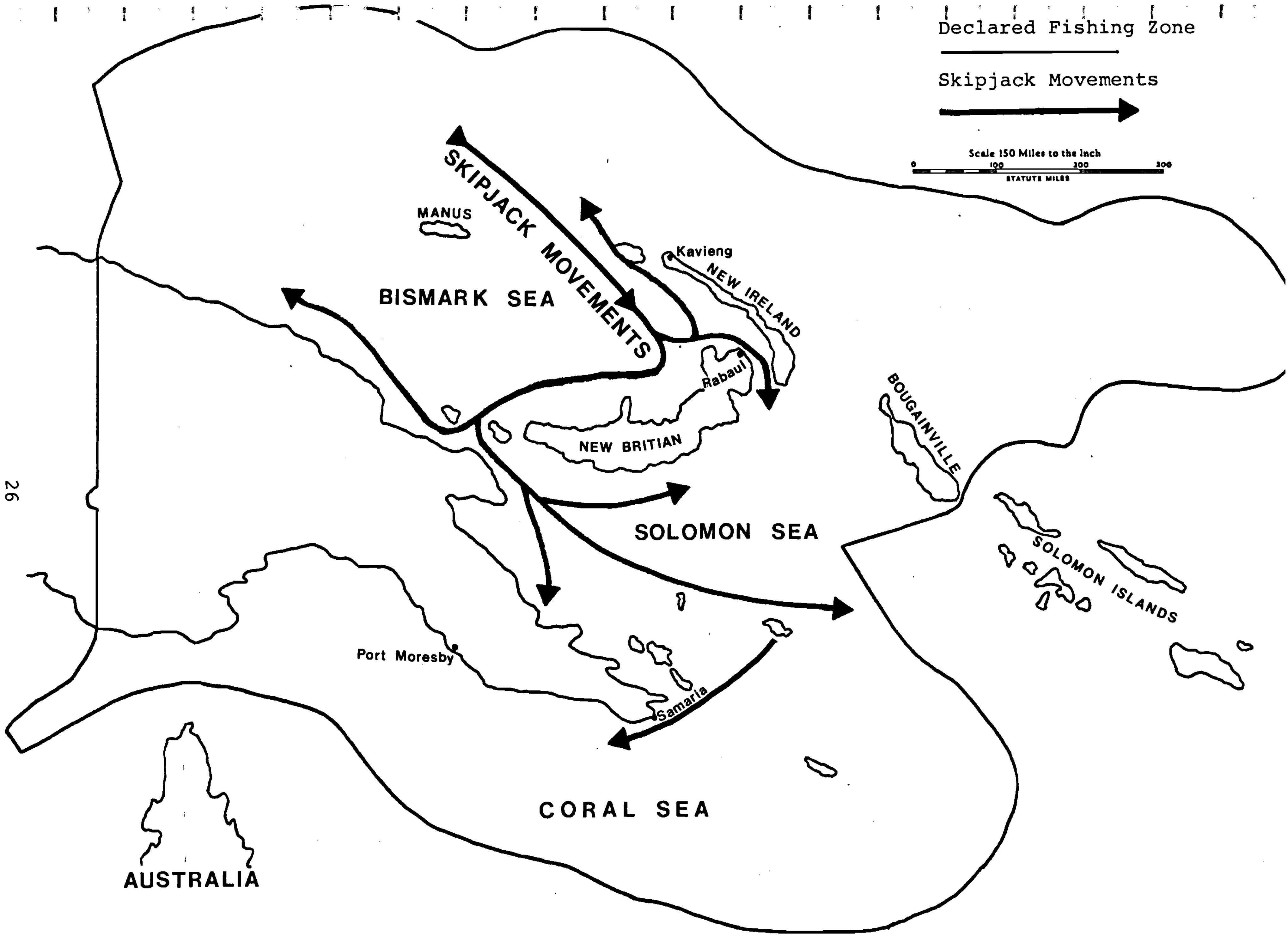


Figure 6: FISHING GROUNDS AND DECLARED FISHING ZONE

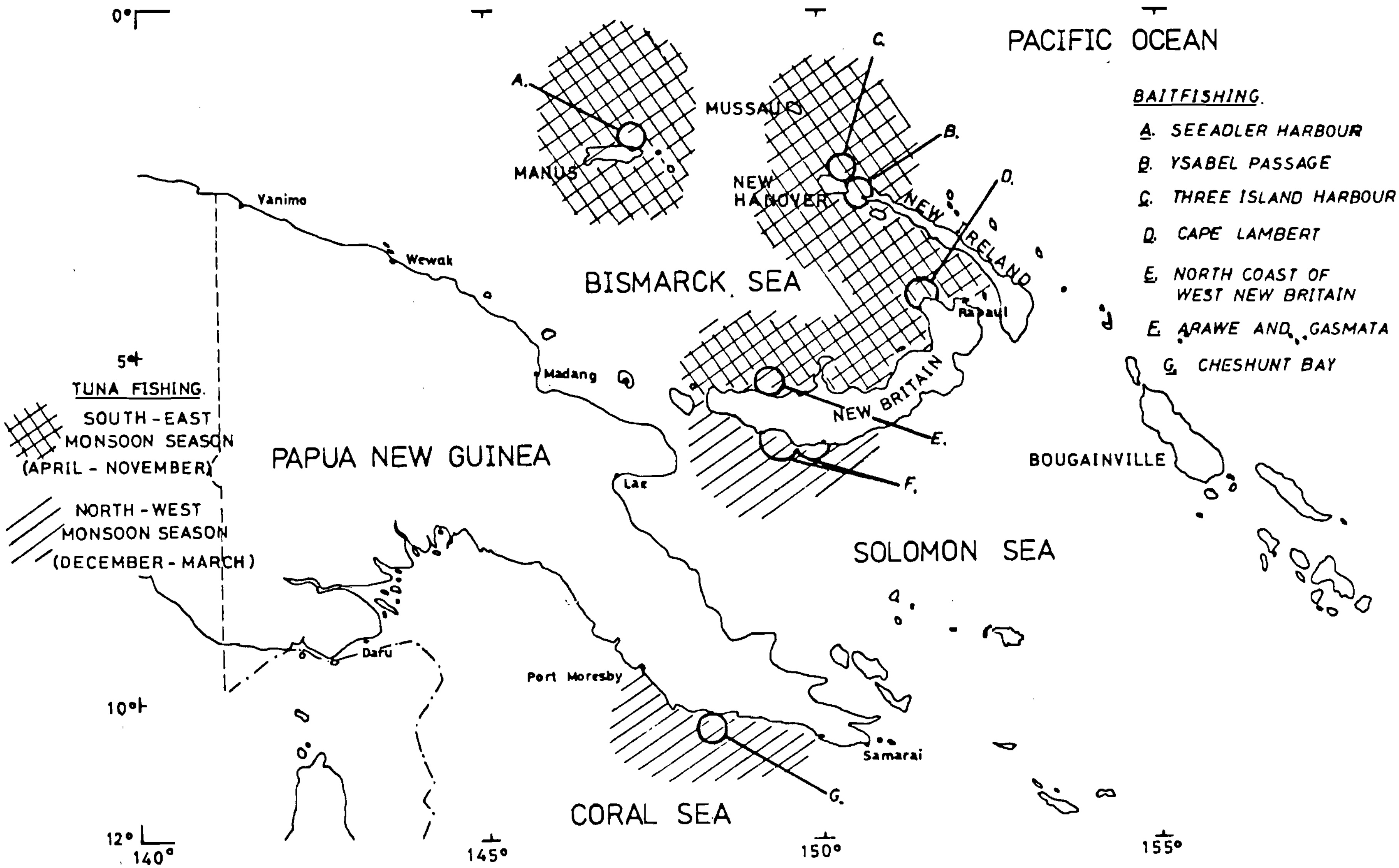


Figure 7: TUNA AND BAIT FISHING AREAS USED BY THE PNG DOMESTIC FISHERY, 1978

this area, twice as much as is taken from the eastern Pacific, and four times as much as is taken from the entire Atlantic.

Production from the eastern Pacific and Atlantic is unlikely to increase. However, as the western Pacific stocks are not being fully utilized, it is believed that production can be increased substantially, perhaps even doubled to some 800,000 tons or more a year.

Within PNG's 200-mile fisheries zone, as much as 100,000 tons of tuna has been harvested in a year's time. In the United States' tuna market, this raw tonnage has a value of US $100 million; fully processed as canned tuna, it would be worth approximately US $250 million.

3.1 PNG Tuna Fishery

Industrial development of the Papua New Guinea skipjack tuna resource started in 1970 and has expanded to the extent that PNG is now the world's third largest producer of skipjack tuna. Estimated annual production by the PNG fleet is in the vicinity of 40,000 tons and predictions are that these catches may approach 80,000 to 100,000 tons per year in the near future. An additional 40,000 to 60,000 tons are now taken annually by foreign vessels.

To foster the development of major tuna fishing and processing industries in Papua New Guinea, a series of agreements were reached between the Governments of Papua New Guinea, Australia, and Japan. The agreements provided for the Japanese Government to cooperate with and, where possible, assist Papua New Guinea in the development of tuna resources in adjacent waters. The agreements also provide for the sharing of research and survey information, conservation of the resources, the use of specified Papua New Guinea ports by Japanese tuna boats, the processing of tuna in Papua New Guinea, provision of technical assistance to the Papua New Guinea fishing industry for progressive increases in local processing of products, and the conversion of fishing fleets to the Papua New Guinea flag. There were also provisions for employing and training of Papua New Guinea fishermen and fishery workers. Local equity participation of 20% or more was also desired.

Initially, four companies began operations from freezer mother ships in the Kavieng, New Ireland, Rabaul, East New Britain, and Madang areas. Due to difficulties over bait license privileges, the latter operation was temporarily suspended in August 1975. Shore facilities at Rabaul included a 15-ton per day ice plant and 300-ton capacity cold storage plant. An aribushi (smoking) plant at Kavieng employed about 60 local laborers and processed about 7 tons of headed/gutted skipjack every 24 hours. However, although protracted negotiations were held between the Government and a consortium of the four joint venture companies, local employment opportunities failed to expand, and as a result, the Government levied a 5% export fee on the f.o.b. price of all unprocessed tuna shipments from the country.

3.1.1 Live Bait

The abundance and proximity of live bait to the skipjack fishing grounds has considerable bearing on the catch per unit of effort for tuna. Exclusive rights to baiting grounds were initially granted by the Government of PNG to the tuna vessel operators, but since the indigenous people have had traditional fishing rights, there was a conflict of interest. This was resolved by the levying of a 2.5% fee on the f.o.b. value of tuna exports. This is now distributed to the indigenous holders of the traditional fishing rights.

3.1.2 PNG Tuna Catch

The total PNG tuna catch has continued to expand since 1972 (Table 3). By 1978 (latest year for complete figures), the catch reached 48,933 tons, the highest since the fishery was established in 1970, with an export value of about 19 million kina (US $27 million). Most (93.5%) of this catch was composed of skipjack with 6% yellowfin and 0.5% other tunas. A record 762,800 buckets of baitfish (equivalent to about 1,900 tons) were caught during this 1978 season. Detailed catch figures for foreign flag vessels fishing under license are not available. As noted earlier, the foreign catch is larger than the current PNG catch. The 1978 PNG landings were over double these landed in 1977 (24,411 tons), and highr than the previous record in 1974 (41,780 tons). However, economically, 1978 was not a good year since the price of skipjack dropped to about K430.00 a ton, from the record high of K680.00 in September 1977.

The average annual CPUE (catch per unit of effort) at 4.9 metric tons per boat fishing day during 1978 was the highest yet recorded (Table 4). However, the catch per bucket of bait was only 64.1 kg. Equal or better results, the latter indicating better use of baitfish stocks, had been obtained in four out of seven previous years, when total catches of both tuna and bait were lower.

At the time of this writing, complete catch data for 1979 were not available. Indications to date are that the 1979 catch will be poor, particularly with respect to the 1978 season (see Table 5). Total tuna catches for the first eight months of 1979 were 22,434 tons; the decline indicates that the total annual catch will probably be below 29,000 tons. Bait catches to the end of August were also comparatively poor, at 380,800 buckets, compared to 457,000 at the same time last year. Over the first six months of the year, the skipjack proportion of the catch was down to 90.5%, yellowfin up to 9.4% and other tunas maintained a 0.1% proportion of the total catch.

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Total tuna catch (MT)	17,003	13,124	28,332	41,780	17,398	33,015	24,411	48,933	
No. of fishing days	4,060	4,915	7,719	9,408	6,435	7,901	9,736	9,941	
Total bait catch (1000's buckets)	224.4	330.4	456.0	518.1	379.0	392.3	750.5	762.8	
Bait CPUE (1) (buckets)	55.2	67.2	59.1	55.1	58.9	49.7	72.5	72.6	
Tuna CPUE (2) (M.T.)	4.2	2.7	3.7	4.5	2.7	4.2	2.5	4.9	
Tuna catch per bucket of bait (kg)	75.8	39.7	62.1	80.6	45.9	84.2	32.5	64.1	

(1) Catch per boat fishing night

(2) Catch per boat fishing day

1 bucket = 2.5 kg of bait on average

Table 3: SUMMARY OF ANNUAL TUNA AND BAITFISH CATCH AND EFFORT

Area*	Number of Fishing Night/Day	Bait Catch (1000's buckets)	Bait CPUE (buckets/ boat night)	Tuna Catch (tonnes)	Tuna CPUE (tonnes/ boat day)
Manus (1)	407/391	27	67	1,222	3.1
Kavieng (2)	6490/6144	506	78	31,580	5.1
Eastern Bismarck (3)	3304/3125	208	63	14,786	4.7
Southern Bismarck	-	-	-	-	-
Solomon Sea (4)	111/105	9	77	719	6.9
Coral Sea (5)	161/150	11	67	544	3.6

*Main baiting grounds:

1. Seeadler Harbour
2. Ysabel Pass, Three-Islands Harbour, Silver Sound.
3. Cape Lambert
4. Gasmata, Arawe Is.
5. Cheshunt Bay

Table 4: SUMMARY CATCH AND EFFORT DATA FOR THE PNG DOMESTIC-BASED FISHERY BY FISHING GROUNDS, 1978

Month	Number of catcher-boat	Number of Fishing Days	Bait Catch (1000's buckets)	Total Tuna Catch (tonnes)	Tuna Catch per boat fishing day (tonnes)
1978					
Jan.	9	95	7.5	212	2.2
Feb.	5	59	5.0	254	4.3
Mar.	33	469	32.0	1,670	3.6
Apr.	42	815	48.1	2,361	2.9
May	45	1,128	87.0	5,335	4.7
June	46	1,146	88.4	5,224	4.6
July	45	1,166	92.2	5,252	4.5
Aug.	45	1,154	96.8	7,010	6.1
Sept.	47	1,066	85.9	6,766	6.3
Oct.	47	1,269	95.2	6,720	5.3
Nov.	47	1,154	93.7	6,218	5.4
Dec.	42	420	31.0	1,912	4.6
1978 Total:		9,941	762.8	48,933	4.9
1979					
Jan.	13	257	20.5	1,313	5.1
Feb.	12	208	16.8	1,123	5.4
Mar.	27	353	26.7	1,702	4.8
Apr.	41	796	50.4	4,458	5.6
May	41	970	64.5	3,547	3.7
June	41	1,017	69.2	4,079	4.0
July	40	1,039	76.5	3,422	3.3
Aug.	39	925	56.2	2,790	3.0
Sept.					
Oct.					
Nov.					
Dec.					
1979 Total:					

Table 5: MONTHLY CATCH STATISTICS SUMMARY FOR THE PNG DOMESTIC-BASED TUNA FISHERY FOR 1978 AND 1979 (1979 Preliminary)

The relationship between 1978 and 1979 landings is similar to that in 1974/75. In both cases, exceptional catches during the first year were followed by a year of relatively poor landings. A clear pattern of alternating good and poor years seems to have become established during the six years since 1976; i.e., 1974/75, 1976/77, 1978/79.

It is equally clear that the present lack of information concerning growth and migration of these stocks is a significant factor affecting development planning in Papua New Guinea and the entire western Pacific. During the period of very poor catches in PNG waters in October and November 1979, the Solomon Islands' fishery was experiencing exceptional landings of tuna; CPUE's in excess of 10 tons were common compared to 1 to 2 tons in PNG. The September to November period in 1979 was characterized by an abundance of large yellowfin in PNG waters (30-50 kg), which are too large to be exploited by the pole-and-line fishery, a situation similar to that prevailing during the same period in 1977, though not in 1978.

Until 1976, the relationship between bait catch and effort was a linear one, showing a remarkably small deviation from the line from year to year. However in 1977 and 1978, catches were about 50% above the previous maximum yield (in 1974) with very little increase in effort. This increase in overall bait CPUE appears to have been due largely to increased use of the Ysabel Passage/Silver Sound/Three Islands Harbour baiting areas. These grounds can apparently sustain fairly intensive fishing pressure. Although most of the baitfish catch now comes from the Ysabel Passage/Silver Sound areas, the gradual opening-up of new bait fishing grounds should, in the future, result in a more equitable spread of both bait and tuna fishing pressure.

Tuna catches continue to show a linear relationship with effort (although less consistently so than bait) indicating under-exploitation at present. However, the great year-to-year variation in tuna catch, even under similar conditions of effort and baitfish availability, coupled with the catch/effort relationship and relative youth of the fishery, make attempts at maximum (or optimum) yield modelling difficult at this time. During good fishing years, it should clearly be possible to land far more tuna than is presently the case, provided that the situation regarding baitfish stocks continues. In 1978, major restraints on tuna catch were primarily the lack of brine freezing capacity on board motherships and, secondly, too few catcher-boats to make use of the available bait and tuna resources.

The occurrence of poor tuna fishing years may put a restraint on the expansion of the PNG tuna fleet. The year 1978 was an exceptionally good one for skipjack catches world-wide, resulting in depressed prices and, consequently, a financially poor year for the fishing companies. This presented a major problem for PNG at the time as it appeared to be not whether its fleet should expand and improve its total catches, but whether it was economically possible to do so. Worldwide demand for tuna has doubled during the past ten years and the current accelerated demand indicates this trend will continue. The available stocks of the eastern Pacific and Atlantic are, for the most part, being fully utilized; therefore, the increased world demand for tuna will cause a continuing upward movement in fish prices. Distant water fishing nations and large tuna processing companies are looking to the undeveloped, rich fishing areas in the western Pacific as a new source of tuna to meet the world's growing demand for tuna. The movement and growth of these tuna stocks are not sufficiently well understood at this time. A fisheries surveillance and monitoring program that would also collect data to support research in these areas would seem particularly appropriate at this time.

3.2 Foreign-Based Fishery Vessels

In 1978, 308 Japanese fishing vessels were granted licenses to fish within PNG's 200-mile DFZ. Of these, 11 were purse seiners, 274 longliners and 23 long-range pole-and-line vessels. One U.S. purse seiner applied for and was granted a license. Also, an unknown number of (unlicensed) Taiwanese boats operated in the DFZ. Estimated catches for purse seiners and longliners were 3,500 and 9,000 tons respectively. Japanese pole-and-line vessels did not fish the DFZ and estimates for the Taiwanese catch are unavailable. Foreign tuna vessels based in PNG harvested nearly 50,000 tons of skipjack in 1978, but PNG received only a small percentage of the full value of this catch.

In January 1979, the Japan-PNG Fishery Agreement lapsed. However, as a result of joint talks between the PNG Government and Japanese fishing industry representatives, a new agreement was established in July 1979. Up to November 1979, a total of 56 Japanese fishing vessels were granted licenses to fish within PNG's DFZ: 12 purse seiners, 43 longliners, and 1 pole-and-line vessel. Three U.S. purse seiners were also granted fishing licenses during 1979.

3.3 Regional Fisheries Management

Papua New Guinea, in cooperation with ten members of the South Pacific Commission, has formed a fisheries organization known as the South Pacific Forum Fisheries Agency. The primary objectives of this organization are to assist member states to coordinate and harmonize policy of the Law of the Sea so as to ensure the maximum benefits for the people and the region as a whole, and to facilitate, promote and coordinate cooperation and mutual fisheries assistance among coastal states in the region. PNG and the South Pacific Commission also support the concept of creating a second larger body, "comprised of coastal States who share the stocks and the distant-water fishing nations who may not share their jurisdiction, but fish them." This second organization will conduct research studies, provide technical advice and assistance, propose conservation measures, and coordinate licensing and surveillance arrangements. Member nations who claim their sovereign right to explore, exploit, conserve, and manage the living resources, including highly migratory species, in their 200-mile zones will be required to go on record with the organization to this effect.

Recent research indicates there are at least five sub-populations of skipjack occuring across the Pacific, each of which will probably have to be managed as a separate fishery. The research organization would assist the coastal nations in their determination of how much fishing should be permitted each year to best serve regional objectives, and how the total catch quota for each stock placed under regulation should be allocated between the coastal nations in whose waters the particular stocks occur.

In 1980, officials of the South Pacific Forum Fisheries Agency will meet to discuss the principles under which they wish to see such a larger organization formed. When concensus on these principles has been agreed, the Agency will consider issuing an invitation, probably toward the latter part of 1980, to interested states to meet to discuss the formation of this organization.

3.3.1 PNG Fisheries Management

Management of fisheries resources is a basic problem encountered by most developing countries. Papua New Guinea and other member nations of the South Pacific Commission hold strongly to the concept that coastal states have the sovereign right to manage the stocks which occur within their fisheries zones.

The 200-mile fisheries zone came about largely through the efforts of South American countries unilaterally declaring 200-mile zones in the eastern Pacific which were being intensively fished by distant-water fishing nations. The Law of the Sea Conference later confirmed the concept of 200-mile exclusive economic zones. This was done primarily to insure that developing nations, rather than the larger more developed fishing nations, would be able to gain real benefits from their fisheries resources as well as to insure the proper conservation and management of the fisheries stocks.

Tunas are a highly migratory species that know no political boundaries and move from one nation's zone to another. Papua New Guinea recognizes the need for cooperation with other nations sharing stocks of tuna or other species in their conservation and management. PNG believes that distant-water fishing nations that do not share stocks with another nation or nations should have no right to make decisions about the management of these stocks. However, those nations with distant water fleets could be invited to participate in recommending conservation and management measures for such stocks.

Papua New Guinea and the South Pacific Commission members hold that it is the right of every nation to plan and develop its own resources in a manner which will bring it optimal benefits. If a state or a group of coastal states can structure a fishery which can harvest the total allowable catch with their own fleets, then foreign or other vessels not authorized by the coastal state or states involved should have no rights to fish in that region.

3.3.2 Regulation of Tuna Stocks

At the preaent time, Papua New Guines feels that it will be ten years before regulation of the tuna stocks in the western Pacific is required, if at all. The rising cost of fuel, labor, vessels and equipment will limit the activities of all but the most successful long-range vessels, thereby reducing pressure on these tuna stocks and ensuring their conservation. However, this will probably be offset to some degree by the establishment of joint venture fleets in those coastal states with tuna stocks, thus achieving in part some benefits for the small developing countries in the region.

The present system whereby the distant-water fishing nations negotiate unilaterally with those countries with large known resources is is not, in many instances, satisfactory for the parties involved. Access to good fishing grounds is restricted to long-range fishing vessels. These cannot afford to purchase fishing licenses or pay royalty payments to all states for the privilege of fishing their waters; therefore, they deal only with those countries with known resources closer to the distant nation's home port. This results in many countries receiving no cash benefits, while the long-range vessels become restricted as to where they fish and consequently operate less efficiently.

Papua New Guinea holds that access arrangements and fees must be structured in such a way as to allow foreign vessels access to the region as a whole rather than only to restricted areas, and that payments should be directly related to the amount of fish actually harvested from within a nation's fisheries zone. PNG believes that such arrangements can best be effected through a regional organization where neighboring nations who share a common stock(s) agree on a unified set of terms for access to the area and a fee for fish taken.

While the members of the South Pacific Forum Fisheries Agency have not yet agreed to such an arrangement, one of the prime reasons for establishing the Agency was to "coordinate and harmonize policies on Law of the Sea so as to ensure the maximum benefits for the people and the region as a whole and specifically to harmonize fisheries policy in the region and to adopt a coordinated approach in negotiations with distant-water fishing nations." A free-access arrangement with catch-related fees would appear to satisfy that goal.

Papua New Guinea and other members of the Fisheries Agency are now working toward the development of a cost-effective surveillance and enforcement system.

The need for such a system is not primarily for protecting the resource from over-fishing as, with the possible exception of some reef fisheries, this could hardly occur without massive fleets which could be easily detected in any case. The initial purpose is to ensure that foreign vessels recognize that failure to take licenses and to provide data and fees for fish taken can result in heavy fines, the loss of their catch, and seizure of the vessel if apprehended fishing illegally.

The costs and problems of detecting and apprehending vessels in such a large area are indeed formidable. With the assistance of the United States, Papua New Guinea is examining the feasibility of establishing a satellite surveillance system in the southwestern Pacific, developing an effective enforcement capability, improving fisheries data collection and processing, and increasing the coordination between national and provincial fisheries agencies. The Government will have total control over fishery resources, but will encourage participation and cooperation of the provincial governments.

The control of coastal states over all fisheries stocks, including tunas, will no doubt bring dramatic changes to the present world tuna industry, but will surely benefit both developed and those developing nations which cooperate on the conservation, management, utilization and marketing of the stocks shared between them.

4.0 FISHING VESSELS UTILIZING PNG WATERS

A brief description of the types of vessels and their methods of operation will lead to a more effective design of a surveillance system. There are six basic types of fishing vessels utilizing PNG waters. They are mother or factory ships, longliners, pole-and-line boats, purse seiners, clam boats, and trawlers. The following descriptions of each have been taken from the Fisheries Division Surveillance Manual of 1977.

4.1 Mother (Factory) Ships

All of the company tuna fleets licensed in Papua-New Guinea have motherships working at its fleet base. They are presently located at Kavieng, Rabaul, Kimbe and Manus. As agreed between the company and the PNG Government, the operational bases may be moved to different locations from time to time.

Motherships are cargo type boats with expanded freezer capacity. Their general appearance is typical of general cargo vessels with large tanks on deck containing refrigerated brine solution. The freshly caught fish are hard-frozen before being placed in storage in the freezers below. The ship itself, which may range in size from 1,000 to 10,000 tons (Photo 1), lies at anchor and the fishing boats visit it daily to deliver fish and receive ice and stores in return. When full, the mothership may be replaced by another similar ship or a passing freighter may off-load her.

Motherships are licensed and must carry a Papua New Guinea identification number as do the fishing boats. Their operations are to be phased out as the companies build up shore bases, but one or more may be retained to supply a proposed central cannery when this becomes operational.

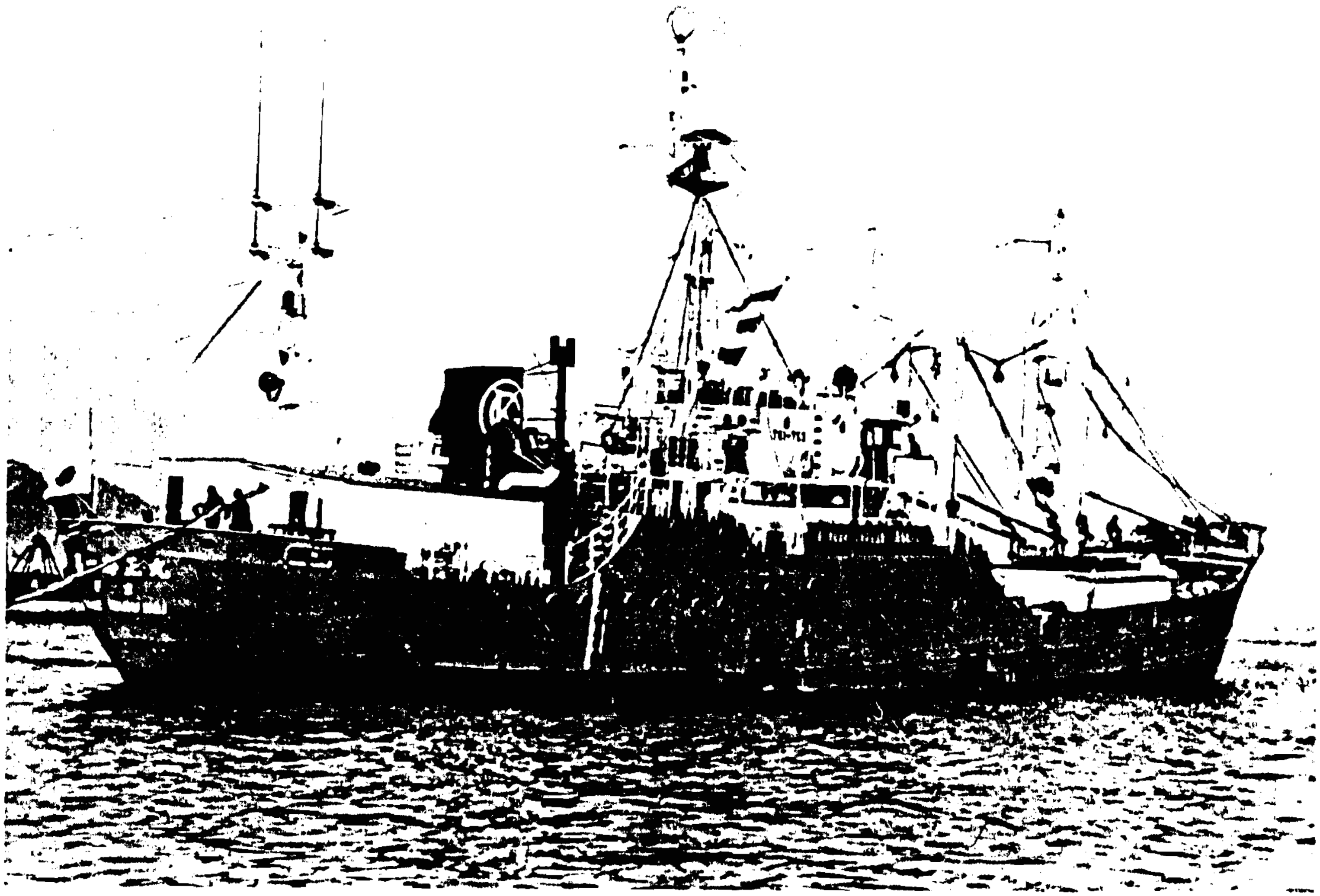


Photo 1: MOTHERSHIP

BEST AVAILABLE COPY

4.2 Longliners

These fishing boats use very long lines set horizontally in the sea and which may extend over 20 to 40 and even 60 miles in length. At intervals along this longline, vertical lines are set at various depths, each having a baited hook. These vessels do not require special construction or design. Since the wheelhouse-aft vessel is the most comfortable at sea, many longliners follow that design and may resemble a coasting vessel at first glance. Longliners come in all sizes, but the majority involved in PNG waters are in the 40 meter class (20-30 tons).

Long distance oceanic longlining was pioneered by countries such as Japan, whose population pressures and limited coastal seas influenced fishermen to go far afield. There are two advantages to longline fishing: the lines can be set floating anywhere in the ocean, and, bottom-set longlines can be used on rough ground where trawlers would lose gear.

The types of fish taken by longliners are large tunas, swordfish and sharks. While longlining is a technically simple operation, skilled procedure is required as well as an expert knowledge of the fishing areas.

A longline consists of several lengths of line joined together (Figure 8). To the line are attached baited hooks (on branch lines), floats, flag buoys, and radio or lighted buoys required to facilitate locating the line. A ground-set longline is anchored in place, but a surface line usually is set drifting freely. The conventional longlining method employs a number of "baskets" Each basket is of a set length with many branch lines attached.

When fishing, a team of men is stationed at the stern. The vessel proceeds at quite a fair speed and the lines are paid out quickly, each section being joined to another one during "shooting". One man will fetch the baskets of lines; another will prepare and pay them out; another will bait and attach branch lines; another will attach floats and flag buoys as

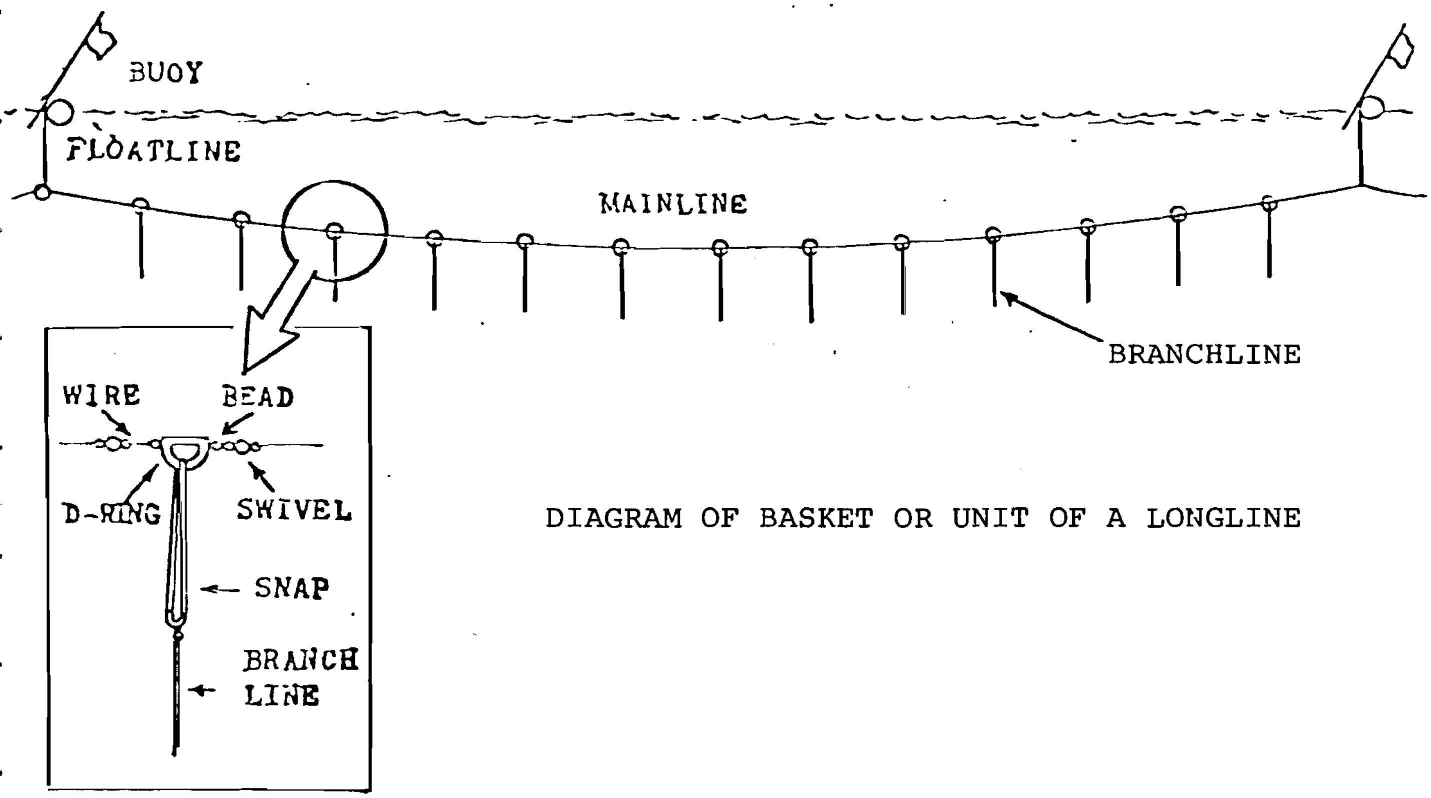


DIAGRAM OF BASKET OR UNIT OF A LONGLINE

TYPES OF LONGLINING GEAR
Bottom, Midwater, Surface
#7 Drifting Surface, Tuna

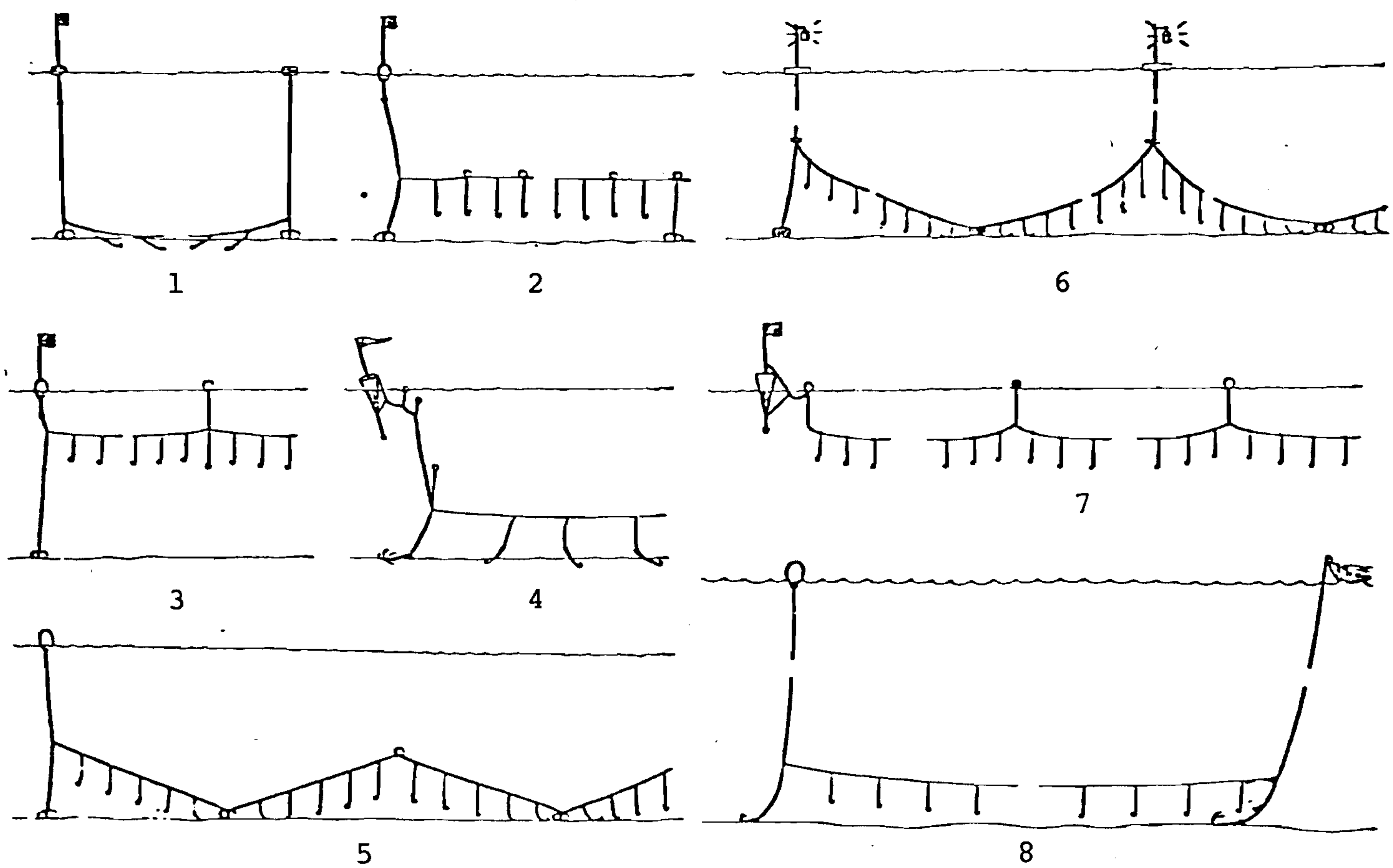


Figure 8: LONGLINING GEAR

required. It is dangerous work and men can be lost overboard very easily if caught by a hook or entangled in a line.

When the lines have been in the sea for the required period, the ship returns to the first and starts to retrieve them. If the length of line shot is long, say 10,000 to 20,000 meters, then the line will be retrieved as soon as the ship returns to the original end. Otherwise it may be left a while to "fish".

The line is taken up over the ship's rail, usually on the forward starboard side where a mechanical line hauler is situated. As the line is retrieved, fish are removed and the lines are coiled as they come off the hauler and sent back to the ship's poop deck in units (baskets). There is often a conveyor belt permanently situated on the port side running from the hauler up onto the poop deck. In attempts to mechanize the process some vessels are equipped with large "line reels" (4m x 2m) holding miles of line and used with "snap-on" hook branch lines. Not many vessels have been seen with this device in PNG.

A longliner requires a large amount of bait, usually carried frozen from the port of origin. The most popular fish is the Japanese "saury" which is about 400 - 600 mm long, and superficially resembles a garfish. Supplies of this bait are now scarce and expensive.

4.3 Pole-and-Line Boats

Tuna pole-and-line fishing started from a survey and experimental stage in PNG in 1970/71 and soon expanded into a serious fishery and four joint-venture companies were formed with Japanese and American participation. This type of fishing has been traditional in the Pacific for many years and has spread worldwide. Pole-and-line boats can be encountered almost anywhere fish school and feed in the desired pattern.

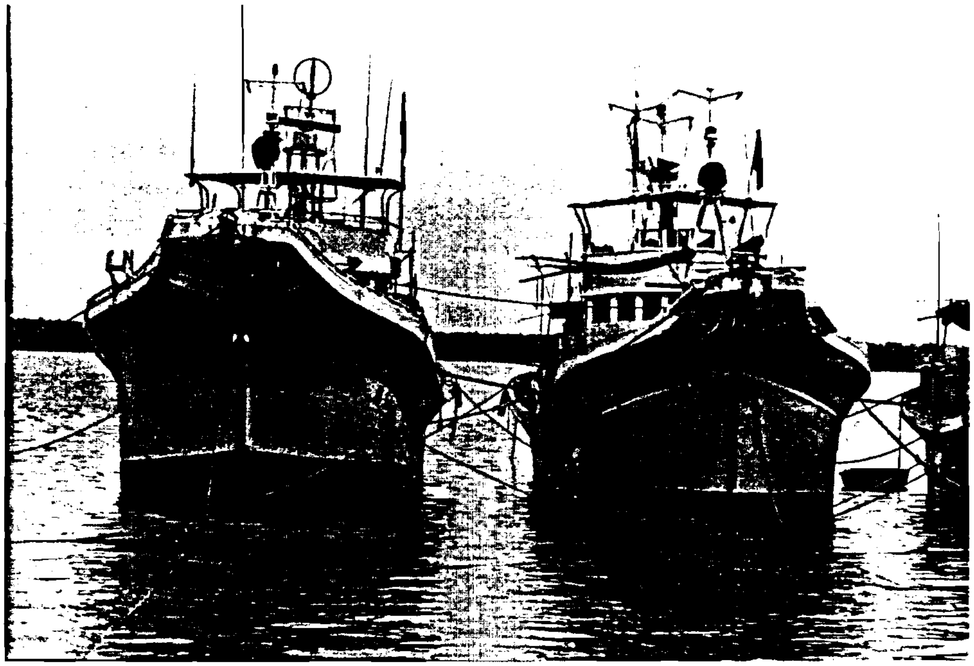
Two types of vessels are presently operating in PNG. One is a 20 meter vessel (39-49 tons) working daily out from a fixed base (mothership); the others are larger 30-40 meter (79-192 ton) vessels with refrigeration which can operate away for several days on an independent basis. Twenty meter vessels are called Short-Range Polers (SRP) (Photos 2 and 3); the 30-40 meter vessels are called Long-Range Polers (LRP) (Photo 4).

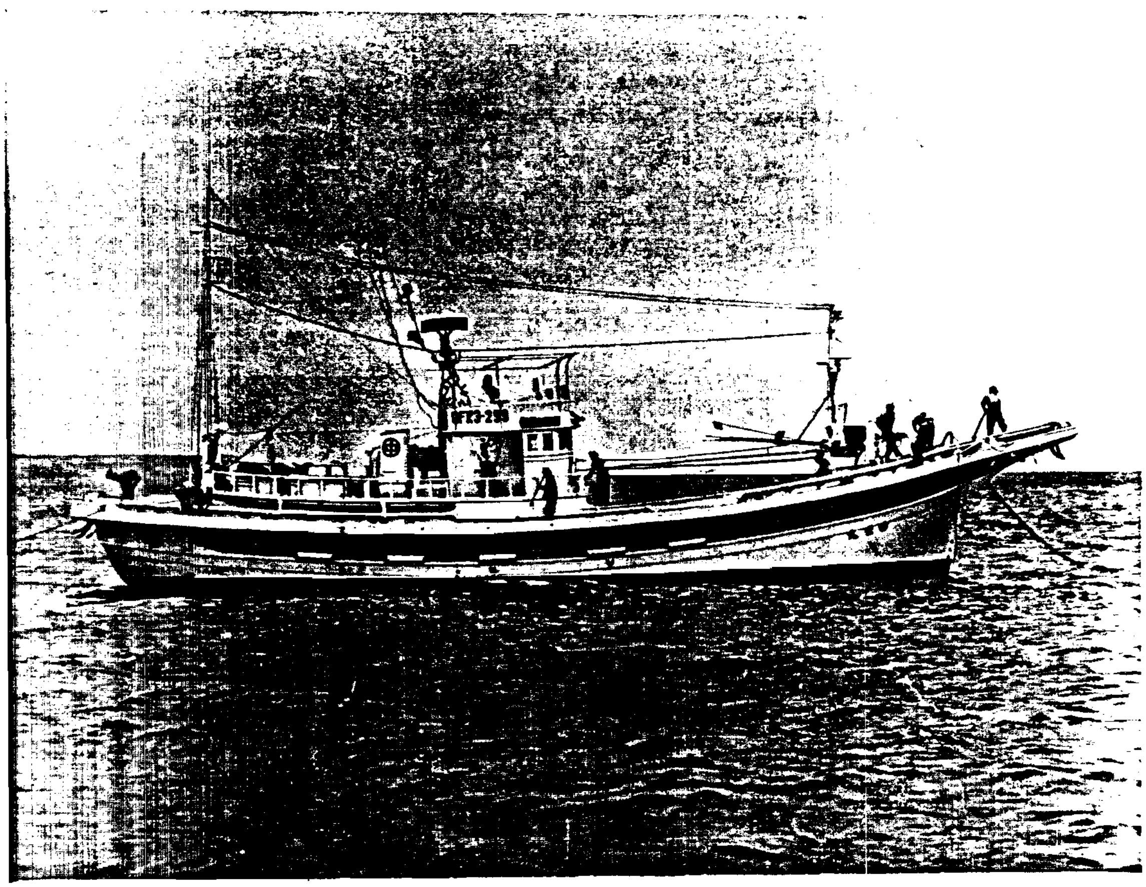
In 1971, the companies began replacing the smaller, older 39-49 ton boats with 59 ton vessels when it appeared that the average catch per unit effort (catch per boat per fishing day) of the 59 ton class of vessels was 15% to 20% higher than for the 39-49 ton class, and 10% to 15% higher than the 192 ton class of vessel.

Up to 1975 each of the four companies operated separate fleets. In 1978, one company ceased operations and the fleet was comprised of 10, 20, and 17 pole-and-line catcher boats working with one, two and two motherships, respectively. The fleet consisted of six size classes: 39 gross tons (1 vessel); 49 tons (10 vessels); 59 tons (26 vessels); 69 tons (1 vessel); 145 tons (1 vessel); 192 tons (8 vessels).

The beginning 1979 year saw the amalgamation of two of the three fishing companies, the resulting two companies operating fleets of 17 and 14 pole-and-line catcher boats and three and two motherships respectively. The 1979 fleet comprised the following distribution amongst size classes: 39 ton (1); 49 ton (4); 59 ton (27); 69 ton (1); 145 ton (2); 192 ton (6).

The fishing method is simple. A pole-and-line catcher boat puts to sea with live bait aboard in tanks of circulating sea water. When a school of feeding tuna is sighted, the catcher moves in and throws live bait into the water. This attracts and excites the tuna which swarm around the catcher and continue to do so as bait is thrown into the water. The pole boat has two fishing stations, one at the bow and one at the stern. The bow station has a peculiar elongated "beak" projecting forward and which provides additional space for fishermen (Photo 3).





Photos 2 and 3: POLE-AND-LINE BOATS
(Note characteristic "beak" upper photo)

BEST AVAILABLE COPY

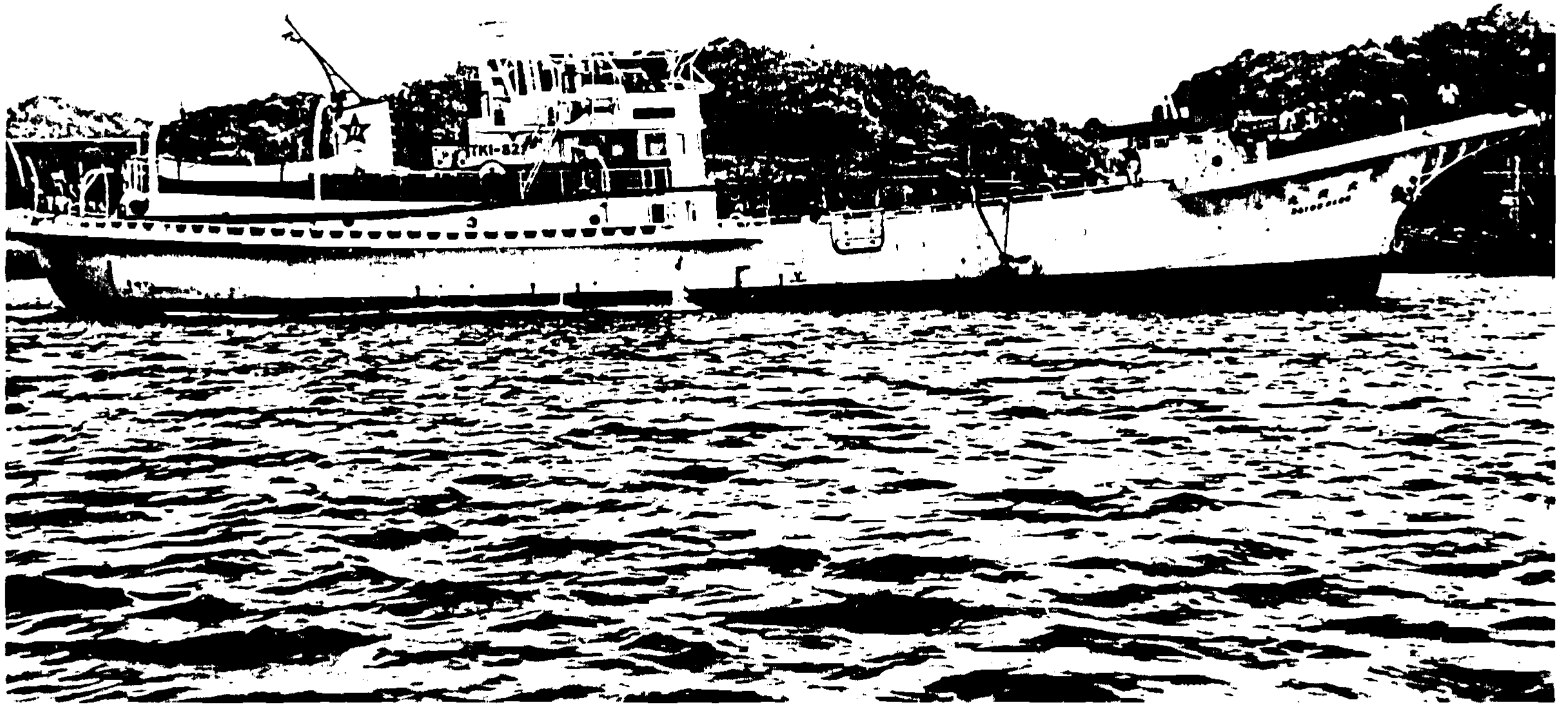


Photo 4: LONG RANGE POLE-AND-LINE BOAT

BEST AVAILABLE COPY

As soon as a school of fish is attracted, the catcher stops and turns on a system of water sprays around the ship. This tends to excite the fish and conceal the fishermen. The crew, each with his own pole, then assemble on the ship's rail and, by means of barbless lures, hook and throw the fish one by one onto the deck. Provided the line is kept taut, the fish cannot throw the hook. Once the fish lands onboard and the line is slackened the fish throws the hook and is free on the deck. The fishing action is usually as fast as the operator can wield his line. One man/pole/fish is usual in skipjack fishing, but for heavier fish two men may join their lines to one hook. Sometimes three men may be involved when very large fish are encountered.

The larger LRP boats will sometimes be fitted with four or more automatic poling machines along one rail. Each consists of a squarish container, about .5 meter in width and a fiberglass "bamboo" is attached to each. The machines are able to catch fish by the same process as the crew, but are said to be less successful on skipjack where the boat is stopped when fishing. Fishing continues until the school of fish stops biting or moves away.

One of the problems in this fishery in PNG is the fact that the desired live-bait has to be obtained from inshore waters where indigenous persons hold the fishing rights. Thus, the whole fishery depends on local rights holders permitting baiting in their areas. This has provided some difficulties, but, on the whole, the industry has managed to maintain its operations.

Many catchers collect bait at night using a dory towed a few meters astern on a line. The dory has a diesel powered generater which lights a submerged lamp. When enough bait has gathered around the submerged light, the parent boat immediately puts out a fine meshed bait "lift net". This is supported away from one side of the vessel by a "goal post" arrangement of large bamboo poles. The "crossbar" of the "goal post" supports the lift net vertically in the water. The bait dory is then slowly pulled in so that it lies between the parent boat and the lift net. The bait comes with the dory which is still using its light.

The lift net is quickly drawn upwards by means of ropes attached to the bottom edging enclosing the dory and bait. The light is turned off and the dory is quietly eased over the top of the net.

The bait net is then further pulled in until the bait is concentrated. It can be then dipped out by hand, using buckets, and passed to the parent boat's live bait tanks. The boat then puts to sea to look for tuna.

4.4 Purse Seiners

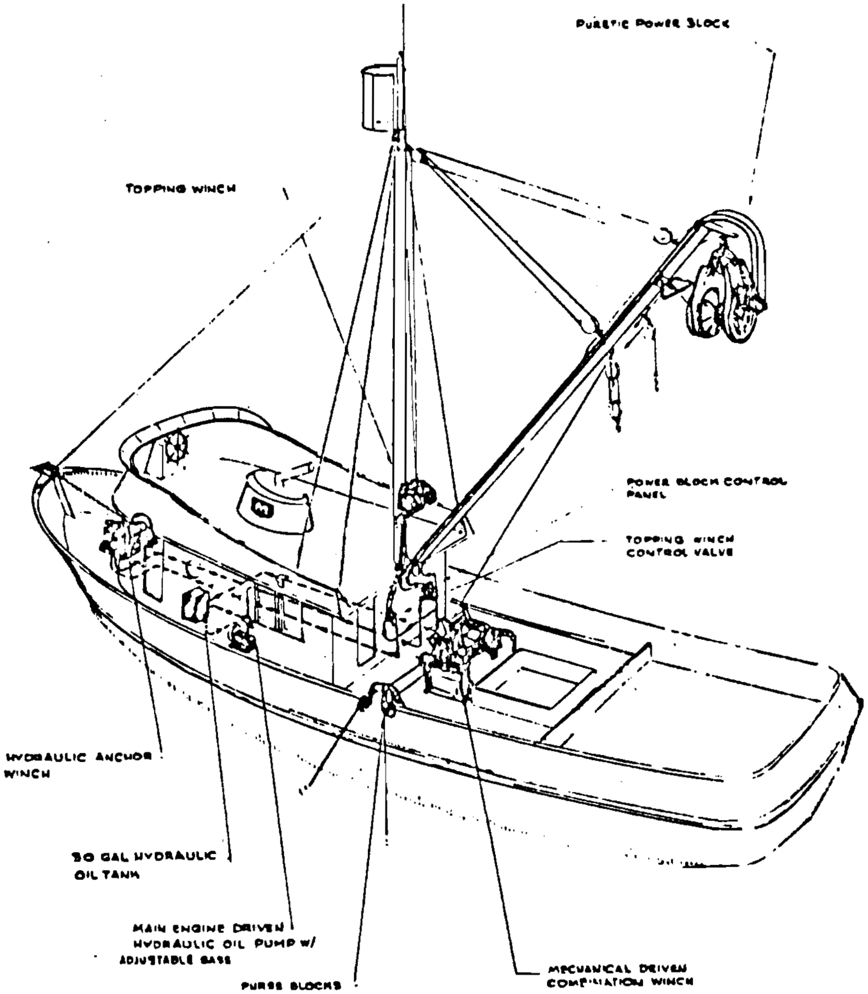
A purse-seine is a net which is set in a circular fashion at the surface of the sea and which has a draw-string at the bottom enabling the net to be "pursed" and so contain any fishes encircled by the net (Figure 9). This method is used worldwide and may be observed inshore and offshore in all sizes of craft and fisheries.

When a school of fish is favorably positioned near the surface of the sea the purse-seiner circles it at top speed, paying out its net from the stern, arriving back at the first end when just shooting the last. Thus, the ideal "set" shows a perfect circle of net floating on the water with the seiner positioned so that both ends of the net are on the boat itself.

When this is done, the pursing-winch is set into motion and the wire pursing rope, which is set in big loose rings along the bottom of the net, is tightened up until the net is drawn in or "pursed" at the bottom and the fish caught inside.

The net is then retrieved until the part in the water is diminished so that the fish are crowded alongside and may be dipped out with net "brails" or even pumped out if small enough. The net is retrieved, nowadays, by means of a large hydraulic pulley, commonly called a "power-block". The pulley has a deep V-shaped, rubber lined groove and the weight of the net, when compacted into a sausage shape in it, is sufficient to provide

PURSE SEINER
Medium Size



PURSE SEINE
Net

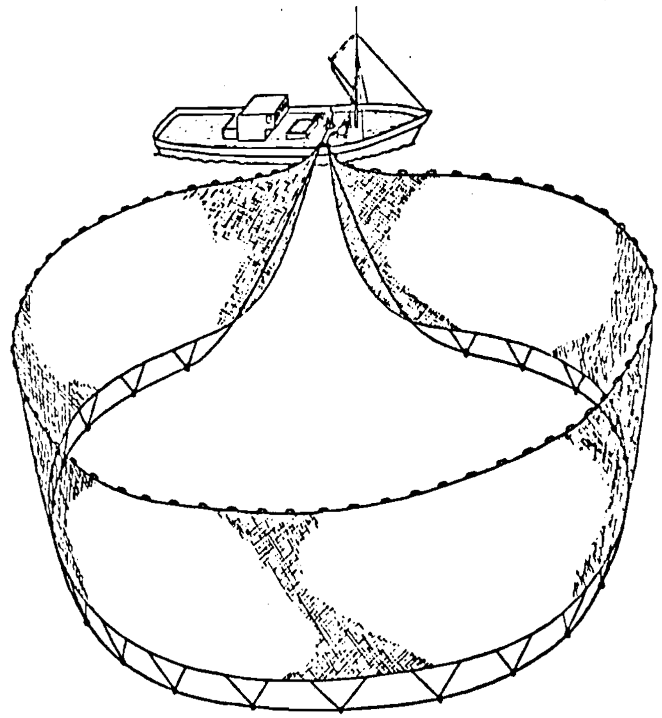


Figure 9: PURSE SEINERS

BEST AVAILABLE COPY

traction. The power-block may be seen at the top of a boom, at quite a height above the water. In rough waters, it may be positioned nearer the deck level where there is less danger of its pull capsizing a boat. The power-block enables a much smaller crew to be used and the net managed more easily.

The winching action and/or windage present may tend to pull the seiner into its own net. To avoid this a powerful skiff (motor boat) helps to tend the net but pulls the mothership away from the net when necessary.

Purse seiners are medium to large vessels from 30-75m with the wheelhouse forward, a high bow, and a long lower after-deck. A very large heap of net on the stern gives a characteristic hump, on which may be perched a 6 or 7 meter power skiff. The larger oceanic tuna seiner fisheries in the Eastern Pacific often carry spotter aircraft on deck. The stern may be sloped down to the water to facilitate operations.

A large boom heeled on the mainmast will usually bear a large power-block of at least 2 meter diameter. This power-block resembles a large narrow pulley and is over one meter in diameter. The purse-seine winch is placed so that the drum axes are fore and aft enabling the pursing wires coming over the side of the ship to enter the fair lead more easily. On some purse seiners fixed power-blocks are installed on pedestals so that they are about man-height above the deck. These deck fixtures may have three rollers (triplex) instead of one V-pulley. The net is pulled by this method and then taken up aloft on a smaller power block so that the net can fall vertically and be stacked in an orderly fashion ready for the next shot.

A brailer is a large metal ring, of about 2 meters diameter from which is hung a strong netting bag. This is lowered into the pursed net and the fish scooped into the bag. The dipped-up fish are released from the brailer by pulling a rope for a quick transfer from seine to ship.

A modern seiner may carry a bow-thruster device in its own hull, below the waterline. This transverse propeller, set in a tunnel is also used to keep a boat out of its own net (also useful for docking in adverse winds).

Development of oceanic purse-seining in the western Pacific has not yet been successful because of technical difficulties. These may include lack of thermocline which allows the fish to dive beneath a seine before it can be pursed; the extreme clarity of the water which allows the fish to see the net; and/or species-specific habits of the tuna in those waters compared to those in temperate zones or other areas where purse seining for tuna is highly successful.

Table 6 summarizes vessel length and tonnage data for purse seiners, pole-and-line boats, and longliners.

4.5 Clam Boats

For many years, Papua New Guinea has been visited by these types of vessels, the majority of which reportedly come from Taiwan (Photo 5). Their main purpose is to collect the giant reef clam which commands a high price in the Orient. Lobsters and other shellfish may also be taken, as well as trochus and green snail, but not usually in any significant quantity. They are fitted for fishing by skindivers which restricts their activities to reefs and other shallow areas. Since there are few shallow water and reef areas which are not claimed by one country or another these days, it follows that these ships are continually poaching as well as infringing on immigration, customs and quarantine laws and regulations. On the average, PNG deals with about a dozen such reported incidents each year with two or three vessels being arrested and the masters brought to court on charges of illegal fishing.

Gross Tonnage Class (Tonnes)	Overall Length (Metres)	Hull Type
1. Pole and Line		
39	19	Wood
49	20	Wood
59	20-24	Wood, Steel
69	24	Steel
79	27	Steel
145	33	Steel
192	35	Steel
350-450	70	Steel
2. Purse Seine		
500	71*	Steel
1,000	76*	Steel
3. Longline		
59	20*	Wood, Steel
<100	?	?
100-200	?	?

*Approximate only.

Table 6: VESSEL LENGTH — TONNAGE DATA

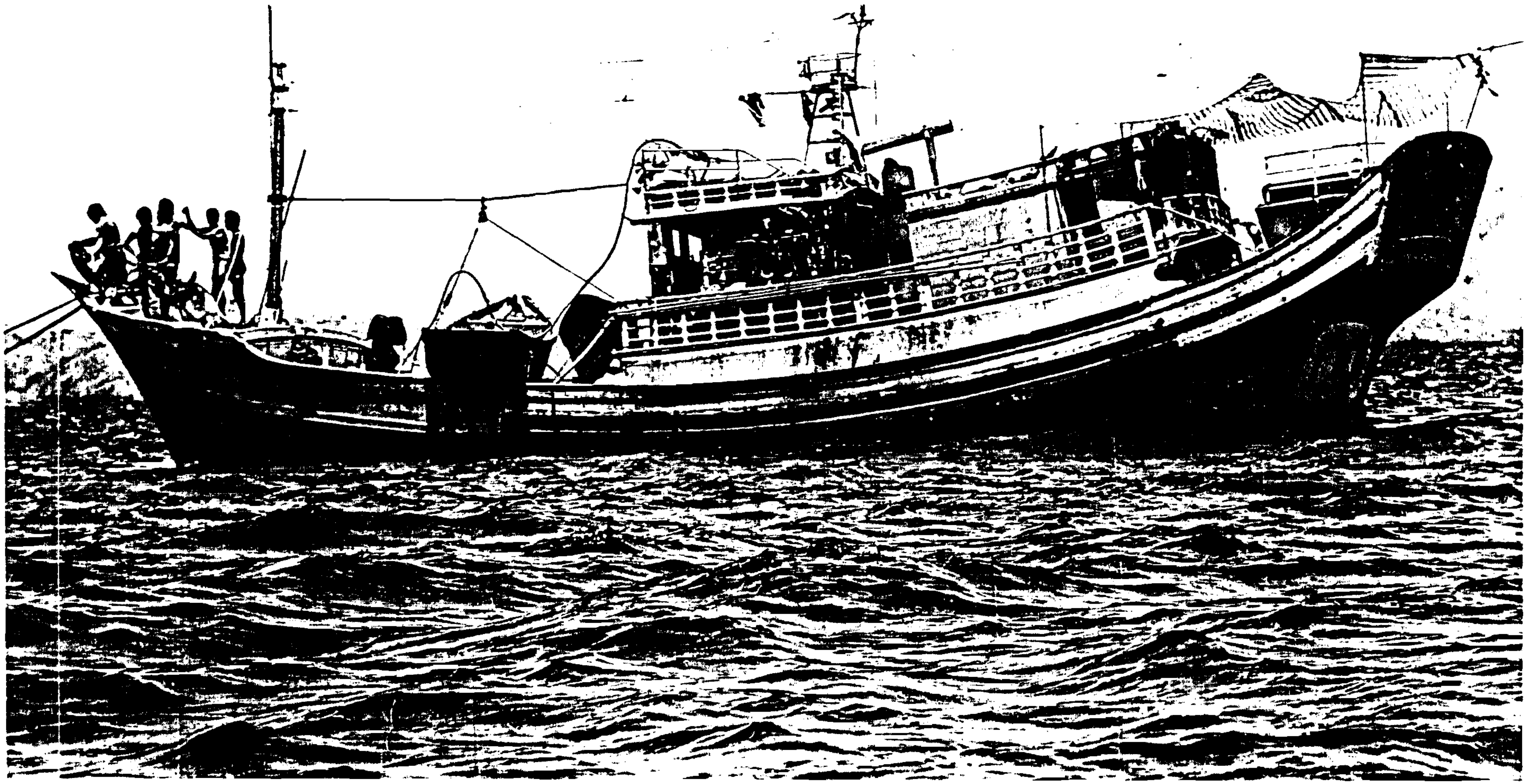


Photo 5: TAIWANESE CLAM BOAT
(Characteristic junk style.
Note diving skiffs on forward deck.)

BEST AVAILABLE COPY

Clam boats have the distinct "Junk" profile with the pronounced sheer of the deckline and a high poop. Dories for fishing on the reef are carried inboard and stowed athwart the deck amidships. The dories have diesel engines of about 6-8 hp and are about 5-6 meters long. When not fishing the dories are pulled inboard and stowed athwart the deck amidships.

These vessels have only one fishing method. The master looks around for a suitable patch of reef and sends his dories inshore each with about 4-5 divers in each and diving takes place in shallow water over the reef.

The produce is frozen and ultimately taken back home, but some groups of these vessels may sometimes work to a mothership one of which ran aground in the Western Island in June 1975. Another mothership was spotted off the Northern District in 1973. It was found sheltering with a group of catchers inside a island a few miles offshore.

4.6 Trawlers (Prawn and Others)

The word "trawlers" has become rather misused. Strictly speaking, a trawler is a vessel which fishes by dragging some kind of nets behind it. Trawling can be accomplished on the sea-bed (down to about 600 meters for practical purposes), in mid-water or on the surface. A trawler is a sturdy fishing boat with lots of power and with a winch capable of shooting and hauling heavy trawling gear (Photo 6).

Trawling in and around PNG is mostly for prawns. This takes place in moderate depths (down to 50 meters usually) over sandy or muddy sea-beds, usually where large silty rivers meet shallow sea-bed; the Gulf of Papua is the main PNG prawning ground.

Trawlers come in all sizes. Five meter dories can trawl in rivers and sheltered waters. Inshore trawlers can be anything from 10 to 15 meters. Offshore trawlers up to 30 meters are commonly seen in PNG waters. In some parts of the world, they run up to 70 meters, or even more.

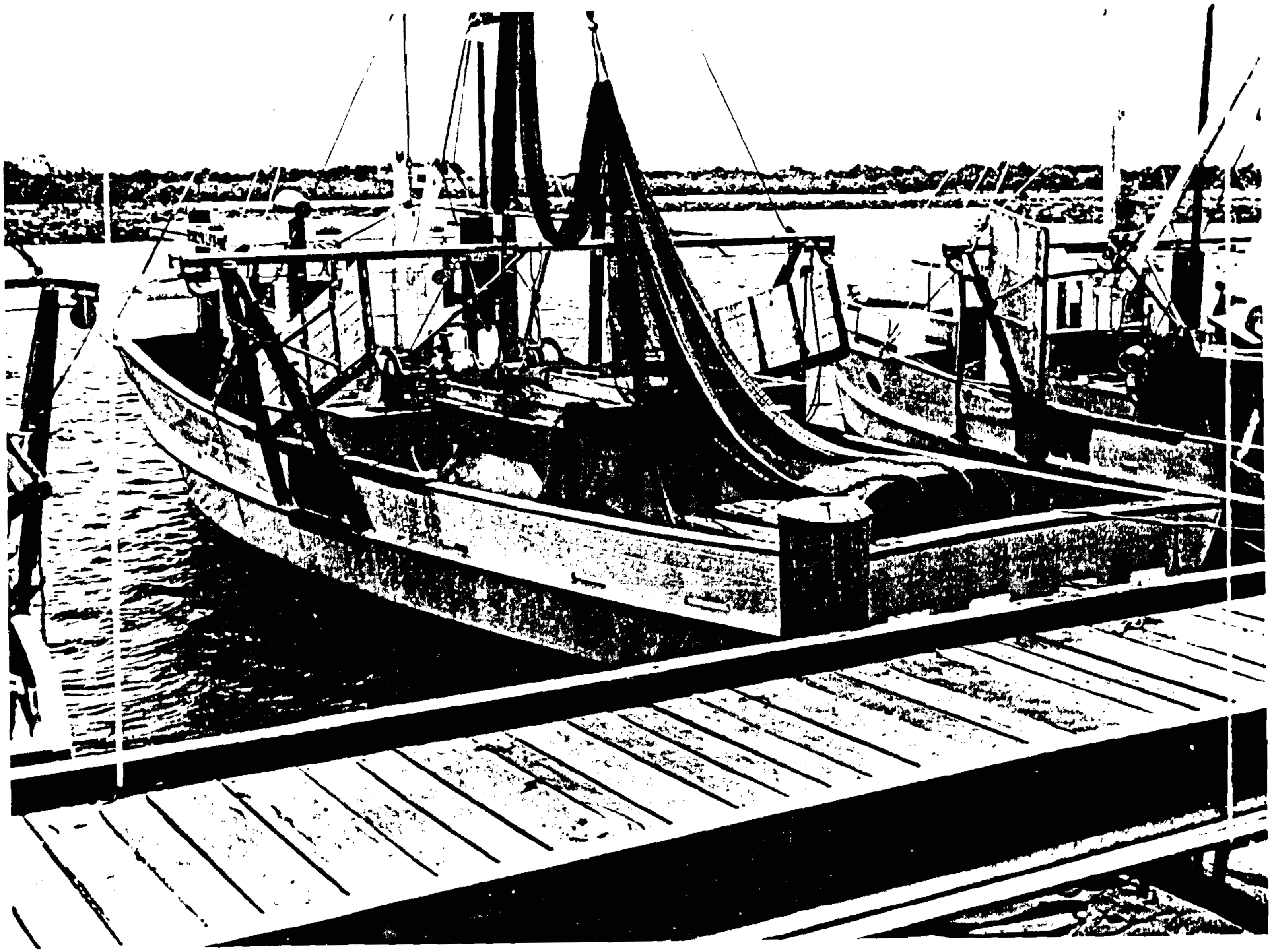


Photo 6: PRAWN TRAWLERS
(Note wooden trawl doors and winches amidship)

BEST AVAILABLE COPY

In PNG, bottom (demersal) trawling is more or less confined to the shallow waters of the Gulf of Papua in depths of about 20 to 30 meters. These trawlers range in size from 15 meters to 20 meters. Larger vessels of 30 meter size usually belong to foreign firms registered in PNG.

Trawlers usually have the wheelhouse forward with clear decks aft for easier working of gear. Probably 95% of the modern prawn trawlers are thus fitted, but the wheelhouse-aft position is still popular in some parts as many older trawlers still exist.

Trawlers have a powerful winch or winches on deck usually close to the wheelhouse, in front or behind, depending on the wheelhouse placement. Depending upon the type of fishing or design of the trawler, one of the following structures will be present:

a. two inverted "U" shaped brackets, about the height of a man, close to the ship's rail,

b. twin booms, either hoisted up vertically or lowered to within about 30 degrees of the horizon,

c. twin booms pivoted like gates on the ship's rail,

d. an "A" frame device stretching athwartships and supported by "A" frames near the ship's rails, possibly with sliding extensions.

To spread the net on the bottom, "trawl doors" or "boards" (sometimes called "otter boards") are used. These are rectangular wood and metal boards. They may be from about 2 x 1 meters, in dimension, up to very large models weighing over a ton on the larger trawlers.

The trawl doors are attached to the wing of the net so that they will keep the mouth of the net open as it is being towed across the bottom. The doors are also given a slight outwards inclination so that they not only sheer outwards, but also downwards thus keeping the net on the sea-bed.

The net is in the shape of a conical bag of heavy twine and has a chain and/or leads attached along the bottom and a few floats to the top (headrope). The mesh of a prawn trawler is small, about 35-50 mm to retain prawns; mesh for fish is larger.

5.0 PRESENT SURVEILLANCE AND REACTION CAPABILITIES

The Fisheries Division of the Ministry of Primary Industry is charged with enforcement of the fishing laws. It is assisted in both surveillance and enforcement by the military arm of the Government, the Papua New Guinea Defence Force.

The Fisheries Division maintains its own seaborne capability. Its fleet consists of two vessels, a confiscated Japanese longliner, "Der Yang", and a 45-foot double decker. These vessels are primarily research vessels, but are also used for enforcement. Der Yang has a cruising speed of eight knots and a range of 1,000 miles. Both vessels are based in Rabaul.

The Papua New Guinea Defense Force operates a fleet of five armed patrol boats and three Nomad patrol aircraft. The patrol boats were obtained with the assistance of the Royal Australian Navy and are about 11 years old. They are approximately 36 meters in length with 400 tons displacement and carry a crew of 19 (Photo 7). Armament consists of a 40mm Bofors MK VII gun mounted on the foredeck. Normal cruise speed is 12-1/2 knots, with a 19-1/2 knot maximum speed. Although a "normal" patrol cruise from their base at Manus Island may be one to one and one-half months long, the boats have limited fresh water carrying capacity and cannot stay at sea for more than three to four days at a time. These boats are equipped with Decca RM-916A radar systems which have a maximum range of 48 nautical miles (nm) (Photo 8). This radar installation can reportedly detect "Taiwanese clam boats" (wood construction, about 10 meters in length) at a range of about 12 nm, and the larger fishing boats (steel construction, 30-50 meters length) at twice this distance. On a typical patrol mission, two to three fishing vessels are encountered per month.

While on patrol, these boats report their position by radio twice daily, at 1000 and 1800 hours. These reports are sent "in the clear", and thus could be intercepted and read by anyone with a standard maritime radio receiver. There is some speculation that fishing vessels monitor these position reports and maneuver so as to avoid the PNGDF maritime patrols.

Photo 7: PNGDF PATROL BOAT "LADAVA"

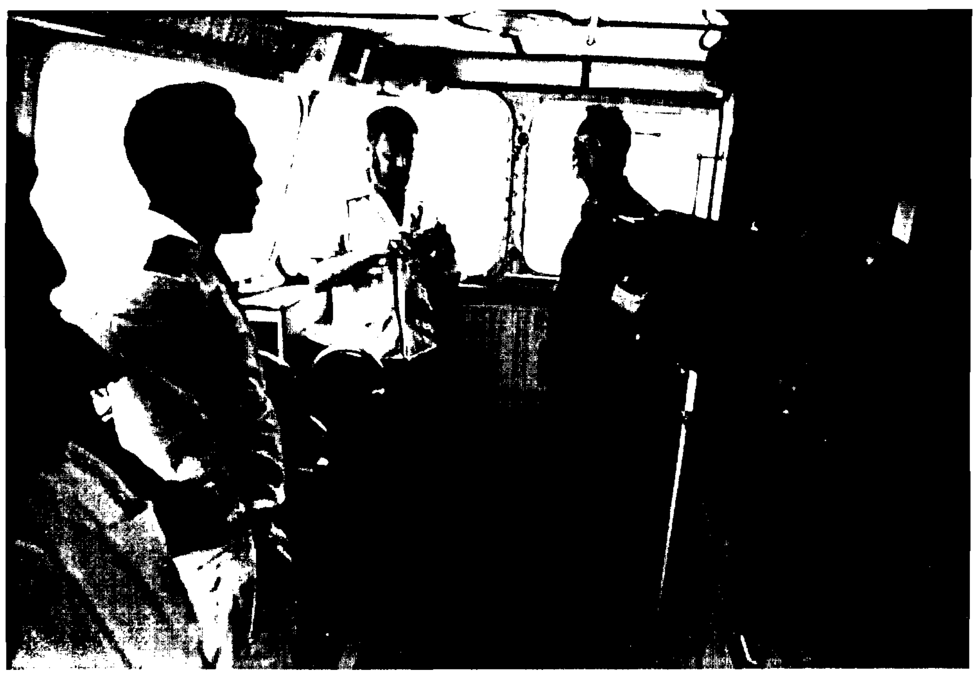


Photo 8: RADAR STATION ONBOARD PNG'S "LADAVA"
(Decca RM-916A)

BEST AVAILABLE COPY

The search aircraft currently in use by the PNG Government is the Australian Nomad Searchmaster 22B (Photo 9). Three of these aircraft are based at Lae. They are relatively new (the oldest is about two years old), in good condition and seem to be reasonably well maintained. The aircraft is powered by twin Allison B17 free turbine turboprop engines which together with double slotted flaps and spoiler/ailerons provide a flight speed range of 65 to 170 knots. Although the aircraft can be operated at altitudes well in excess of 10,000 feet, it is unpressurized and thus is seldom flown above this altitude for any extended time.

The aircraft are currently equipped with GNS-500A Omega/VLF navigation systems and Bendix RDR-1400 radar. On maritime surveillance missions, an auxiliary fuel ferry tank is installed in the cabin to provide an eight-hour mission capability with reserve (Photo 10). Missions are normally flown at altitudes of 1,500 and 2,500 feet.

One problem with this aircraft is the fact that with the ferry tank installed, full fuel, two pilots and one observer, the aircraft is at maximum allowable gross weight. If any additional equipment is added, such as advanced radar or electronic detection gear, then fuel will have to be off-loaded and flight time reduced. At the present time, the PNGDF aircraft are not equipped with autopilot or air conditioning, both of which should be added if regular long-endurance surveillance missions are to be flown. Addition of these items alone will cut approximately one hour off available flight time. Advanced surveillance gear and an additional crew member would decrease this time still further, to probably no more than six hours with adequate reserve.

The Bendix RDR-1400 system is mounted in the nose and scans through a horizontal angle of 120° (Photo 11). Although this system is basically a weather radar, PNGDF pilots report considerable success using it as a sea surveillance radar and have "detected clam boats" at ranges up to 30nm and the larger

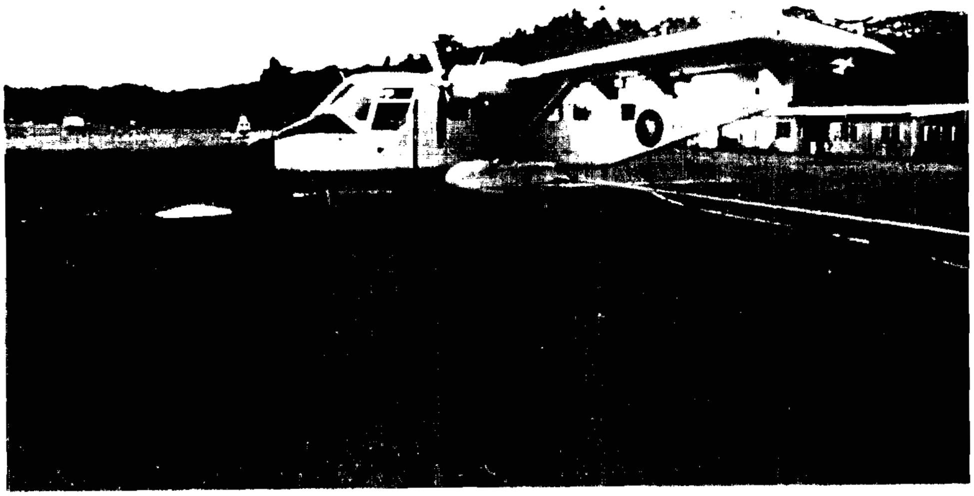


Photo 9: PNGDF NOMAD 22B AIRCRAFT

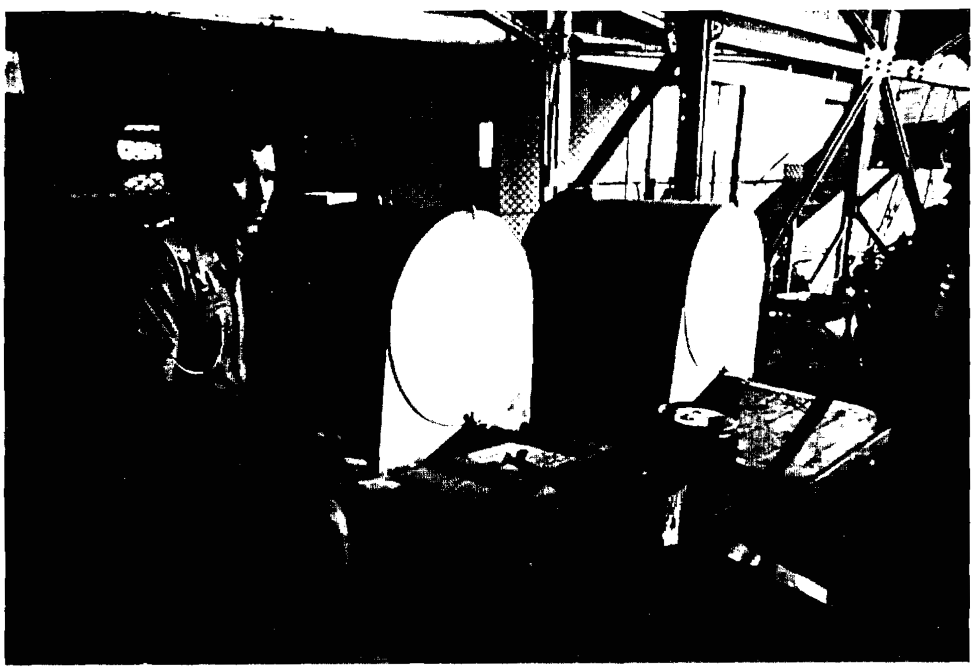


Photo 10: REMOVABLE "FERRY" FUEL TANKS
(Carried by Nomad 22B aircraft on maritime surveillance missions to extend flight time)

BEST AVAILABLE COPY

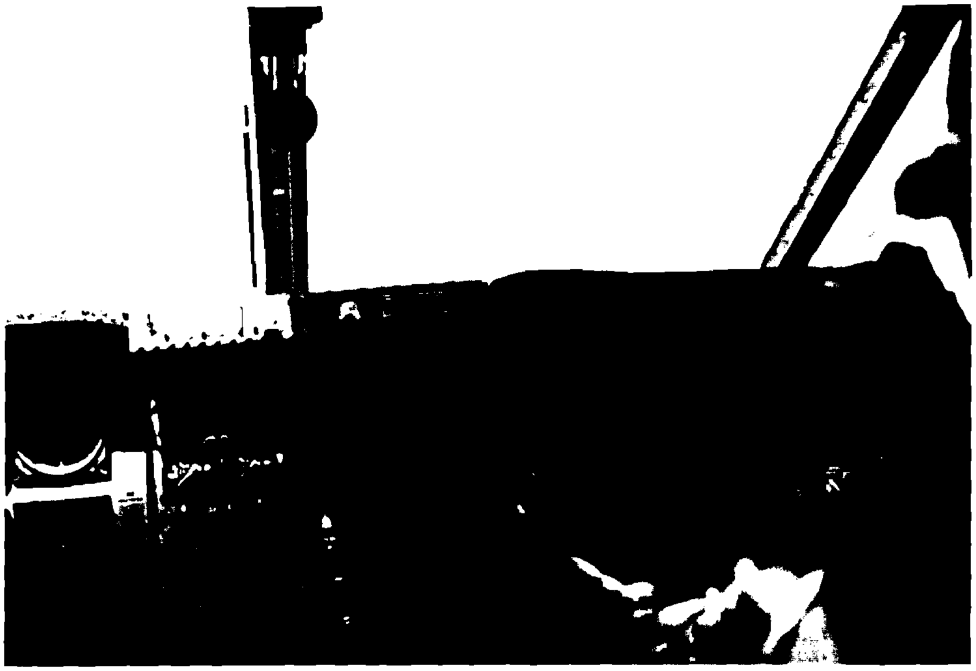


Photo 11: RADAR SYSTEM DISPLAY IN NOMAD COCKPIT
(The pilot is pointing out a radar
contact now inside 10 nm range.)

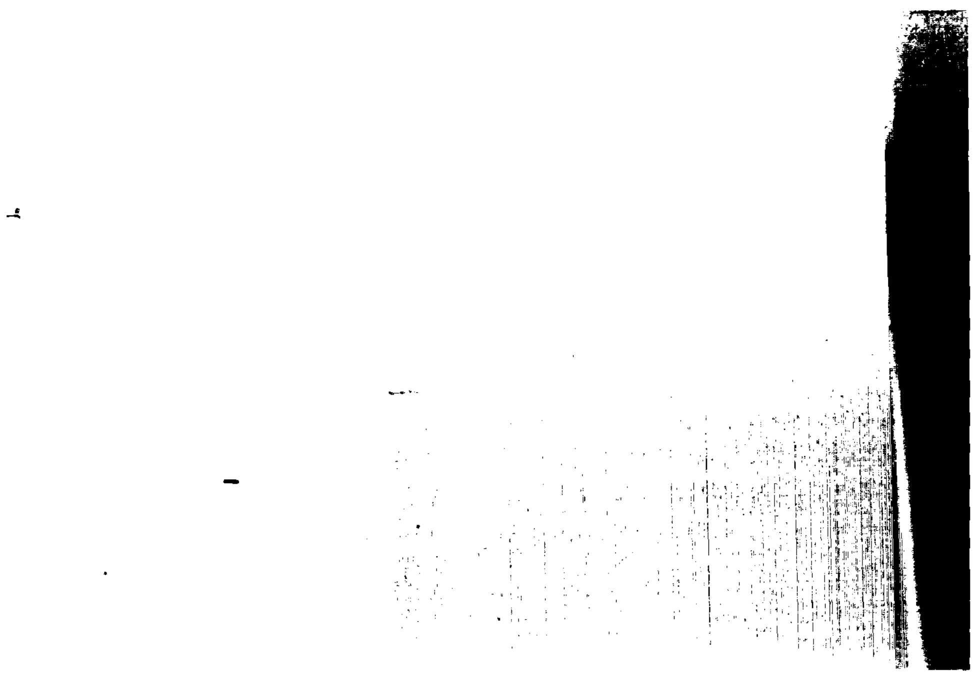


Photo 12: VESSEL SHOWN AS A RADAR CONTACT IN PHOTO 11
(Sailing canoe, wooden construction, estimated to be
about 15 meters in length)

BEST AVAILABLE COPY

fishing vessels at up to 60nm under ideal conditions. These ranges are unusual and about twice that normally expected under operational conditions. On a flight test conducted on December 7, 1979, few vessels of any size were picked up at ranges in excess of 20nm. One contact at 15 miles range turned out to be a sailing canoe (estimated 15 meters, wood construction) with a large sail (Photos 11 and 12).

Over the past two years, each of these aircraft has been operated at an average of about 400 hours per year for all purposes. At the present time, they are scheduled for one surveillance mission/fortnight, with a combined patrol boat/aircraft operation about once each month. Some communications problems have been experienced on these operations, not all of which have been due to equipment malfunction. During flight operations, the surveillance aircraft sends a position report every 30 minutes on CAA frequencies. Although these reports are sent in the clear and could be intercepted and read, positions are normally given as distances from pre-selected turning points and thus would be meaningless to the casual listener. It should be noted, however, that these coordinate points are sent via open telex a few days before the mission is to be flown, and these telex messages could be intercepted. Although this might seem an unlikely possibility, such patrol flight routes would be a matter of extreme interest to the master of any large and expensive fishing vessel, and this possibility of inadvertant disclosure could be easily guarded against.

The fishing vessels that are the object of these sea surveillance missions range in size and complexity from the small wooden 10-meter "Taiwanese clam boats" which may not even carry simple radio gear to 76-meter 1,000 ton steel-hulled purse seiners with elaborate radar and communications equipment, and the even larger "mother ships" that are floating refrigeration and processing plants. At any point in time 200 or more of these vessels may be actively fishing in PNG waters. Detection and identification are complicated by the size of the PNG Declared

Fishing Zone (over 750,000 square nautical miles) and by the presence of other coastal and transocean shipping that may produce a similar radar return.

There are at present over 240 registered PNG ships trading in PNG waters, in addition to transit vessels. Under existing law, all ships over 10 meters in length in PNG waters must report their position twice daily to the Coast Radio Station network. The "ships in range" summary reports prepared by the Coast Stations indicate an average of about 1,500 vessels worked per month. Unfortunately, as one observer noted, "fishing vessels never give accurate position reports, and really come on the air only when they need something". In November 1979, 14 foreign fishing vessels were known to be working one area of PNG waters. Only three of these were reported to be sending position reports as required, and these with questionable accuracy.

The operational surveillance task facing the PNG Fisheries Division is first one of detecting fishing vessels scattered among other ships over an extremely large area, second of unambiguously identifying these vessels and separating licensed from unlicensed ships, third of precisely locating their geographic position, and fourth, if warranted, directing and assisting surface vessels to intercept illegal traffic.

The presently existing PNG capability to accomplish this task is marginal at best. Over the past seven years, approximately 30 vessels have been caught and fined for illegal fishing, for an average of slightly more than four per year. Most of these have been small vessels. Two longliners have been captured, one that was sighted visually before being noticed on radar, chased and forced to heave to by the patrol boat PNGS AITAPE on June 19, 1978, and one that ran aground on Pocklington Reef on October 4, 1979. Reliance on conveniently placed reefs and visual detection from ships would seem less than desirable in any operational fisheries monitoring program.

6.0 ALTERNATIVE METHODS OF DETECTION, SURVEILLANCE AND MONITORING

Surveillance systems may be tailored to suit a variety of purposes and applications. Design of an appropriate and effective surveillance system requires, as a prerequisite, definitions of the overall goals of the system, specific detection and monitoring parameters, and restrictions placed on the system. Once these features have been defined, then various candidate approaches can be evaluated leading to selection of the most appropriate procedure.

6.1 Overall System Requirements and Considerations

Papua New Guinea's purpose in establishment of a fishing vessel detection, surveillance, and monitoring system is three-fold. First, as an expression of national interest and enforcement of national law, it wishes to detect violators of that law, specifically unlicensed fishing vessels fishing in the restricted areas of PNG's 200-mile Declared Fishing Zone. Such detection must be able to be expeditiously followed by enforcement action.

Second, PNG wishes to monitor the location of licensed fishing vessels, both domestic and foreign, in order to equitably assess appropriate tariffs in accordance with actual, rather than predicted, catch. To do so, they must also gather detailed catch data which may be correlated with the location.

Third, PNG wishes to obtain location-specific environmental and oceanographic data which may be correlated with fish catch. The purpose of this is to develop better prediction models which will lead to more efficient utilization of the resource and to a rational regional management process.

Design of a system to accomplish these goals must satisfy various system requirements. These include requirements for identification, location, total system capacity, real-time capability, peripheral data capability, cooperative versus non-cooperative targets, budget limitations, and potential military classification.

First, a detection system must be capable of not only detecting fishing vessels but also of differentiating them from other likely targets in the area, such as merchant vessels. Ideally, the system should also allow one to determine the type of fishing vessel and whether it is currently fishing or merely transiting the waters.

Second, the system must allow for accurate location of the target. In most of the waters of the 200-mile zone, no landmarks are visible. Location of the vessel is of prime importance since the entire legal situation is based on restriction from certain locales. Both the accuracy and frequency of location must be specified as system parameters. The required accuracy of the system can be quite crude from the standpoint of navigational standards. Most of the perimeter of the 200-mile zone does not lie near particularly critical fishing areas, with the possible exception of the area in the Gulf of Papua where the Australian waters extend to within 10 nautical miles or less of the PNG coast. Except for this small area, which happens to lie near productive prawn, clam, and lobster grounds, incursions only a few miles into the 200-mile zone would have a minimal effect. Thus, required accuracy of the system can be on the order of several nautical miles.

Frequency of obtaining a locational fix is another parameter. Ideally, one would want a continuous recording of movement of all target vessels. This is expensive and would appear to be impractical. A one/day fix is probably too infrequent. In 24 hours a large ship capable of making 20 knots could steam 100 miles into the zone, fish for 14 hours and steam out of the zone without being detected. A frequency of location of 4 hours might seem reasonable if it could be achieved. This would prevent deep incursions into the waters and severely limit fishing time for shallow incursions.

The total number of vessels which the system can handle; i.e., system capacity, must be addressed. At present, there are slightly over 100 licensed domestic and foreign fishing vessels operating in PNG's waters. At times in the past, over 400 vessels have used PNG waters during the year. Should the system be expanded to cover all waters of the South Pacific, a total system capacity of over 1000 will be required.

The surveillance system must have a capability to provide information in real time or close to real time. This is necessary if one wishes to have an enforcement capability. Should one wish to only document the locations of the vessels for later use (for instance, assessment of tariffs), then a real-time capability is unnecessary. In the case of PNG, enforcement is required and thus the system must provide data within a few minutes of real time.

It is highly desirable that certain types of peripheral data be gathered concomitant with the identification and location of the vessel. This data might include: daily catch by species, water temperature, pH, salinity, total dissolved solids, total organic carbon, atmospheric pressure, or other parameters.

The total surveillance system must be capable of detecting and monitoring the location of cooperative and non-cooperative targets. A cooperative target is a vessel, presumably licensed and acting within the law, which will cooperate with the surveillance system. Such cooperation might require, as a condition of licensing, the installation of an electronic device which would aid the surveillance system in tracking the vessel. A non-cooperative target is one which intrudes into PNG waters unknown to any authorities and which might make definite efforts to do so surreptitiously.

In actuality, the division as cooperative or non-cooperative is an arbitrary one. Vessels "cooperate" only because it is in their best interests to do so. Vessels purchasing licenses to fish in PNG waters do so primarily because <u>failure</u> to do so carries with it the threat of capture by PNG with subsequent heavy fines and confiscation of gear. If PNG had no aerial maritime surveillance capability and no surface patrol vessels, then it is likely that fewer fishing vessels would concern themselves with the formality of license purchase. An enforcement system (patrol boats) is therefore required both to capture "non-cooperative" targets and to insure that "cooperative" targets continue to cooperate.

Cost and manpower is a serious consideration for a program of this sort. Should it be necessary to install hardware on individual fishing vessels, the costs of such hardware must be kept to a minimum. It is anticipated that any such costs will be directly passed on to the fishing vessels as part of their license fee. Present license fees range from $5,000 to $10,000/year for foreign vessels operating in PNG waters. The cost of the shipboard hardware should not exceed this by any substantial amount or it may discourage foreign vessels from entering the waters..

Many surveillance techniques are militarily classified. Even though there may be classified techniques appropriate to the task, the design of this system must be such that it remains unclassified by the any government. If possible, all basic hardware design should be commercial off-the-shelf.

6.2 Alternative Techniques of Remote Position Location

The detection, surveillance, and monitoring system requires that the position of a vessel must be determined remotely. There are at least five feasible methods by which one may do so. They include photographic and imaging methods, radio determination methods with a data relay, remote radio determination methods, doppler shift satellite methods with a data relay, and remote doppler shift satellite methods. All will allow a remote observer to monitor the movement of a vessel. Each has its advantages and disadvantages from the standpoint of effectiveness and cost.

6.2.1 Photographic and Imaging Methods

Taking an aerial photograph of a vessel from a known location is one of the most obvious means of locating that vessel. Likewise, scanning the vessel with an optical scanner (a device used to create a photo-like "image") in either visible or infrared bands can also provide one with its location if the location of the scanner is known. Platforms to carry a camera system or a scanner system can be either aircraft or spacecraft. Photographic systems are commonly restricted to use in aircraft since it is difficult at best to retrieve film from spacecraft. Scanners, which may create an image in discrete wavelength regions ("colors") ranging from the ultraviolet to the far or thermal infrared ("heat pictures"), are used in both aircraft and spacecraft. They are particularly useful in collecting images from space in that the data making up the image are collected in a serial bit stream and may be easily telemetered to earth and reconstituted in the same manner.

Aerial photographs are commonly taken with special aerial cameras mounted through the belly of an aircraft. The area covered by an aerial photograph depends on both the altitude of the aircraft and the focal length of the camera. For example, when flying at 10,000 feet with a six-inch lens, a single aerial photograph covers an area of 8 square miles. An aircraft traveling at 150 mph can take 53 such photos per hour for a coverage of 424 square miles/hour. The total area encompassed by the 200 mile Declared Fishing Zone is 750,000 square miles. Thus coverage of the whole area would take almost 1,800 hours of flying time. This is too great, by several orders of magnitude, to be considered as an effective search tool. Aircraft imaging systems likewise cover too small an area per unit of search time to be considered.

Spacecraft systems do not have this disadvantage. Images from spacecraft scanners commonly cover an area of 10,000 to 30,000 square miles. Only a few such images would be necessary to cover the total area of PNG waters. Unfortunately, most spaceborne scanner systems are limited by their spatial resolution or ground resolution. Ground resolution may be defined as a dimension that is equivalent to the smallest object that can be distinguished on the ground when that object presents a high contrast (1000:1) with the background. Most satellite scanner systems have been designed to image large features such as land masses or weather systems. Their spatial resolution is quite poor. Table 7 outlines the spatial resolution of some representative imaging and photographic sensors, both airborne and spaceborne. As can easily be seen by a casual inspection of the table, even the best satellite systems have resolutions larger than or at best approximating the size of a large fishing ship. Even in cases where the size of the ship is 1-2 times the resolution, one would find that the image of the ship would be unrecognizable. It might consist only of 1 or 2 bright dots on the image and would not be identifiable as a ship.

Thus, it would appear that such techniques are inappropriate for the detection, monitoring, and surveillance of fishing vessels. However, the data from many of these sensors may be quite valuable as a source of oceanographic data for the fishing industry. In particular, Landsat, Seasat, the Coastal Zone Color Scanner of Nimbus-7, and the infrared scanners of the TIROS-N weather satellites are providing data useful to the scientific fisheries community. Appendix A provides examples of data available from many of these systems and a brief description of their capabilities.

In summary, photographic and imaging systems provide the following advantages and disadvantages for fishing vessel surveillance:

<u>Advantages</u>

a. Aerial photography can provide a positive documented identification of a fishing vessel which when combined with a known and documented location of the aircraft will locate the fishing vessel.

b. Satellite images cover a vast area, necessitating only a few to blanket PNG's DFZ

<u>GOES + SMS VISSR</u>	
o Visible	1,000 meters (3,281 feet)
o IR	8,000 meters (26,248 feet)
<u>Japanese GMS VISSR</u>	
o Visible	1,250 meters (4,101 feet)
o IR	5,000 meters (16,405 feet)
<u>TIROS-N AVHRR</u>	
o High Resolution	1,100 meters (3,609 feet)
o Standard Resolution	4,000 meters (13,124 feet)
<u>Nimbus-7</u>	
o CZCS	825 meters (2,706 feet)
<u>Landsat</u>	
o MSS	78 meters (256 feet)
o RBV	40 meters (131 feet)
<u>Seasat</u>	
o SAR	25 meters (82 feet)
<u>Airborne SLAR</u>	
o Westinghouse APQ-97	15 meters (50 feet)
<u>Airborne Imaging Scanner</u>	
o 1.0 mrad. angular resolution @ 20,000 feet	6 meters (20 feet)
<u>Aerial Photography</u>	
o 10,000 feet with 6-inch lens:	
-- with 25 lines/mm resolution	2.6 feet
-- with 630 lines/mm resolution	0.1 feet
o 40,000 feet with 6-inch lens:	
-- with 25 lines/mm resolution	10.5 feet
-- with 630 lines/mm resolution	0.4 feet

Table 7: SPATIAL RESOLUTION OF REPRESENTATIVE IMAGING AND PHOTOGRAPHIC SENSORS

Disadvantages

a. Spatial resolution of all satellite scanning systems is insufficient to see fishing vessels.

b. Frequency of coverage of most satellite systems is insufficient to monitor vessel movements.

c. Aerial photography, in a search or reconnaissance mode, is an extremely slow process covering relatively small areas. Daily coverage of PNG's waters is impossible.

d. Aerial photography does not present data in real-time.

e. Satellite imagery may be obtained real-time only with the use of extremely expensive and sophisticated ground stations.

6.2.2 Radio Determination Methods with Data Relay

Various radio-determination techniques have been in common use as shipboard navigational tools for many years. These techniques allow the navigator to determine lines of position relative to synchronized pairs of radio transmitters on shore. Thus, the navigational fix is determined onboard the ship from information received remotely. In order for a shore-based system to monitor the location of the ship, it would be necessary to transmit to the monitoring system the navigational data received on the ship. Such a system could be automated. Upon receiving a coded request from the shore station, the automated shipboard system would receive the appropriate radio determination data and relay it to the shore station where it could be reduced and plotted, thereby providing a remote navigational fix on the position of the ship.

The basis of most of the radio-determination position-fixing systems is that it is possible to measure the difference of the distances to two radio transmitting stations which transmit signals either simultaneously or with a known and fixed lag. The time delay in receiving one signal after the other corresponds directly to a difference in distance. The loci of all positions having a constant distance (time) difference describe a hyperbola whose foci are the transmitting stations.

The differences of distance are measured on the surface of the Earth, taking into account the shape of the Earth. If the shape of the Earth is considered to be a sphere the lines of constant difference in distance are called "spherical hyperbolas". If the shape is considered to be an ellipsoid the lines are called "spheroidal hyperbolas". The lines are shown on charts.

On the charts, time differences for hyperbolic position-fixing systems are indicated in microseconds or other units near the hyperbolas. This enables the navigator to determine for a certain region the distance in nautical miles corresponding to a change of, say, 1 microsecond in the time difference. For this, he only has to divide the number of nautical miles between the two adjacent hyperbolas near the position of his ship by the difference in the microsecond values marked near the hyperbolas.

By measuring the difference of the distances to two fixed points the navigator is furnished with a line of position of a hyperbolic character. A similar measurement to two other fixed points gives a second line of position, and the point of intersection of the two lines is the position of the navigator.

Many such radio-determination systems have been devised. They differ mainly in their methods of calculating a time difference and in their frequency. Some use phase differences; some use times of first arrival of pulses.

Frequencies start with Omega at 10-14 kHz and continue to Loran-C, Loran-D, and Decca at or near 100 kHz; and marine navigation and positioning systems such as Loran-A, ARGO, Lorac, Decca Hi-Fix and Sea-Fix, and Raydist in the range from 1.6 to 5.0 MHz.

The greatest drawback to these systems is that the vessel must be within range of at least two pairs of transmitters. These systems are in general established only in certain parts of the world, commonly the heavily-travelled shipping lanes. The only system of this type presently covering the Papua New Guinea waters is the Omega system.

Details of the Omega system may be found in section 7.2 and Appendix D of this report.

6.2.3 Remote Radio Frequency (rf) Determination Methods

There are several means of directly locating the position of a vessel from a remote location using rf methods. Either active or passive systems may be applicable. An active system is one which actively emits an rf signal and then listens for a reflected return of that signal. Radar is such an example. A passive system emits no signal. It merely "listens" to signals emitted by other sources, in this case, presumably fishing vessels. An example is a radio direction finder.

Two general principles are used in radar sets: a continuous transmission of electromagnetic radiation and the measure of phase shift of radiation returned from a moving target, and discontinuous or "pulsed" transmission. Radar sets using continuous transmission take advantage of the doppler effect, by which the frequency of the echo wave is changed when the object, which reflects the wave, is moving toward or away from the radar. By knowing the frequency shift as a function of the speed, it is possible to detect the presence and speed of an approaching target. Radar sets using discontinuous or "pulsed" radiation depend on the accurate measurement of the time required for the radiation to travel to the target and return to the set. Using this principal combined with the knowledge of the direction (azimuth and inclination) in which the radar is pointing, it is possible to accurately determine the location of a reflecting target.

Radar is desirable for the following reasons. It is an all-weather sensor. It has typical dynamic range of 70 db compared with 30 db for photography. Maximum attentuation for heavy rain is up to 20 db. There is little spectral influence from the atmosphere and large areal coverage is possible.

Sidelooking imaging radar (SLAR), was developed for use on aircraft to produce a photograph-like image of terrain. A narrow fan beam of rf energy is transmitted from an antenna ("aperture") and the return across the "fan" is imaged on a CRT oscilloscope. The forward motion of the aircraft permits successive parallel and adjacent bands to be imaged sequentially. The bands are photographed by a camera in which the film moves continuously at a uniform rate synchronized with the speed of the aircraft. Two types of sidelooking imaging radars have been developed; "real aperture" or "brute force", and "synthetic aperture" or "coherent" systems.

Real aperture radar uses a single large antenna whose size is proportional to the resolution achieved. Rf energy transmitted by real aperture sidelooking imaging radar sets is polarized, generally in a horizontal or vertical plane. Most sets are designed to receive cross polarized return radiation.

Although the terrain image produced by photographing the CRT oscilloscope resembles an aerial photography of the terrain, it differs in many respects from an aerial photography, both as to geometry and information content. Examples of real aperture systems are those of Motorola (X-band) and Westinghouse (Ka-band).

Synthetic aperture sidelooking radar makes use of doppler frequency shifts and associated phase history to achieve the effect of a very long antenna. The actual antenna or aperture used may be but a few meters long, but the effective length that is achieved electronically is many times the actual length; hence, the term "synthetic aperture". As the spatial resolution of a real aperture sidelooking radar system depends mainly on the beam width, and as the beam width depends on the length of the antenna (aperture) in multiples of the wavelength of the rf energy, the longer the antenna (greater the aperture), the narrower the beam and hence, the smaller the object or feature that can be resolved. Conversely, two or more objects at the same range within the beam formed by a single pulse (and thus, imaged by a single scan) are not distinguished from each other. The major advantage of synthetic aperture SLAR is that its azimuthal resolution is independent of range. The Goodyear X-band SLAR is an example of such a system.

Sidelooking imaging radar systems are commonly installed in high speed aircraft. Dual systems, one looking out of each side of the aircraft, can image a swath of approximately 60 miles in width. If the aircraft travels at 300 mph, area covered equals 18,000 square miles/hour. In 42 hours flight time, the DFZ of PNG may be covered. With a fleet of 10 such aircraft, the zone could be monitored twice a day. The cost of such a system (radar and aircraft) would be extremely high.

Sidelooking radar presents another problem. Except for certain classified systems, the images cannot be inspected real-time. They must be returned to a base for reconstitution.

Radio direction finders may be used to determine the location of a remote transmitter when it is transmitting. All ocean-going vessels are equipped with radio equipment, and a large percentage also carry radar for navigation. Radio frequencies are allocated for specific uses by international agreement and each radio-equipped vessel is assigned an international radio call sign for use in identifying its radio messages. Likewise, navigational radar frequencies are confined to specified bands and the kind of radar (and its characteristics) carried by a particular vessel can frequently be determined from official or semi-official records.

The foregoing circumstances raise the possibility of detecting and/or classifying foreign fishing vessels by inspecting and analyzing their radio or radar emissions. Two techniques are potentially applicable. One, based on direction finding, provides a means for determining the position of detected targets. The second involves the classification of a detected target on the basis of information derived from intercept of its radio transmissions. Both techniques can be combined in a single system.

The technology for both the vessel radio and radar equipment and equipment for direction finding and communications interception and analysis is highly developed and numbers of systems have been developed both for military and civilian use. Direction finders and intercept/analysis equipment can be operated on shore or from floating or airborne platforms.

A radio direction finder consists of a receiver and antenna system used together to determine the direction of incoming radio waves. Simple direction finders may use a loop antenna or a series of loop antennas. The antenna is rotated about a vertical axis until the amplitude of the received signal maximizes. At this point, the plane of the loop intersects or points toward the transmitter. When the loop receives no signal, its plane is 90 from the direction of the transmitter. More sophisticated systems may employ directional parabolic dish antennas which receive signals only from the direction in which they are pointing. At any one time, a single direction finder can provide a single line of position. Several direction finders in different locations simultaneously receiving the same signal can provide several lines of position which will intersect at the location of the transmitter. Likewise, a single direction finder moving at a high speed relative to the transmitter (as in an aircraft) can plot several lines of position over a short period of time and thereby also triangulate a position.

Any radio frequency transmission may be used by a direction finder as long as the receiver is capable of receiving that frequency. Such transmissions might include voice or cw transmissions, radio beacons placed onboard the vessel, or the vessel's own radar system. One must first determine the frequency on which the target is transmitting, tune his receiver accordingly, and then determine the direction. In order to determine the frequency, one may use a frequency scanner, a receiver which rapidly scans all frequencies and indicates those which are transmitting.

The propagation range of radio and radar signals depends largely on the radio frequency. In general, radio frequencies above about 30 MHz are limited to line-of-sight. However, depending on ionospheric conditions, radio frequencies below 30 MHz (HF) may propagate by skywave well beyond line-of-sight and international boundaries. Because of extended range skywave propagation, HF direction finding (DF) has the potential to cover large areas of earth. However, this area coverage is constrained by signal frequency, time of day, season of the year, latitude, and sun-spot cycle. Thus, areas of immediate interest may not be accessible for hours, months, or years from a land-based DF station. The line-of-sight range for signals above about 30 MHz requires that the direction finder be within line-of-sight for signal intercept and DF. This range can be extended by the use of airborne and space platforms.

The technique for HF radio direction finding is highly developed. A DF network consists of two or more DF stations, which are tied together via a communications system. The exchange of signal frequency, and signal bearing information between the DF stations, allows the location of the signal source to be determined by triangulation. The sophistication of the DF network ranges from one-man, manually-operated, portable DF stations to highly-automated, fixed-site, DF stations each costing several millions of dollars.

Most military surveillance services have airborne HF, VHF, and microwave DF systems. Modern systems use onboard digital computers to tune radio receivers, make DF measurements, apply known corrections, and to exchange data between other airborne systems for real-time triangulation. These systems not only plot lines of position to transmitters, but perform analyses of the signal to allow unique identification of radar types and in some unusual cases, identification of unique transmitters.

An airborne platform at 20,000 foot altitude will have a line-of-sight range of 175 nautical miles and will be able to receive radio signals from an area of 95,000 square miles. With a platform speed of 300 knots it is possible to have a line-of-sight access to 200,000 square miles of sea surface per hour. Two or more airborne platforms can be used to decrease the time to intercept and locate an emitter. These aircraft can be flown at, say 100-mile separation and can be coordinated in DF operation so that a near instanteous triangulation may be made.

This type of operation requires an air-to-air data link between the aircraft. Preferably, one aircraft is the master interceptor and controls the receiver tuning and direction finder operation in the slave aircraft via a digital data link. A single airborne platform may be used to take one, or more, DF cuts on the emitter as the aircraft flies a known path.

Since most ship-to-shore radio communications are infrequent and of short duration, they are difficult to use for DF purposes. Radar systems are another matter.

A discussion of the operational utility of rf direction finding systems is presented in Section 7.3.1 of this report.

6.2.4 Doppler Shift Satellite Methods with Data Relay

Doppler shift navigation is a passive technique relying on the principle that the orbits of earth satellites follow precise laws. If one knows the satellite orbit, doppler shift measurement of the signal emanating from the satellite can be used to determine one's position on the earth. The doppler shift experienced by a signal received at a fixed point on the earth's surface from an orbiting satellite may be expressed by the formula:

$$\Delta f = \frac{f_o Vr}{c}$$

where:

Δf is the doppler shift in Hz

f_o is the carrier frequency in Hz

v_r = the relative velocity between the satellite and the fixed point

and c = the speed of light (in the same units as v_r).

Satellites in near-earth orbits (around 600 NM) have a tangential velocity of 3.86 NM per second. This would produce a relative velocity (v_r) of about 3.28 NM per second between a point on the earth's surface and the satellite as it appears to rise over the horizon from that point. From the above equation, this would produce a doppler shift of $20.2 \times 10^{-6} \times f$. Assuming a carrier frequency f_o of 150 MHz, the maximum doppler shift under the above conditions would be about 3 KHz.

The U.S. Navy Navigation Satellite System (NVSS), better known as TRANSIT, employes this doppler technique with a series of polar orbit satellites orbiting the earth at a nominal altitude of 1100 km. Stable carrier frequencies of 150 and 400 MHz are radiated from the satellites and received by specially designed shipboard receivers which measure the doppler shift against an offset frequency of known value. The doppler shift is plotted as a function of time and the ship's position computed from this data plus the orbital parameters of the satellite.

Since the doppler shift technique requires only that the vehicle receive and measure the signal characteristics, it is relatively immune from jamming, will permit an unlimited number of users, and eliminates all chance of disclosure of vehicle location. Motion by the receiving platform must be accurately accounted for.

Details on the TRANSIT system may be found in Section 7.2 and Appendix D of this report.

The system of the future is the NAVSTAR Global Positioning System (GPS). Although it is not yet operational, it may revolutionize navigation with its potential accuracy. It cannot be considered for the present fishing vessel surveillance requirement, but it may be an option for future systems.

GPS will consist of a constellation of satellites, a master control station, four tracking stations (including one at master control), an upload station (also at master control), and an unlimited number of users. The satellites will broadcast navigation information continuously so that any user located in any part of the world will be able to compute near-real-time fixes at any time. In addition, time dissemination accurate to fractions of microseconds will be made available.

A total of 24 satellites, eight in each of three circular planes, and approximately 20,000 kilometers in radius, will comprise the space segment. This will ensure that at least six satellites will be "visible" at any given location and time. The first of these satellites was launched in the summer of 1977. By 1981, 9-11 satellites are to be in orbit, providing periodic precise three-dimensional and continuous coarse two-dimensional capability.

User equipment development is presently under contract to the U.S. Department of Defense. The initial user sets will be used exclusively for tests and evaluation by the DOD and DOD-contracted agencies. Present contracts are for six classes of equipment which are for high accuracy, medium dynamics of user; high accuracy, high dynamics of user; medium accuracy, medium dynamics of user (low cost); high accuracy, low dynamics of user; a manpack; and submarine applications. The GPS user equipment will be quite different from TRANSIT equipment. In addition to the different frequencies, signal structure and modulation methods, the outstanding differences between the systems are that GPS operates on three or four satellite signals simultaneously as compared to one for TRANSIT, and the ranging method is one of "pseudo-ranging" for GPS whereas TRANSIT operates on doppler information.

The basis of GPS ranging is that the satellites transmit time ticks with a "tag" which indicates the time it was transmitted. The user equipment determines ranges to the satellites by measuring the difference between the time that the signal (tick) is transmitted and the time that it is received (distance equals time multiplied by signal propagation velocity). If this is done for three satellites (three lines adequately define a point), a position is described which is in error by the amount proportional to the difference between the user and satellite clocks. Time can be solved by ranging on one additional satellite (4 equations, 4 unknowns, X, Y, and Z coordinates and time). Since each signal contains a time-bias error, the individually determined ranges are called pseudo-ranges.

Present predictions are that GPS will provide instantaneous three-dimensional fix accuracy of about 13 meters, two-sigma (8 meters in the horizontal plane), when dual-frequency four satellite reception techniques are observed. Accuracy predictions have become better as the GPS program has developed and improved error reduction techniques have been developed. The final result may be that the system will provide better accuracy than that presently projected.

In the case of either TRANSIT or GPS, the system is designed to provide locational information onboard the ship. In order for a remote observer to monitor the location of the ship, he must have that data relayed to his monitoring post in much the same manner as that described in Section 6.2.2.

6.2.5 Remote Doppler Shift Methods

In the doppler satellite methods previously discussed, the satellite transmits a frequency which is received by the shipboard receiver. The receiver measures frequency shift and calculates a line of position for the receiver, knowing in advance the position of the satellite. If this process is reversed, then it is possible for the satellite to determine the position of a ground-based transmitter. A transmitter, placed aboard a ship can transmit the fixed frequency. The satellite can receive the signal, calculate doppler information and transmit the information to a shore station.

This is the principle behind the position-locating capabilities of the Nimbus-7 and TIROS-N satellite series. Nimbus is a prototype NASA experimental satellite. TIROS-N is an operational outgrowth of the NIMBUS experiment. TIROS-N, which is primarily an imaging weather satellite, is operated by the U.S. National Oceanic and Atmospheric Administration (NOAA). One of the instrument systems onboard is the ARGOS Data Collection System. The ARGOS system has two primary functions. It locates, by means of the doppler shift, the position of certain types of radio transmitters and then acts as a data relay to retransmit digital data provided by the transmitter system.

The ARGOS system requires a cooperative target. The vessel must install a small radio transmitter which intermittantly transmits a string of digital data at a precise frequency. The digital data contains information regarding vessel identification, and any peripheral data desired, such as digitized data from a series of oceanographic sensors. The radio receiver onboard the satellite receives the data and calculates the doppler shift. It then does two things simultaneously. It stores the data on an onboard tape recorder for later transmission to a ground station in France and it immediately retransmits the data to any local receiving station within range.

The receiving station receives the data from the satellite. The data consists of transmitter ID, several doppler shift measurements, and the peripheral data. A microcomputer at the receiving station then calculates the latitutde, longitude, and elevation of each transmitter.

Details of the technical aspects of the TIROS-N ARGOS system may be found in Appendix B and section 7.1 of this report.

7.0 RECOMMENDED ALTERNATIVE SURVEILLANCE AND MONITORING SYSTEMS

The applicability of each of the techniques investigated has been summarized in Table 8. Each technique has been evaluated in regard to its capability to satisfy the general system requirements outlined in Section 6.1. An inspection of this table allows one to easily discard various techniques and to select those which should be pursued. Table 9 outlines relative surveillance rates (square miles covered/hour) of all airborne systems which were considered. A more detailed explanation of airborne coverage is found in Section 8.0 of this report. This information allows one to estimate the number of continuously operating search units required to cover the DFZ for any particular frequency of location.

Aerial photographic, imaging and visual methods can be discarded because of their low surveillance rate and consequent high cost. Imaging from satellites cannot identify or locate a vessel because of limitations of spatial resolution. Imaging radar cannot easily identify vessels, provide data in real time or gather meaningful oceanographic data and its cost is high. This leaves as possibilities only OMEGA or TRANSIT with data relays and the TIROS-N ARGOS system for cooperative targets. Details regarding these systems are included in this section.

The best alternatives for the non-cooperative targets are surface search (sea surveillance) radar and passive RF direction finding. The direction finding technique is commonly referred to by many other names, among them electronic intelligence (ELINT), electronic detection, electromagnetic intercept, and electronic signal monitoring (ESM). At least one special purpose surveillance aircraft would be required with these systems.

The PNG Fisheries Division is seriously considering the purchase of a maritime surveillance aircraft. Although not a formal requirement of this study, a brief analysis of candidate aircraft has been included as Section 7.4 of this report. Such an analysis is necessary to insure that the aircraft is compatible with the operational requirements of the recommended surveillance systems.

Alternative Techniques	Capability to Identify Vessel	Capability to Locate Vessel	Frequency of Location	System Capacity	Surveillance Rate	Real-Time Data	Peripheral (Oceanographic) Data Gathering Capability	Cooperation Required	Capital Cost* Range of Total System
Visual (from aircraft)	Yes	Yes			Low	Yes	No	No	High**
Aerial Photography	Yes	Yes	Dependent on # of aircraft (infrequent)	Unlimited	Low	No	Yes	No	High**
Aerial Imaging	Yes	Yes			Low	Yes	Yes	No	High**
Satellite Imaging	No	No	N/A	N/A	Medium	Possible	Yes	No	Very low - very high
OMEGA with Data Relay	Yes	Yes	As often as desired	Unlimited	High	Yes	Yes	Yes	Medium
Passive RF Direction Finders	Possible	Yes	As often as desired	Unlimited	High	Yes	No	Vessel must be actively transmitting	Medium - High**
Surface Search Radar	No	Yes	As often as desired	Unlimited	High	Yes	No	No	Medium - High**
Imaging Radar	No	Yes	Dependent on # of aircraft	Unlimited	Medium	No	Limited	No	High**
TRANSIT with data Relay	Yes	Yes	As often as desired	Unlimited	High	Yes	Yes	Yes	Medium
TIROS-N ARGOS	Yes	Yes	4 Hours	400 vessels	High	Yes	Yes	Yes	Low

* Low = < $500,000
Medium = $500,000 - $2,000,000
High = > $2,000,000

** Including cost of surveillance aircraft

Table 8: SUMMARY CHART

	Instantaneous Coverage	Speed (mph)	Coverage/Hour (mi^2)
Aerial Photography:			
6" lens @ 10,000 ft.	8 mi^2	150	424
6" lens @ 30,000 ft.	73 mi^2	300	2570
Imaging Scanner with 120°FOV @ 10,000 ft.	6.5 mi swath	150	975
		300	1950
Surface Search Radar @ 10,000 ft.	200 mi swath*	150	30,000
		300	60,000
SLAR	60 mi swath	300	18,000
Airborne DF @:			
10,000 ft.	250 mi swath*	150	37,500
		300	75,000
20,000 ft.	350 mi swath*	150	52,500
		300	105,000
30,000 ft.	430 mi swath*	150	64,500
		300	129,000

* Assumes length of flight path >> radius of coverage

Table 9: SURVEILLANCE RATES WITH AIRBORNE TECHNIQUES

7.1 TIROS-N ARGOS Data Collection System

The ARGOS Data Collection System of TIROS-N appears to be the most appropriate system for monitoring the location of cooperative vessels from both technical and cost standpoints. The only drawbacks to implementation of this system are the present uncertainties regarding permission to use the system and the possible limitations of system capacity should it be implemented on a regional (multi-nation) basis. The latter drawbacks can probably be overcome with ingenious modifications to the operation of the system and to the design of the transmitters. Accordingly, we recommend that the Government of Papua New Guinea proceed with appropriate actions to secure permission to use the system. Should these efforts fail, it may be necessary to fall back to the second recommended system for cooperative targets, the TRANSIT/OMEGA system described in Section 7.2.

Implementation of the ARGOS DCS will require each cooperating vessel to install a government-supplied Platform Transmitter Terminal (PTT). In addition, the government must install and operate a satellite receiving station for the ARGOS data. It is estimated that a single receiving station will provide more than sufficient coverage for all of the waters of PNG's DFZ. Appendix B contains technical information regarding this system.

The biggest uncertainty with this system is access to the satellite. It is controlled by the ARGOS committee made up of representatives from NASA, NOAA, and the French governmental agency for space, CNES. This committee requires the user to show that at least part of the reason for using the satellite is to transmit environmental data. This should cause no problems since a major portion of the effort will be directed toward gathering oceanographic data. Once access is granted to the satellite, operational satellite systems are guaranteed at least up through 1985 by interagency agreements. Appendices B-2 and B-3 contain the forms necessary to meet the requirements of the ARGOS system.

7.1.1 Platform Transmitter Terminal (PTT)

The heart of the ARGOS DCS system is the Platform Transmitter Terminal. This is a small radio transmitter operating at a precise 401.650 MHz frequency. Every 40-60 seconds (determined by user), it transmits a digital message which can vary from 360-920 msec. in length. This message contains digitally encoded data including a platform ID (manually pre-set by user) and from four to 32 eight-bit data strings from environmental sensor or manually-controlled data switches. Each of the 32 eight-bit data strings can be used to relay sensor or other data coded from 0 to 255. For example, if one wished to transmit digital temperature data over the range of 40°F to 100°F, one single eight-bit data set (byte) could handle this range in one-quarter degree increments (60 difference x 4 = 240 unique temperatures).

If it was necessary to transmit greater than 32 bytes, a switching device could be employed. Assuming a 10 minute pass by TIROS-N and assuming that the messages are transmitted once per minute, it is conceivable that 10 x 32 or 320 bytes could be transmitted by sequentially switching to a different 32 byte string on each of the 10 transmissions.

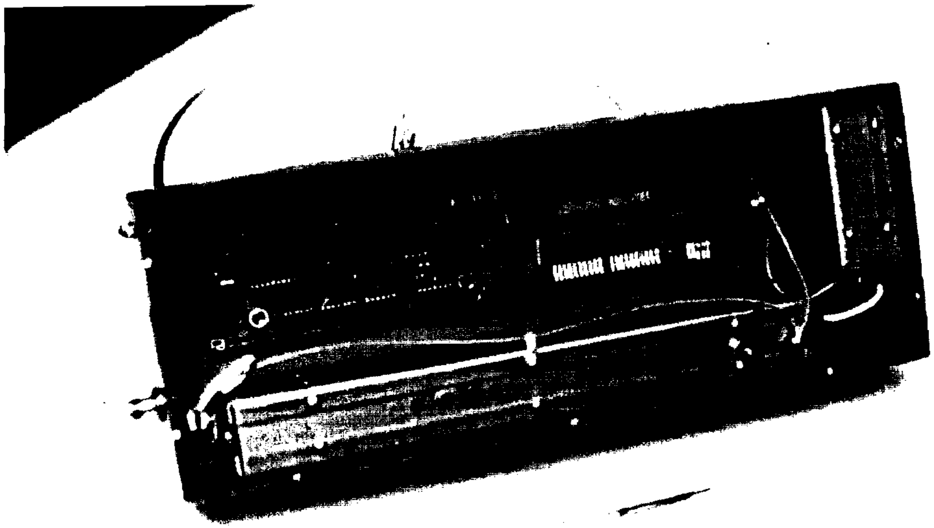
One of the firm requirements of the ARGOS committee for use of the system is that it be used to collect environmental data. The mere location of fishing vessels to protect a country's national interest is not sufficient to obtain permission. However, one of the goals of this program is to obtain frequent oceanographic data and catch information as well as location. In order to do so, the PTT system must have, as an integral part, a capability to collect or input such information.

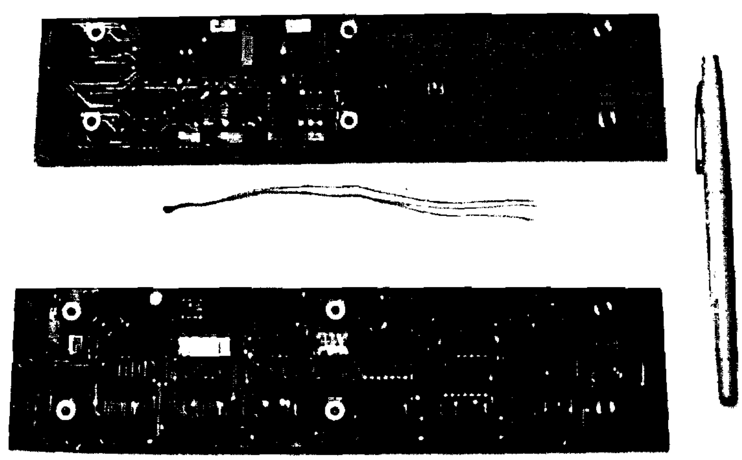
It is anticipated that the PTT system will be comprised of three basic elements, a series of oceanographic sensors linked to the transmitter, a provision to manually input catch data (weight, species, etc.), also linked to the transmitter, and the transmitter. Most of the modular elements of this system already exist. The major design required to produce this system will encompass interface and packaging.

The basic transmitter is produced by several companies, among them Handar, Inc. and Polar Research Laboratory of the United States. Information regarding these products is to be found in Appendix B-5 The transmitter is a rather simple, small and compact unit. Photos 13 and 14 show an internal view of a Handar transmitter. The outside dimensions of the case are approximately 15" x 6" x 2". The only other components necessary for a working transmitter are an aerial (about 6" in length) and a battery pack. Batteries are available to power the system reliably for over one year. The cases as seen in Photos 13 and 14 are not weatherproof. The transmitting unit is commonly housed, with batteries, in weatherproof containers such as seen in Photos 15, 16, and 17. Photos 15 and 16 show the Handar transmitter with a representative watertight container.

A wide variety of environmental sensors may be interfaced with the transmitter. Virtually any device having an electrical output can be so interfaced. Several types of sensors are commonly provided as accessories with the PTT's manufactured in the U.S. They include sea surface temperature, air temperature, barometric pressure, and internal battery voltage. These and other parameters may provide information valuable to the fishery management community. Other parameters may include pH, salinity, dissolved oxygen, and total organic carbon. Ideally, any sensor installed with the PTT should be automated such that no manual operation or calibration is required.

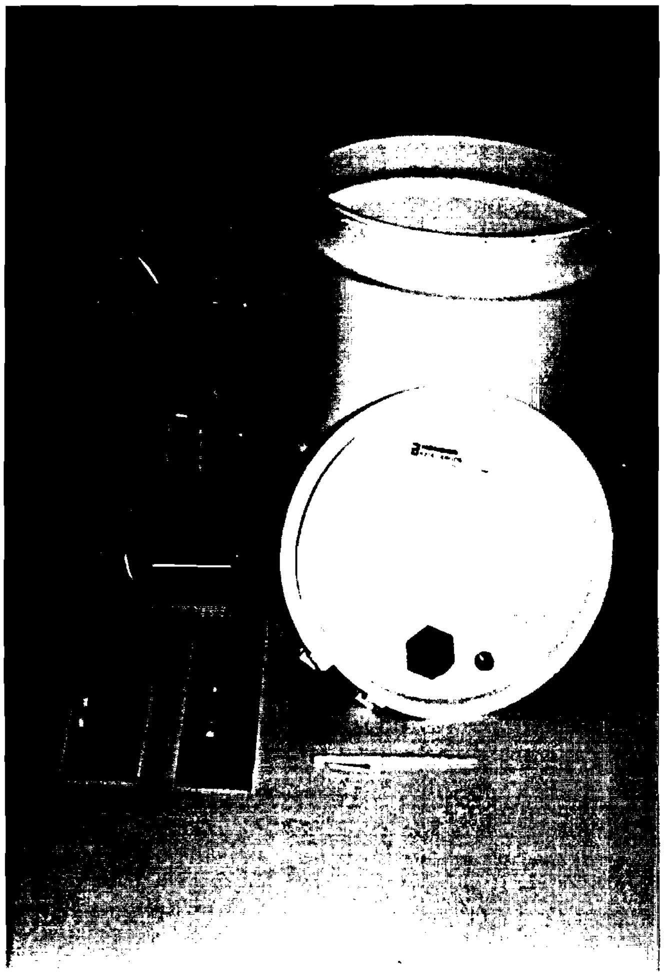
Certain types of data must be manually input. Catch data is one such type. Digital thumbwheel switches can be installed on the exterior of the PTT container. These switches can be used to input tons of fish caught, number of fish caught, schools chummed, schools fished, buckets of bait, sea condition, number of baskets, number of hooks, species of fish (by code), time of day fish were caught, etc. A further refinement might be to add an additional code wheel to automatically pass requests or

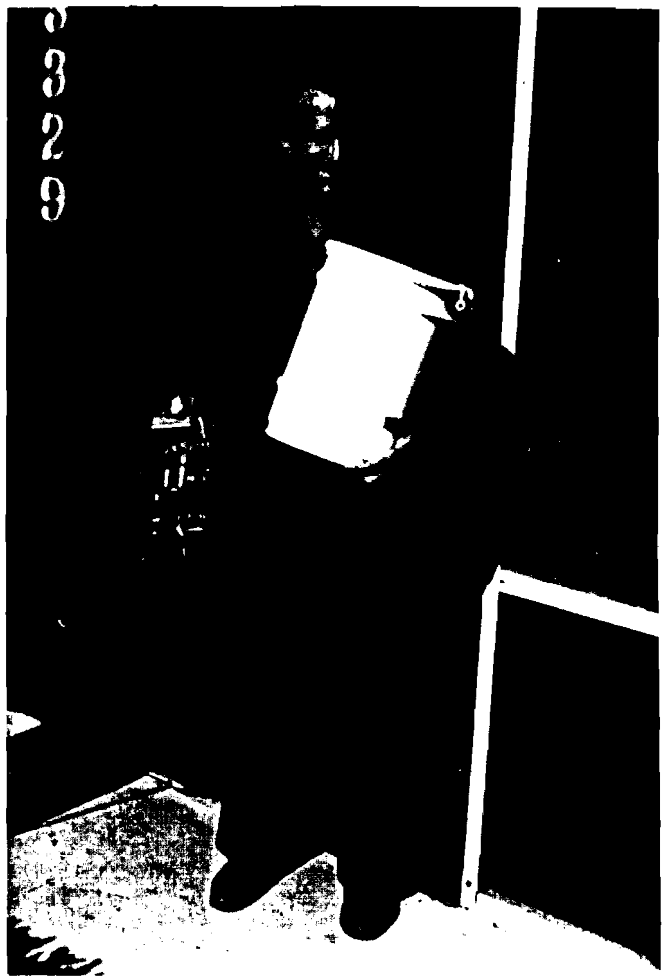




Photos 13 and 14: INTERNAL VIEW OF HANDOR ARGOS TRANSMITTER

BEST AVAILABLE COPY





Photos 15 and 16: HANDOR ARGOS TRANSMITTER WITH WATERTIGHT CONTAINER

Photo 17 EXPERIMENT USCG ARGOS TRANSMITTER, ANTENNA, AND CONTROL BOX (BLACK)

BEST AVAILABLE COPY

emergency information to shore. Photo 17 shows a prototype USCG system designed in this manner. On the left is the watertight container and antenna for the system. The transmitter and digital sensor interface is on the right. In the center is the manual input box. It has thumbwheel switches, as described, and an emergency toggle switch which can be used to automatically send a distress call to the ARGOS shore station.

The technology and many of the components of this system are "off-the-shelf" and commercially available. However, the ARGOS system is sufficiently new that most PTT systems require some custom design. This is particularly true for the interfaces and container design. Specific sensors must be chosen. The interface must be designed to match their outputs with the required format of the digital PTT system. Sensor installation procedures must be devised to require a minimum of custom work for each different vessel.

7.1.2 ARGOS DCS Receiving Station

DCP data may be obtained in two different ways. One may purchase the data from CNES in France or one may install his own receiving station to directly receive the data from the satellite. In order to receive the data in real time and at a reasonable cost, it is recommended that PNG install its own receiving station.

The receiving stations for the ARGOS system are completely self-contained automated systems. They consist of a directable antenna, a radio receiver, a decommutator, a microprocessor, and an input/output terminal. The microprocessor controls the entire system. It calculates in advance when and at what azimuth the satellite will rise over the horizon. It turns on the receiver and points the antenna in the proper direction at the appropriate time. The receiver receives the data from the satellite. The decommutator and microprocessor determine several lines of position from the doppler data and calculate latitude, longitude, and height. The peripheral data is received, processed and printed. After the pass, the microprocessor calculates the next pass and waits.

Stand-alone systems such as this can be purchased, with all necessary software, from both the French CNES and from an American firm, Old Dominion Systems, Inc. Old Dominion has supplied the systems presently in use by NASA at Goddard Spaceflight Center and by the U. S. Coast Guard. These systems are capable of receiving the ARGOS data from both TIROS-N and from Nimbus, the experimental NASA satellite.

The VHF antenna system is relatively small. It is a twin cross dipole circularly polarized yagi antenna approximately 8' x 12' in size. It is mounted on a directable azimuth/elevation mount controlled by the microprocessor. Photos 18 and 19 show the antennas presently in use at both NASA/Goddard and at the Old Dominion offices.

The remainder of the receiving station is mounted in a single standard electronic equipment rack with the exception of the printer terminal or optional video terminal. Inclusion of optional data recording and diagnostic test equipment may require a second rack. Appendix B-6 provides a brief description of the Old Dominion item. Photos 20 through 26 show various views of systems installed at the USCG Oceanographic Unit, NASA/Goddard, and the Old Dominion offices. Photos 27 shows typical output from the printer.

The accuracy of the ARGOS system in locating a platform depends on how precisely the computer "knows" the correct position of the satellite during the time of the pass. Theoretical calculations can predict in a rough manner where the satellite should be, but this is not sufficient to maximize the accuracy of the system. In order to do so, one must use reference transmitters. Several PTT's are placed at precisely known locations throughout the area of interest. As the satellite comes over, it "locates" these transmitters. The

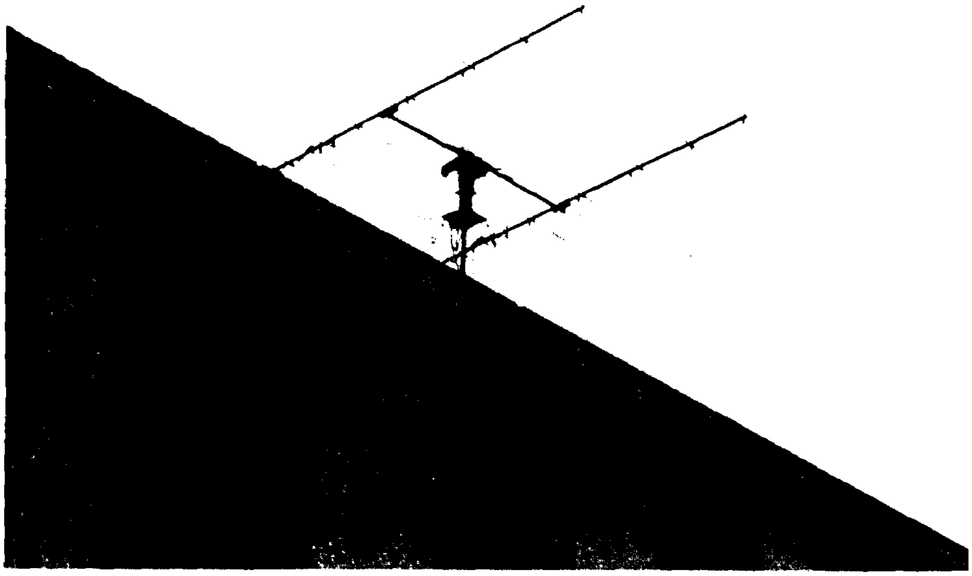


Photo 18 - GODDARD ARGOS RECEIVING ANTENNA

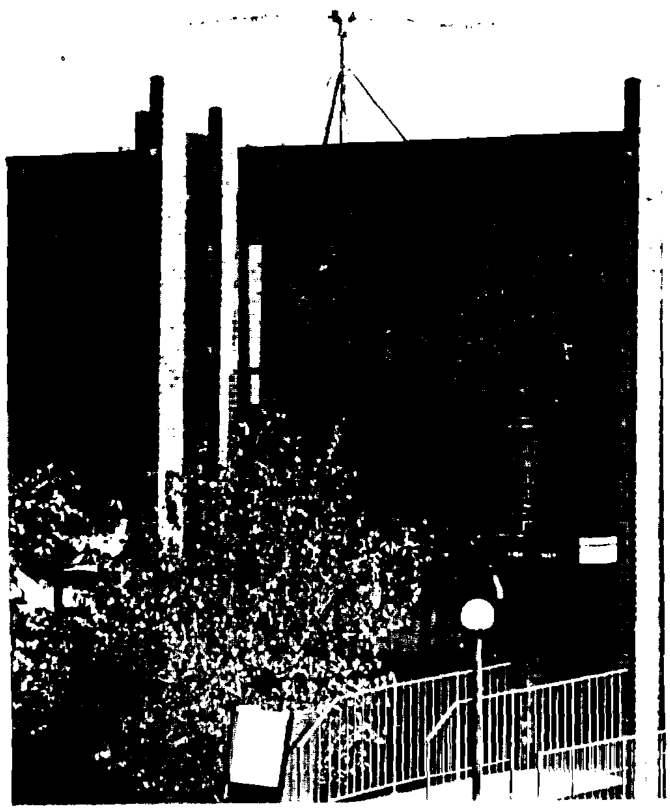


Photo 19- OLD DOMINION RECEIVING ANTENNA

BEST AVAILABLE COPY

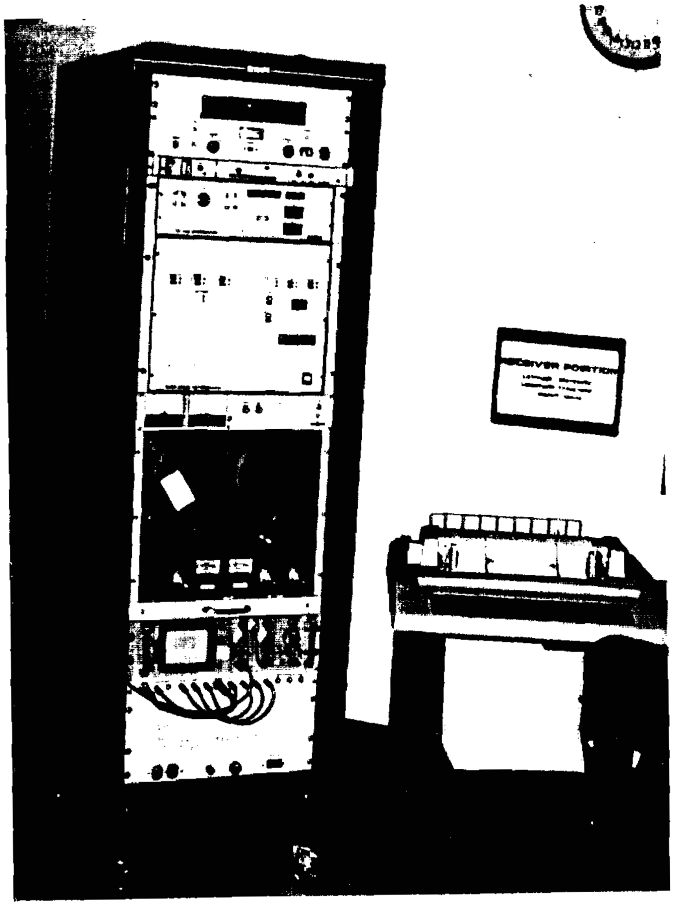


Photo 20 - USCG ARGOS RECEIVING STATION

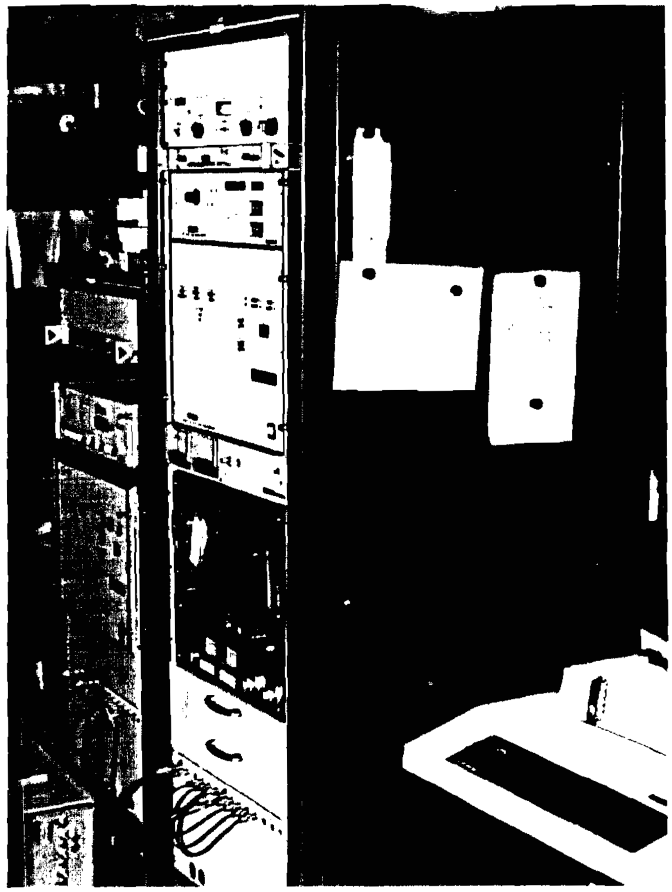


Photo 21 - NASA GODDARD ARGOS RECEIVING STATION

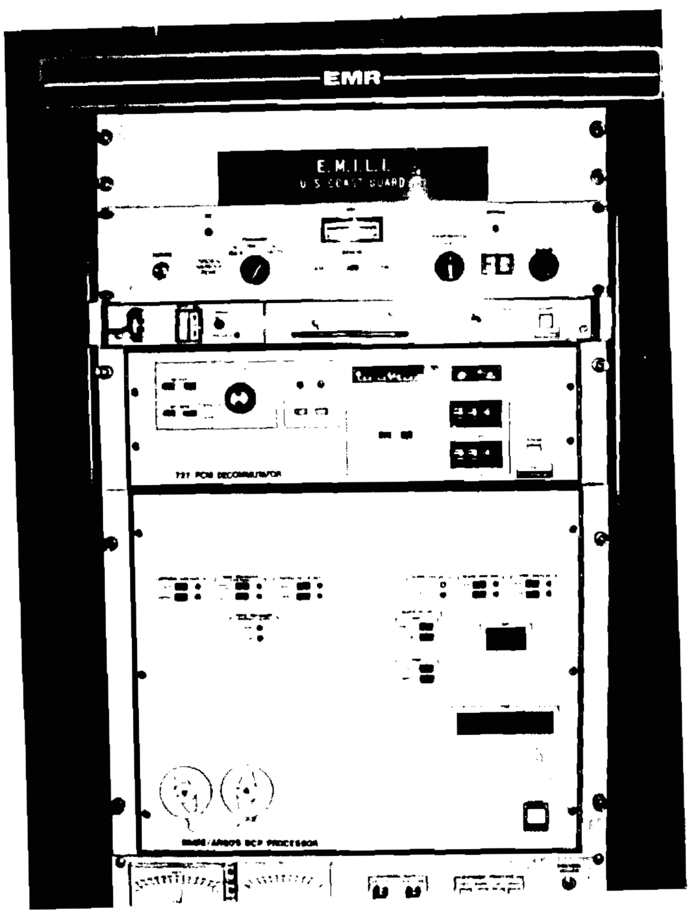


Photo 22 - RECEIVER, DECOMMUTATOR AND PROCESSOR

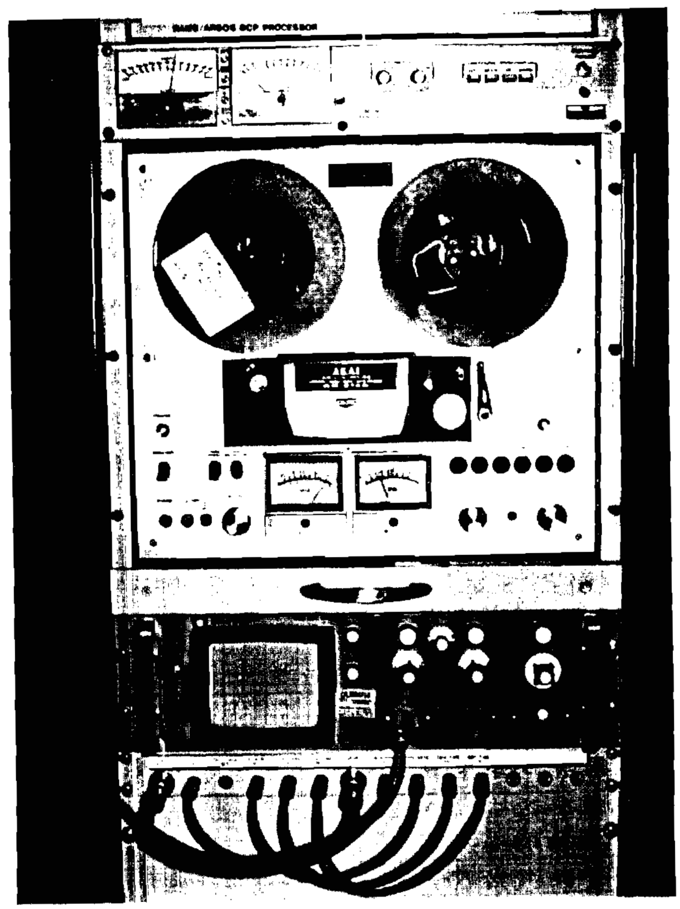


Photo 23 - TAPE RECORDER AND TEST CRT

BEST AVAILABLE COPY

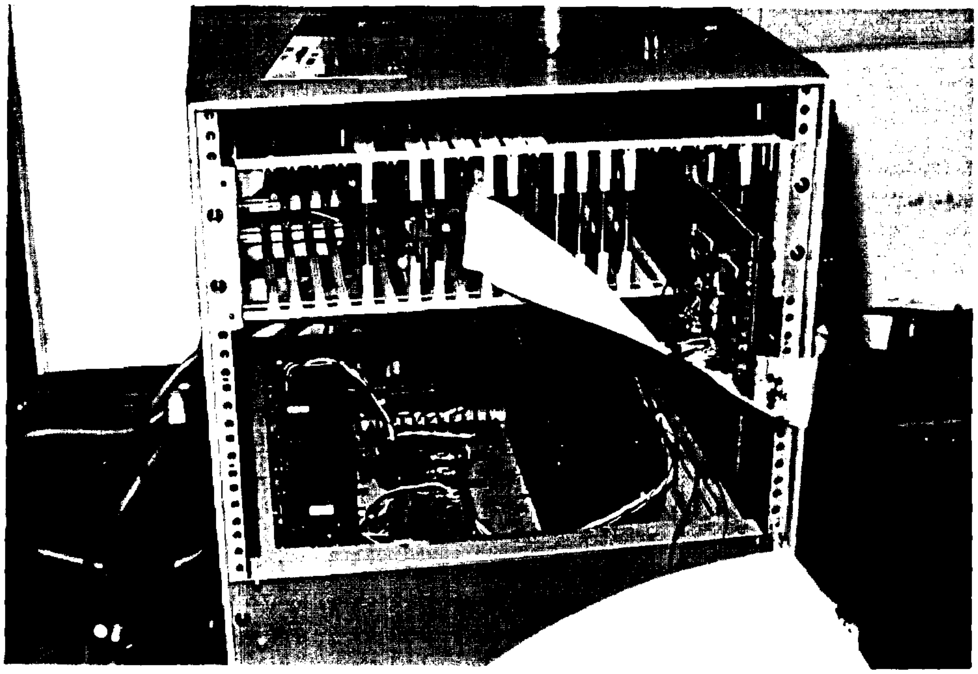


Photo 24 - OLD DOMINION SYSTEMS MICROPROCESSOR

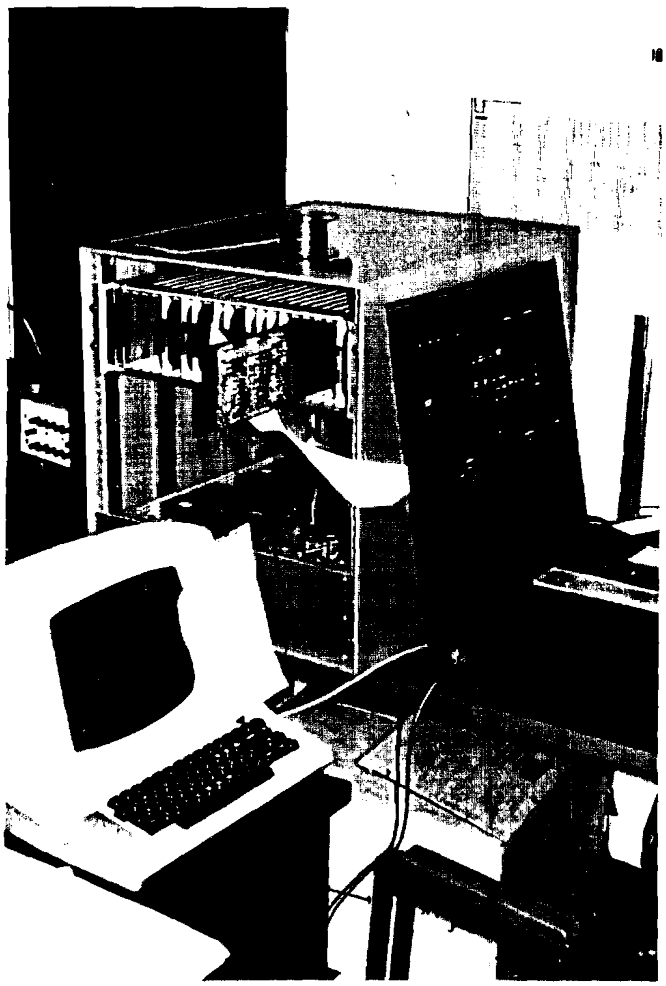


Photo 25 - OLD DOMINION SYSTEMS MICROPROCESSOR AND CRT KEYBOARD

BEST AVAILABLE COPY

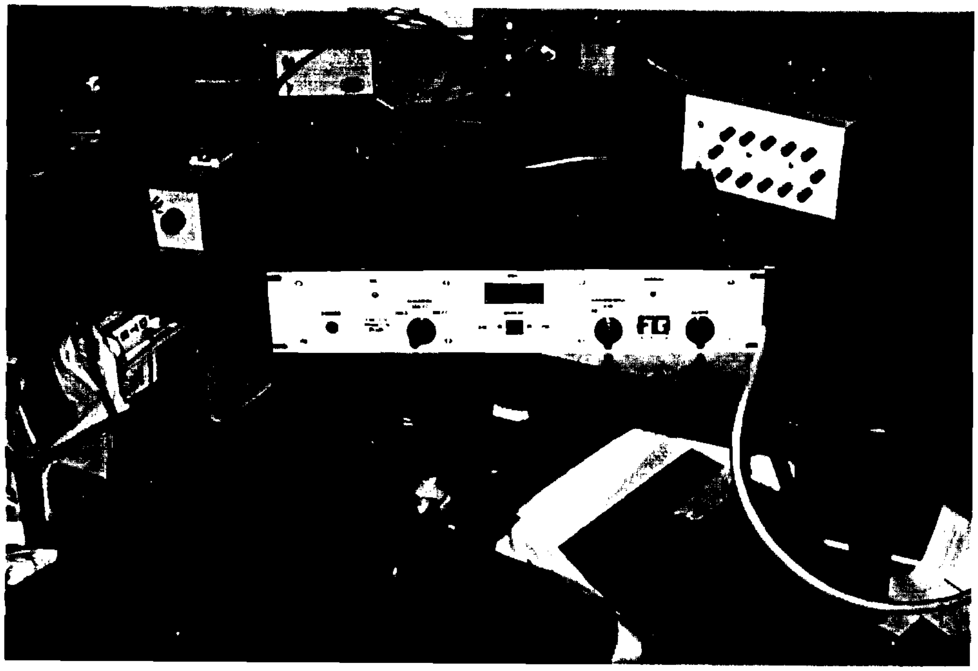


Photo 26 - ARGOS RECEIVER OLD DOMINION SYSTEMS

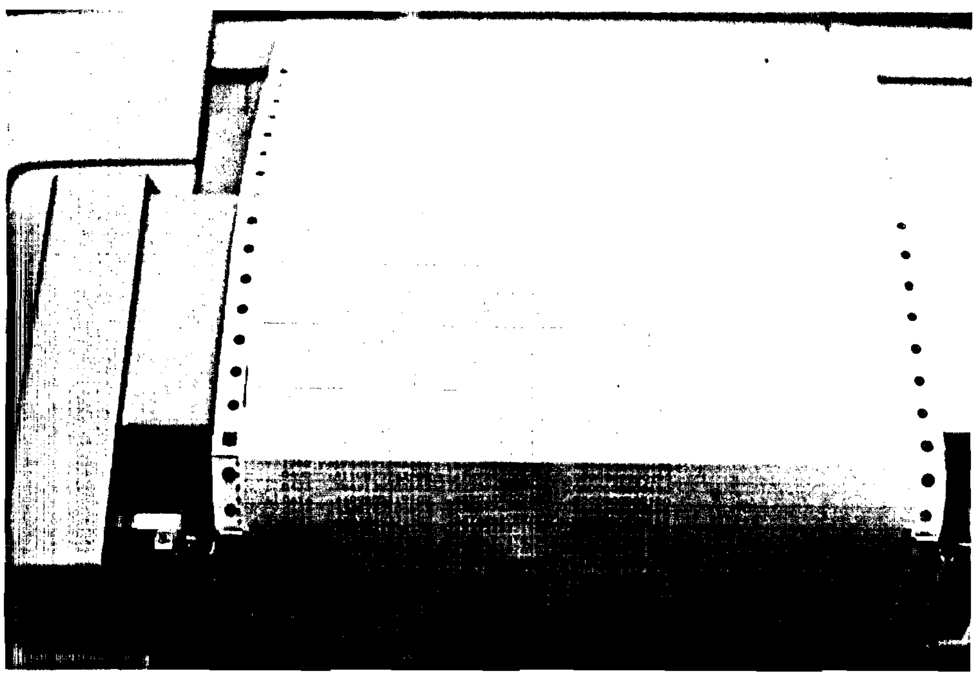


Photo 27 - MICROPROCESSOR LINEPRINTER OUTPUT
(Platform ID, Latitude, Longitude, Height)

BEST AVAILABLE COPY

receiving station recognizes that these are references. Using the known position of the reference transmitters, it recalculates the actual position of the satellite from the satellite's "location" of the reference transmitter, by essentially working backwards. Once the actual position of the satellite is so calculated, the receiving station proceeds to calculate the actual positions of the other PTT's.

The standard receiving station provided by Old Dominion Systems is limited to reception of data from 50 PTT's. This is a function of the storage space in the computer. As the receiver receives data from the satellite, it must immediately store it since the data processing time for each PTT is much longer than its transmission time. Also, a capability of 50 PTT's has seemed sufficient since no one has ever operationally required more than 50 at any one time. This problem can be overcome by the simple addition of more memory to the computer system. Such a decision should be made at the time of purchase.

7.1.3 System Installation, Operation and Maintenance

The PTT's would be initially installed on each of the cooperative vessels, on other platforms such as the military patrol boats, and fish-attracting rafts, and as reference beacons. Installation of the PTT itself will be very simple. Since it will be self-contained (batteries included), it will only be necessary to bolt it to a protected location, install its antenna and run a cable between the two.

The oceanographic sensors may be another matter. Dependent on the general and specific types of sensors desired, it may be necessary to mount probes either through the hull or over the side. Decisions regarding these factors must be postponed until specific sensors are selected. This should be one of the subjects to be addressed in a follow-on design phase.

Certain PTT's should be installed as reference platforms. Ideally, they should be spaced in an equidistant grid over the prime area of interest. Seven references should be sufficient. A suggested placement includes Wewak, Manus, Rabaul, Lae, Port Moresby, Kieta, and Tagula (see Figure 10).

A site for the receiving station must be chosen. Port Moresby appears to be satisfactory. Figure 11 shows the expected range of the system if the receiving station is placed at Moresby. The inner circle defines an area of almost certain reception and the outer circle defines an area of probable reception. As can be seen, the inner circle, centered at Moresby, more than covers the entire DFZ of Papua New Guinea. As a matter of interest, coverage of a second receiving station has also been plotted. Its center lies on Pago Pago. It appears that two such receiving stations would provide coverage over most of the entire area of those countries comprising the South Pacific Commission.

The antenna for the receiving station must be placed on high ground such that any blockage from surrounding terrain rises no higher than 10° above the horizon. There appear to be several such sites in the vicinity of Port Moresby.

Installation and checkout of the receiving station should take no longer than two weeks. Installation of the PTT's will depend on many factors, the most important of which is the complexity of the sensors. Installation time could vary from one day to one week per vessel.

Operation of the system will be quite simple. Theoretically, the receiving station will operate automatically and unattended. However, it is advisable to have an individual available during the times of the passes to monitor the operation and assist if necessary. The system will be gathering information 24 hours/day on approximate 3-4 hour intervals. It is recommended that a minimum of three individuals be trained in operation of the system. These should be middle-level professionals having some general background in computer programming and operations.

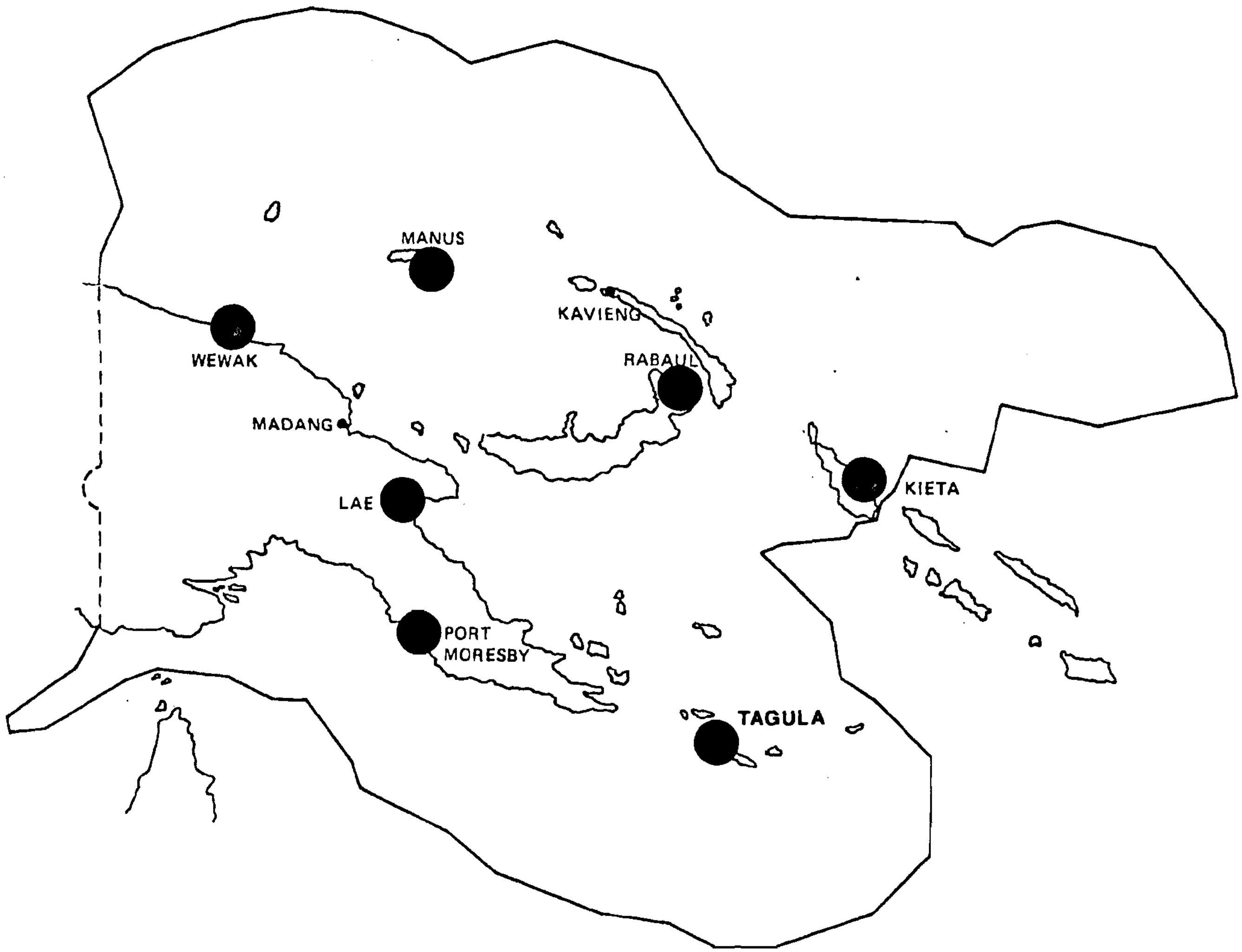


Figure 10: RECOMMENDED POSITIONS OF REFERENCE PLATFORMS

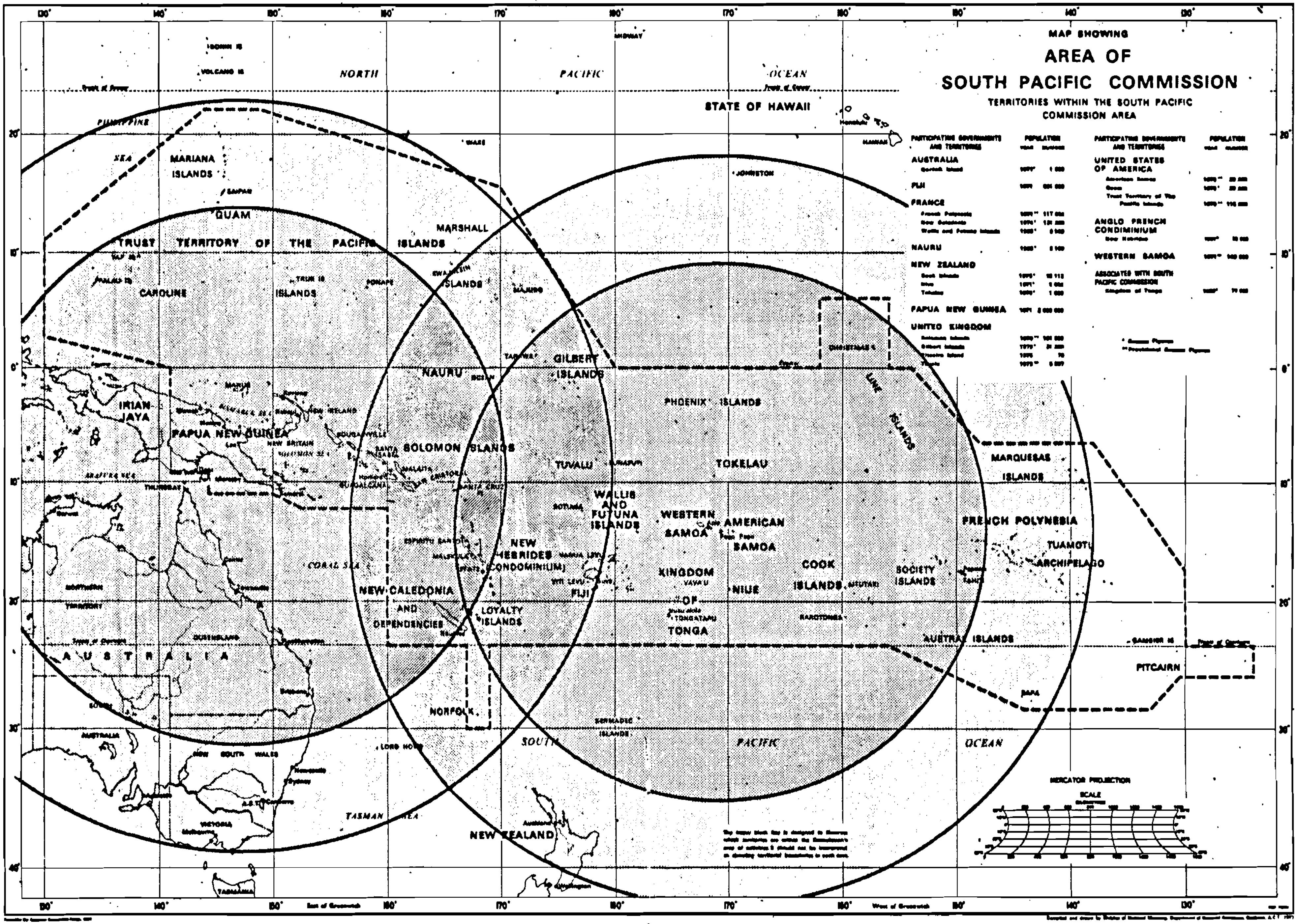


Figure 11: EXPECTED RANGE OF ARGOS SYSTEM

BEST AVAILABLE COPY

Operation of the PTT's will be automatic with the exception of daily input of catch data. The PTT's will be designed such that this data will be input once a day by the captain of the vessel. Accurate reporting can be a mandatory requirement enforceable by random spot checks of fish onboard by the patrol craft.

Maintenance requirements are rather low. The PTT's will require a change of batteries once per year. This should take approximately two hours/vessel. In the case of failure of a PTT, spares may be kept at a central location. Interchange could be made within a day or so. Failed units could be returned to Port Moresby for repair or transshipped to the manufacturer for repair. Based on prior failure rates (information from manufacturer), a maintenance level of two man-days per PTT per year is estimated.

There undoubtedly will be required maintenance for the receiving station. No firm figures are available. It is recommended that at least one technician be trained in standard trouble-shooting and low-level maintenance. The system is designed such that most problems can be cured with replacement of standard plug-in printed circuit boards. Failed units can be returned to the manufacturer. Exact details of the manufacturer's responsibilities and liabilities must be spelled out in the original purchase agreements. Recommendations can be made in a design phase sudy.

If the ARGOS system is implemented, it is recommended that the Government of Papua New Guinea also purchase an ARGOS airborne platform interrogator and field test set for use on each patrol aircraft and patrol boat. The field test set allows the patrol craft to query a vessel and receive the PTT transmissions directly thus effectively determining whether the vessel is cooperative and whether its PTT is functioning properly.

7.1.4 Estimated Purchase Costs of System

Four basic components make up the ARGOS system as recommended. They are the PTT, the sensors, the receiving station and the airborne platform interrogator and field test set. The total system costs as presented here assume a total of 50 or 100 platforms in operation. Costs are F.O.B. USA and do not include installation, training, operation, or maintenance.

System Purchase Costs

Platform Transmitter Terminals Plus Sensors	Per Unit	50 Platforms	100 Platforms
Basic Transmitter (e.g. Handar 620A with options 001, 002, 003	$2,400	$120,000	$240,000
Sensors (sea surface, temperature, air temperature, internal battery voltage, barometer, salinity, etc.)	3,500	175,000	350,000
Interface	500	25,000	50,000
Packaging plus Manual Input Plus Batteries	500	25,000	50,000
TOTAL PER PTT	$6,900	$345,000	$690,000
Receiving Station			
Complete System (e.g., Old Dominion Systems)		$49,000	$80,000
Airborne Platform Interrogator (e.g., Handar 602A)		$9,000	$9,000
TOTAL SYSTEM PURCHASE COSTS		$403,000	$779,000

7.2 TRANSIT/OMEGA Navigation System with Digital Radio Link

If it is impossible to use the ARGOS system for any reason, there is an alternate system which is also recommended. From a purely technical standpoint, this alternate may be in fact, superior to the ARGOS system to perform the required tasks. Unfortunately, it is also considerably more expensive than the ARGOS system.

The alternate system consists of a shipboard TRANSIT or TRANSIT/OMEGA navigation system with peripheral environmental sensors linked to a selective-call digital high-frequency single-side-band radio system. The base stations would consist of complementary HF SSB transceivers and digital printers.

This alternate system could provide position location of even greater accuracy than that provided by ARGOS, the option of updating location as often as desired, and collection and relay of the same type of environmental data as that provided by the ARGOS system. In addition, should it be so desired, the system could also be used as a voice communication system. Appendices C, D and E contain detailed technical information regarding this system as well as manufacturers' brochures of representative systems.

7.2.1 Hardware Description

Position location for each vessel will be determined onboard by a self-contained and semi-automated navigation system. The TRANSIT satellite navigation system is the prime component. It receives, every few hours, information from the TRANSIT series of satellites and plots a very accurate fix. Between satellite passes, the internal computer from the system calculates position by dead reckoning using inputs from the ship's gyros and speed indicators.

A more sophisticated version of this navigation system uses input from an automated OMEGA receiver to continually update position between satellite fixes. This TRANSIT/OMEGA system will provide the most accurate and reliable position information. For the purposes of this project, it may be more sophisticated than required. A single TRANSIT receiver with a dead reckoning computer should provide sufficient information.

One of the major manufacturers of such navigation systems is Magnavox. It produces several appropriate systems including the TRANSIT/OMEGA system.

A major advantage of this type of system is that accurate navigation data will be available to each fishing vessel. This, in itself, would be of great benefit and would tend to encourage shipowners to enthusiastically embrace the system. Most of the present fleet using PNG waters have navigation systems nowhere near this sophisticated or accurate.

There is a disadvantage besides cost. Operation of the system requires the navigator to initialize it. It is not a completely automated system. Also, a cunning operator could program the system in such a way that it would provide false readings to the monitoring system.

Environmental sensors, although not bureaucratically mandated for use of the system, would still be desirable. The same type of sensors as used in the ARGOS system could be used here. Likewise, catch information could be input.

Interface hardware would be required to join the navigation system and sensors to the data relay system. Such interfaces are not commercially available and would have to be designed and built.

The data relay system will allow the navigation and environmental data to be automatically transferred to a monitoring system. The relay will be a high frequency single-side-band digital radio system. Data will be converted to digital format and automatically transmitted upon receipt of a selective call from a shore station. Each vessel will have a unique digital call code. The operator of the shore station will dial in the code and initiate the shore transceiver. It will signal the vessel transceiver to dump its data. The selection could also be automatically triggered at any time desired. The shore transceiver would pass the signal to a microprocessor which would process and printout the data.

An advantage of this type of data relay system is that the vessel may be queried on demand. If it is in the vicinity of a critical area, the monitor may check its position very frequently. Likewise, in areas of little concern, in port for example, it may be totally ignored.

7.2.2 System Installation, Operation and Maintenance

Installation of the navigation system is straightforward but more complex and time consuming than the ARGOS system. Unlike the ARGOS PTTs, the navigation systems will require ship's power. Connection will have to be made to the vessel's gyros and speed indicator systems. The radio and its antenna will have to be installed and checked. Sensor installation will be similar to that required for the ARGOS. A minimum of one week per vessel will be required for installation.

Several monitoring stations will have to be set up. The range of the SSB system is uncertain at this time. A minimum of two stations and possibly three will be necessary to adequately cover the DFZ. At present, Port Moresby and Rabaul appear to be logical choices. Each presently is the site of a coast radio station manned by the Postal and Telecommunication Services.

Operation of the system will require three operators plus one standby operator per station. This will allow 24 hour/day coverage. For the minimum two stations, this means that eight individuals must be committed to the system. They should be professionals with some background in radio systems and computer programming and operation.

Maintenance has been estimated at 1-1/2 man-years per year for each station. The shipboard systems will require 4-6 man-days/vessel/year for routine and emergency maintenance.

7.2.3 Estimated Purchase Costs of System

Four basic components make up the TRANSIT/OMEGA system as recommended. They are the navigation system, the sensors, the data relay, and the monitoring station. Total system purchase costs presened here assume a total of 50 or 100 systems in operation. Costs are F.O.B. USA and do not include installation, training, operation, or maintenance.

SYSTEM PURCHASE COSTS

Shipboard Hardware	Per Unit	50 Systems	100 Systems
TRANSIT Receiver (e.g., MX 1242)	11,000	550,000	1,100,000
or			
TRANSIT/OMEGA Receiver (e.g., MX 1105)	20,000	1,000,000	2,000,000
Interface	15,000	750,000	1,500,000
Sensors	3,500	175,000	350,000
SSB Radio Relay System	10,000	500,000	1,000,000
TOTAL SHIPBOARD COST	39,500 to 48,500	1,975,000 to 2,425,000	3,950,000 to 4,850,000
Monitoring Station			
SSB Transceiver, 1 Kw, 4 frequencies	70,000	140,000	140,000
Interface	5,000	10,000	10,000
Microcomputer plus terminal	20,000	40,000	40,000
TOTAL MONITORING STATION COST		190,000	190,000
TOTAL COST:			
With TRANSIT		2,165,000	4,140,000
With TRANSIT/OMEGA		2,615,000	5,040,000

7.3 Operational Maritime Surveillance Aircraft Systems

Monitoring and control of fishing operations in the PNG Declared Fishing Zone requires two separate operations: surveillance, which includes detection, identification and location; and reaction, which consists of direct contact with and if necessary, interception of vessels on the sea surface. Patrol boats are an obvious requirement for interception and boarding at sea, while aircraft by virtue of their speed and vantage point are much to be preferred for the surveillance role. As an example, a radar-equipped patrol boat cruising at 12.5 knots can survey an area of approximately 2,000 square kilometers per hour under good sea conditions. A similarly equipped aircraft cruising at 10,000 feet altitude and 120 knots can cover more than 40,000 square kilometers in this same period of time. When equipped with more sophisticated electronic detection systems, this same aircraft can cover an area in excess of 100,000 square kilometers in one hour.

In developing recommendations for an operational maritime (fisheries) surveillance system, it seems best to first review those detection/identification "systems" or equipment that should be carried onboard the surveillance aircraft (which is itself part of the total "surveillance system") and then review those aircraft capable of carrying that equipment and the required crew through typical mission profiles. Detection/identification surveillance systems are separated here as "primary" and "secondary" for convenience of discussion. Primary systems are those that should definitely be considered for inclusion in any new aircraft fisheries surveillance program for Papua New Guinea. Secondary systems are those that would normally occupy a less important role and may as a general rule be considered as options. It should be noted that, depending on particular mission requirements, these "secondary" systems may become the primary and in some cases the only system capable of doing the job.

The fisheries surveillance task facing the Government of Papua New Guinea is much more related to tactical than to strategic reconnaissance. The objects of interest (illegal fishing vessels) are highly mobile and may move in and out of the DFZ in a matter of hours. Information on their location and movement, whether collected from boats, aircraft or satellites, is thus highly perishable and must be acted upon immediately. For this reason, photographic mapping cameras, side-looking airborne radar, thermal infrared mapping systems and similar sensors whose data often requires time-consuming ground processing are not considered here as "primary" systems. The data they collect could be extremely important in any analysis of surface currents, thermal interfaces, fish movement or similar problems, but because of built-in delays in data handling and analysis it will seldom be of use for reaction and law enforcement purposes. Sea surveillance (surface search) radar, ELINT, and electro-optical systems, on the other hand, can provide real-time information that can be acted upon immediately.

7.3.1 Primary Surveillance Systems

Two primary surveillance systems are recommended for the PNG program - sea surveillance radar, and an electronic intelligence (ELINT) detection system. These units are both compatible and complementary. Although the systems themselves would appear to represent advanced technology, they have been well-tested for years in other applications and are available as "off-the-shelf" hardware.

7.3.1.1 Radar

A wide variety of radar systems, primarily designed and intended for weather avoidance and navigation, have been installed in aircraft and used for maritime surveillance.

Relatively fewer systems have been specifically designed and optimized for maritime surveillance and detection of small targets in high sea states. These systems in general feature higher output power, a physically larger antenna and narrower beam width than found in weather radar systems, multiple pulse widths and PRF rates to maximize resolution at short, medium and long ranges, and various electronic techniques to decrease sea return clutter and enhance the signal-to-noise ratio, thus improving target detectability. These systems are normally mounted in a radome or pod carried below the aircraft and scan through a full 360 degrees. An installation of this type is preferred for the sea surveillance mission for two principal reasons. First, the radar return signal from any target is a function of the target material (e.g., wood or steel), the target surface area presented to the radar pulse, and the angle between that surface and the transmitting radar. If a ship is headed directly at a radar-equipped aircraft, the radar return signal will be much smaller than if the ship is broad-side to the aircraft. Radar systems that are restricted to scan only a limited angle in front of an aircraft run a significantly higher risk of not detecting such targets at the longer ranges and may lose the target entirely during aircraft maneuvers. Second, higher antenna rotation rates (more scans per minute) may be desired for small target detection under certain sea conditions. A balanced antenna that is free to rotate continuously through a full 360 degrees can achieve much higher scan rates over a larger area than can a system that must scan through a limited angle, stop, and reverse its direction of travel.

Two such sea surveillance radar systems presently available are the Litton AN/APS-504(V)-2 and the AIL (Cutler-Hammer) AN/APS-128. Performance of these systems is similar in many respects and choice between them, or others, should be based on the particular program requirements.

As noted earlier, target detectability is a function of target material (steel is a better reflector than wood or canvas), target size, relative target heading, sea state, weather conditions, range and aircraft altitude. If relative heading and local weather conditions are taken as random, then for any given target type, detectability can be plotted as a function of sea state, ground range and aircraft altitude. Fisheries surveillance targets in the Papua New Guinea DFZ might be grouped into four approximate target size classes as:

1. 20 square meters ("clam boats")
2. 150 square meters (the smaller pole-and-line and longliner vessels)
3. 300 square meters (purse seiners and the larger longliners)
4. 1,000 square meters (factory ships, "mother" ships).

Detectability of these targets as a function of range and altitude with a typical sea surveillance radar and sea state 2 conditions is summarized in Table 10. More detailed information for alternate targets and sea state conditions is presented in Appendix F. As these data are derived primarily from metal (steel) targets, detectability of the smaller wooden "clam boats" will be slightly less than shown here.

Since the radar horizon or area of possible electronic surveillance increases with altitude, the search aircraft should operate at as high an altitude as possible, consistent with target detectability. As reflected in the chart in Table 10, detection range for the smaller 20 square meter targets decreases markedly above about 2,000 feet altitude, whereas most of the larger targets can be seen as well or better at 10,000 feet. This would indicate that two separate types of surveillance missions might be appropriate - a high altitude regional sweep for the larger and more economically important targets, and a low altitude patrol over selected areas against the less "expensive" but more locally destructive illegal "clam boats".

Radar Target Area (m^2)	Aircraft Altitude (ft)			
	1,000	2,000	5,000	10,000
20	30 nm	30 nm	10 nm	10 nm
150	40 nm	50 nm	60 nm	55 nm
300	40 nm	55 nm	70 nm	70 nm
1000	40 nm	55 nm	85 nm	95 nm

Table 10: RADAR DETECTION RANGE (nm) UNDER SS2 CONDITIONS

7.3.1.2 ELINT

Electronic intelligence (ELINT) techniques and equipment evolved during World War II as a means to detect, analyze, and develop countermeasures for enemy radar. Many of these techniques were highly effective and, because of their military importance, have remained classified and restricted to military use. Recent advances in the military state-of-the-art have resulted in declassification of many of these techniques and methods, and a wide variety of effective and reliable equipment is now available for commercial purposes. Many of these systems are ideally suited to the fisheries and maritime surveillance task.

Radar systems are considered "active" surveillance systems, in that they transmit a pulse and listen for an "echo" signal return. Since the amount of energy reflected back from the target is only a small percent of that transmitted, radar systems require very sensitive receivers. ELINT systems, in contrast, are "passive" in that they are "listening devices" only. Using receivers similar to those in radar systems, they listen for transmissions from active radar.

ELINT systems have several unique advantages over radar for maritime surveillance. The principal advantage is target detection range. Effective range for any radar system is primarily limited by 1) the line-of-sight horizon and 2) the strength of the return signal, or radar echo. Thus, typical radar systems on fishing vessels or maritime patrol boats will have a maximum range of 30 to 50 nautical miles, limited by the height of the antenna above the sea surface, while sea surveillance radar carried on aircraft will have a maximum range of 50 to 100 miles for various targets, limited by the strength of the radar return and the ability of the receiver to detect the signal. Since by far the major part of any radar pulse is not reflected back to the transceiver but continues on, it follows that this pulse transmission can itself be "detected" at much greater distances. In actual practice, ELINT reception is limited mainly by the line-of-sight horizon, and radar transmitters of the type commonly found on commercial fishing and marine vessels can be detected and tracked at ranges of 200 to 300 nautical miles from moderate altitudes, or at up to ten times the effective range of radar. As an example, the radar system currently installed on PNGDF patrol boats has an effective target detection range of about 24 miles. A boat operating this radar system can be effectively detected and tracked at a range of 250 miles by an appropriately equipped aircraft flying at an altitude of 25,000 feet.

The operational implications of this combination of systems are shown in Figure 12. A typical radar-equipped fishing vessel at point A would be unaware of the presence of a PNG patrol boat at point B. The patrol boat would have to close to a range of about 24 nm to establish contact. A radar surveillance aircraft at 10,000 feet altitude could detect and track the target from a distance of 50 nm or more (point C). With ELINT equipment, this same aircraft could monitor and track both the target and the patrol boat at ranges of 200 to 250 miles, or in this example, while flying over the airfield on Manus Island.

Another major advantage of ELINT systems is their ability to extract additional information ("intelligence") directly from the received radar signal itself. A radar operator with even the most sophisticated radar system can do little more than detect the presence of a "target", its range and bearing. An ELINT operator, on the other hand, can identify the specific type of transmitting radar as well as the type and nationality of the vessel carrying it. An experienced operator can even recognize and identify specific vessels.

This is possible because different classes of radar systems are designed to do different jobs and meet specific requirements. Thus, warships of any nation will tend to carry high-power radar systems to enable them to detect targets at longer ranges. Fishing vessels will carry lower powered systems that can detect other vessels within a reasonable distance and identify coastal

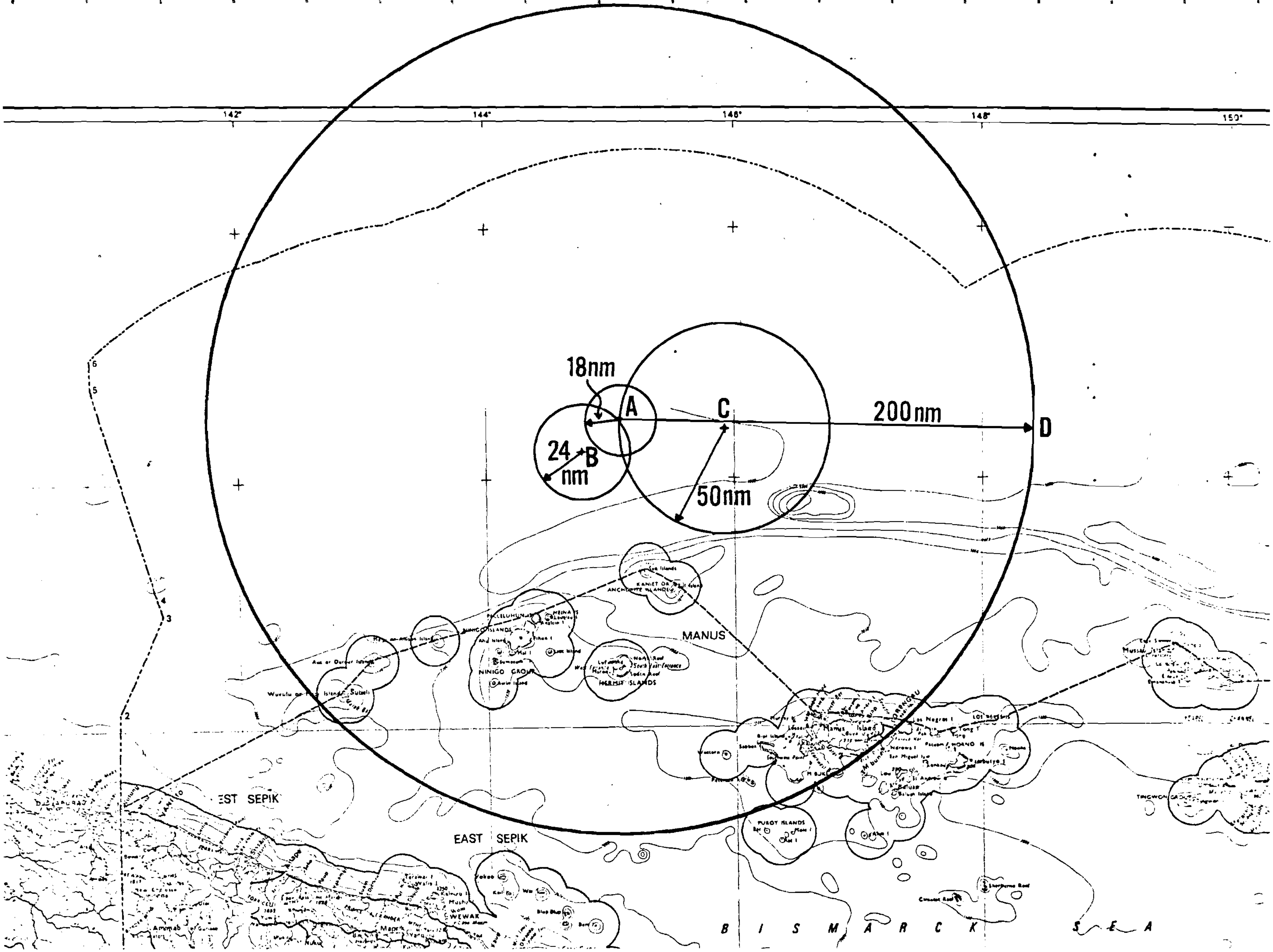


Figure 12: AN OPERATIONAL EXAMPLE

landmarks at somewhat longer ranges. Merchant ships will in general carry higher powered radar than fishing vessels, if only because they require more room (and thus more advance warning) in which to maneuver. Their radar will usually also have a very short pulse-width/high pulse-repetition-frequency capability to provide the high-resolution data required when maneuvering at close range in crowded waterways and harbors. Radar systems built by different manufacturers for the same purpose will also differ in operation as a function of different design philosophies and construction techniques. Since major-nation ships tend to purchase and install systems most readily available (and repairable) in their own countries, vessel nationality may often be determined by identifying the specific radar type. Thus, through analysis of operating radar signals, fishing vessels can usually be separated from merchant ships, Japanese vessels from United States vessels, etc.

Principal characteristics of some typical shipboard radar systems are summarized in Figure 13. By comparing five easily measured parameters, each of the radar systems shown here can be uniquely identified at distances of 200 miles or more. Photos 28 through 30 show the different types of radar characteristically carried by major warships, merchant ships and smaller patrol vessels. Photos 31 and 32 show a typical Japanese radar system installed on a pole-and-line fishing vessel in Kavieng harbor. Photos 33 through 35 show similar installations on fishing vessels at Rabaul. All of these pole-and-line vessels appear to be equipped with Japanese "Furuno" radar, which, although similar in purpose and operation to similar-class U.S. radar, can be easily identified with ELINT equipment. Three of these latter vessels (Photo 35) are equipped with different models of Furuno radar, here distinguishable by different type, size and shape of antenna and drive gear. The operating characteristics of these three systems, while similar enough to be identifiable as Furuno "fishing vessel" class, are also sufficiently different that a trained ELINT operator could easily distinguish between them and separately identify each of these three vessels.

Ship Type	Frequency (MHz)	PRF (pps)	PW (Msec)	Scan (sec)	Peak Power (kw)	Representative Model
U.S. Yacht	9415-9475	1500	0.1	2.6	3	Decca - 5050
U.S. Commercial Fishing Boat	9410-9480	1500	0.5	2.0	3	Decca - 110
		3000	0.08			
Japanese Commercial Fishing Boat	9380-9440	800	1.0	2.5	5	Furuno - FR701
		1600	0.6			
		3200	0.08			
Russian Commercial Fishing Boat	9200	810	1.0	4.6	50	Don
		1620	0.5			
Merchant Vessel	9380-9440	825	1.0	2.1	25	Decca - RM926
		1650	0.25			
		3300	0.05			
Papua-New Guinea Patrol Vessel	9415-9475	850	0.75	2.1	7	Decca - RM916A
		1700	0.25			
		3400	0.05			
U.S. Naval Vessel	9300	800	0.5	4.0	100	AN/SPS-53

Figure 13: CHARACTERISTICS OF TYPICAL SHIPBOARD NAVIGATION RADAR SYSTEMS

Photo 28: EARLY WARNING HIGH POWER RADAR ON AUSTRALIAN WARSHIPS IN SYDNEY HARBOR

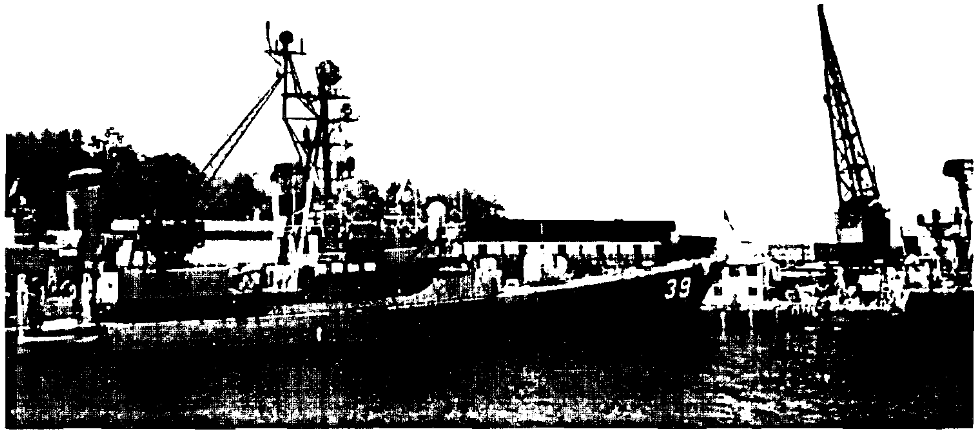


Photo 29: MEDIUM POWER RADAR CARRIED BY RUSSIAN MERCHANT VESSEL

BEST AVAILABLE COPY

Photo 30: DECCA RM 916A RADAR CARRIED BY PNG PATROL BOAT

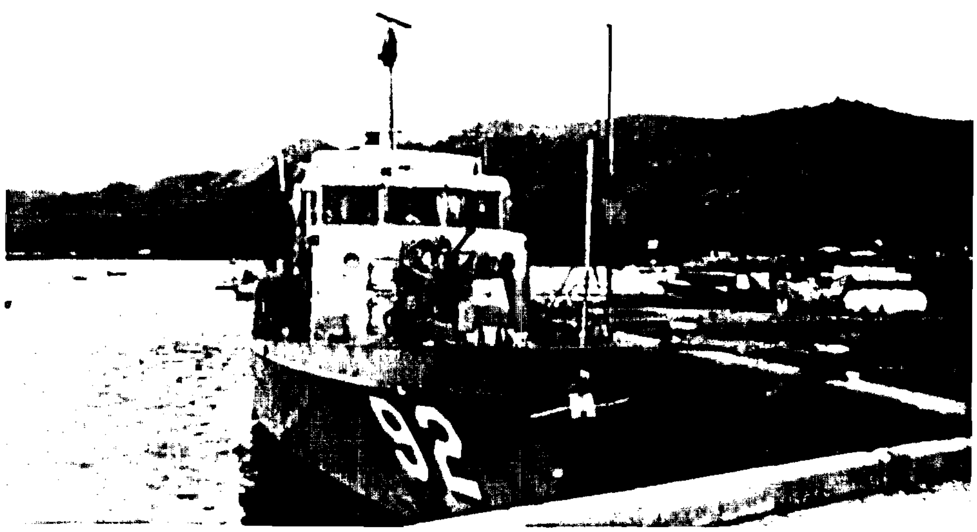


Photo 31: FURUNO RADAR INSTALLED ON POLE-AND-LINE FISHING VESSEL "MADANG STAR" IN KAVIENG HARBOR

Photo 32: BRIDGE OF "MADANG STAR" SHOWING RADAR DISPLAY AND CONTROL CONSOLE

BEST AVAILABLE COPY

Photo 33: JAPANESE POLE-AND-LINE FISHING VESSELS IN HARBOR AT RABAUL (All are equipped with Furuno radar, with at least three model types in use here.)

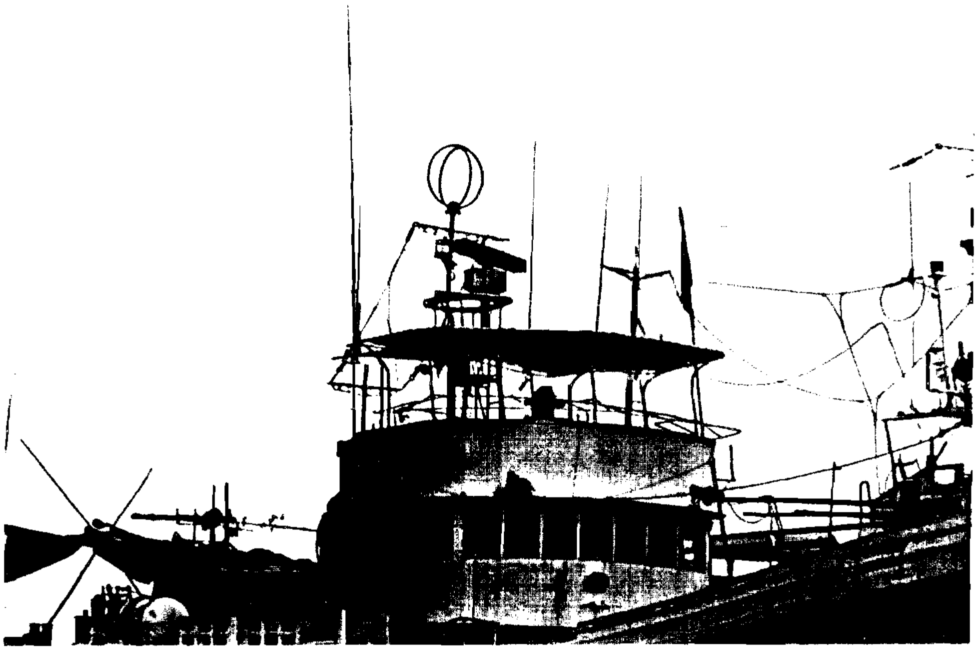


Photo 34: CLOSE-UP VIEW OF RADAR INSTALLATION ON BOAT AT FAR LEFT IN PHOTO 33

BEST AVAILABLE COPY

Photo 35: THREE VESSELS AT LEFT IN PHOTO 33 EACH EQUIPPED WITH A DIFFERENT MODEL FURUNO RADAR

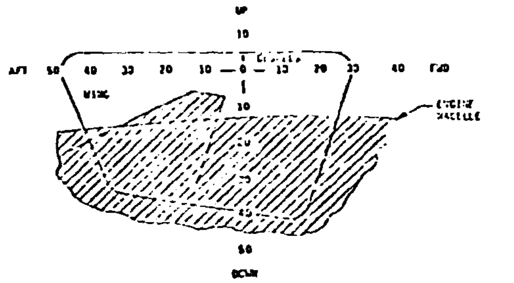
7.3.2 Secondary Surveillance Systems

"Secondary" detection/identification systems for sea surveillance and monitoring purposes include both direct vision and electro-optical systems and associated support equipment. These are discussed separately.

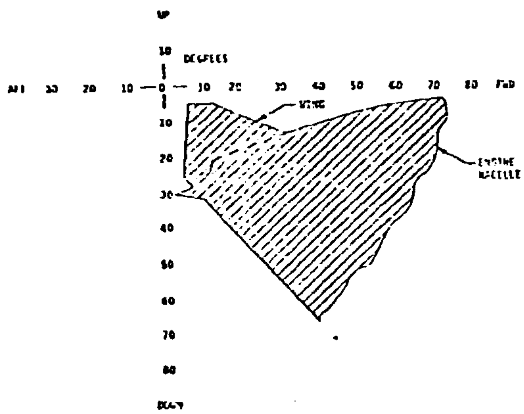
7.3.2.1 Direct Vision

Since most electronic (radar and ELINT) surveillance missions will be flown at relatively high altitudes for maximum area coverage, visual detection of target vessels will be much more difficult than would be the case at lower altitudes, and initial contact will seldom be by direct vision. Unambiguous identification of vessels, however, will often require visual contact, and low-altitude missions against small targets or for search and rescue purposes may rely heavily on human observers. High-wing aircraft, such as the Nomad presently operated by the PNGDF, have an obvious advantage in this respect as placement of the wing is such that downward vision is relatively unobstructed. Although percentage area obstructed in low-wing aircraft will vary with placement of the observer and type of aircraft, the situation depicted in Figure 14 is typical. Dimensional visibility may be substantially improved by the addition or incorporation of physically larger windows and/or "bubble" observation windows as shown here for the "left observer" station, but high-wing aircraft will still retain an advantage in this respect.

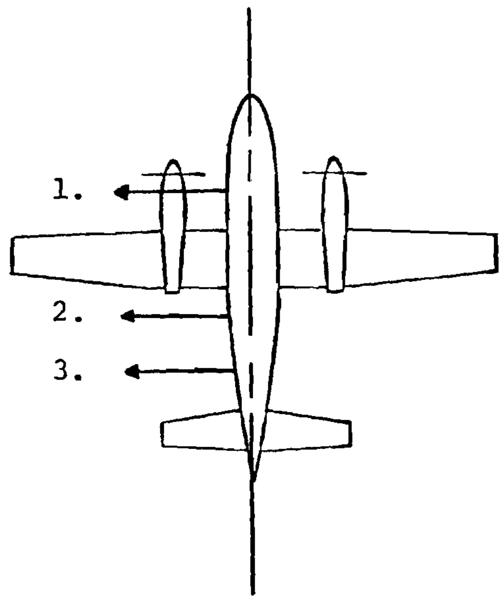
Vertical navigation viewfinders and driftsights of the type used in photo mapping missions or found on reconnaissance aircraft would be a useful addition to any maritime surveillance aircraft. These systems are simple, reliable, relatively inexpensive and can be installed in a wide variety of aircraft. With fields of view from 30 to 90 degrees, they can be rotated through 360 degrees to view the horizon as well as providing a

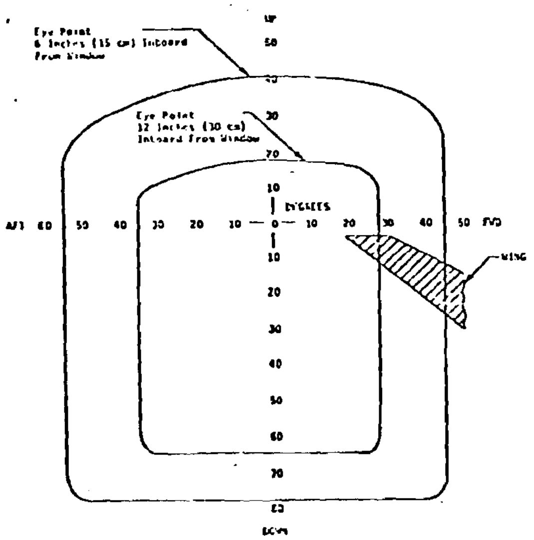


1. Pilot's Left Window



2. Operator's Window





3. Left Observer's Window

Figure 14: DIMENSIONAL VISIBILITY, LOW-WING AIRCRAFT

view directly below the aircraft. Typical systems would include the gyro-stabilized Bendix B3B and Wild NF-28 driftsights or the Chicago Aerial A-17VF or VF-57 viewfinders.

Stabilized binoculars might also be a useful tool, particularly at low altitude or when flying in rough air. These hand-held systems employ an internal gyro or similar device to optically stabilize a magnified image presented to the eye. Although the outer case of the binocular (or the observer himself) may be subjected to severe vibration or abrupt movement, the image seen through the binocular will remain remarkably steady, enabling identification of objects at unusually long distances under poor operating conditions.

7.3.2.2 Electro-Optical Systems

Low-light-level television (LLLTV) systems have been installed in a number of aircraft as an aid to operations under conditions of reduced visibility. The simplest of these systems employ high-quality optics and internal light amplification devices to make maximum use of any available light. Although perhaps best used at lower altitudes at dusk and dawn, some LLLTV systems can be effectively used at night under starlight conditions. These units can be pod-mounted and carried externally or may be installed directly in the aircraft.

Forward-looking infrared systems (FLIR) may be similarly installed. These systems detect and display differences in temperature, or the intrinsic radiation of warm objects and surfaces rather than reflected light, and are thus equally effective in day or night operations. In addition to detecting the presence of vessels and floating objects, these system can also provide a record of sea surface temperatures over a large area. As with LLLTV, the principal use of FLIR systems on most missions would be as an adjunct to radar or for night operations against small targets.

Under good weather conditions, LLLTV or FLIR systems might detect targets at ranges up to 10 miles or more. Clouds or rain may reduce this range to zero.

7.3.3 Ancillary Equipment

A number of additional items might be installed or carried on a fisheries surveillance aircraft to increase its capability or flexibility. These might include a drop hatch for search-and-rescue missions or for dropping markers, an external high-powered search light for night operations, a loud-hailer for aircraft-to-surface direct communications, and a variety of cameras for recording purposes. Some hand-held cameras are available with a navigation system interconnect that will automatically print time, date and geographic coordinate position on each photograph, providing a permanent record.

Computer graphic systems are also available as navigation and documentation aids. Particularly useful in a "tactical coordination" role, these systems can accept inputs from radar, ELINT, VLF/OMEGA, an onboard computer or direct keyboard and provide a television type display of aircraft position relative to land, targets, waypoints or any other coordinates or data desired.

In addition to the standard navigation and communications systems, the aircraft should also be equipped with HF radio for direct communications with the Fisheries Department "control center", so as to receive updated position reports on licensed fishing vessels within the search area or on other traffic of interest. As the position of licensed vessels carrying satellite transmitters can be determined with the recommended ELINT equipment, this could be used to vector the aircraft to the fishing fleet area as well as a check on the satellite system itself.

7.3.4 Estimated Systems Costs

Surveillance system costs can easily equal or exceed half the cost of the light or medium twin-engine turbo-prop aircraft required to carry them. In many cases, a significant portion of the total package (aircraft and surveillance systems) costs may be in modifications required to physically install a given system in a particular aircraft. For these reasons, it is difficult to present an adequate picture of systems costs, aircraft costs, and modification costs in isolation. They are best discussed and compared as alternative package configurations. A comparison of basic system purchase costs may, however, serve to illustrate relative system costs and thus provide some indication of total costs. It should be specifically noted, however, that these costs do not include installation or any modification that may be required to either surveillance system or aircraft. Prices shown are in 1980 U.S. dollars for typical systems with standard options.

Radar	
Weather Radar	$ 20,000 - 30,000
Sea Surveillance Radar	150,000 - 250,000
ELINT (Highly dependent on specific equipment)	100,000 - 200,000
Direct Vision	
Driftsight	1,000 - 2,500
Viewfinder	2,000 - 4,000
Stabilized Binoculars	2,500 - 5,000
Electro-Optical	
LLLTV	15,000 - 40,000
FLIR	75,000 - 150,000

8.0 MARITIME SURVEILLANCE AIRCRAFT

As a general rule, the principal requirements for aircraft selected for non-military maritime surveillance activities are (in order of importance): range or endurance on station, payload, speed and altitude capability. Ease of maintenance, repair, commonality of equipment and availability of support services are other factors that together with systems cost will define the specific aircraft or combinations of aircraft that offer the most cost-effective soluion to any nation's maritime surveillance problem.

A variety of aircraft including high-performance jet aircraft, long-range patrol planes and low altitude STOL aircraft have been proposed to the patrol planes and low altitude STOL aircraft have been proposed to the PNG Government by various manufacturers and suppliers for the fisheries and maritime surveillance role. Each manufacturer has naturally sought to present his product in its best light. As a consequence, comparisons of alternative aircraft or systems contained in such presentations are usually less than complete and may in fact be based on unrealistic (and often unstated) assumptions regarding altitude, airspeed, payload or flight endurance requirements.

A complete comparative analysis of the costs and effectiveness of alternative aircraft systems for PNG is beyond the scope of this report. Some simple observations may be made, however. The optimum flying height for radar and ELINT-equipped sea surveillance aircraft has been shown to be in the range of 2,000 to 25,000 feet altitude. Operating between these altitudes, moderately sized targets may be detected at ranges up to approximately 70 nm by radar and 250 nm with ELINT. Below 2,000 feet, detection range is severely limited by the line-of-sight horizon, while above 10,000 feet radar detection range for moderate size targets may actually decrease as a function of increasing "sea return" and changing target angle.

The principal advantages of pure jet aircraft are their high speed, which decreases the time required to fly from point to point, and their ability to operate at high altitude, above the weather. They are most fuel-efficient at altitudes above 30,000 feet. In contrast, turboprop (or jet prop) aircraft are most fuel-efficient at altitudes between 10,000 and 25,000 feet. Although they operate at slower speeds, they also consume less fuel per hour and thus have similar range capability.

In the typical maritime surveillance role, an aircraft might be required to conduct a wide-area search at, say, 10,000 feet altitude. When an "unidentified" vessel is detected by radar or other means, the aircraft may be required to descend below 3,000 feet to determine vessel type and below 1,000 feet for positive identification. Positive vessel identification is required to determine if a vessel is illegally fishing in PNG waters. Such identification is best achieved from an aircraft that is capable of flying safely at speeds of 100 knots or less at altitudes below 1,000 feet.

In general, turboprop aircraft with their combination of operating efficiency and low speed/low altitude capability would appear to be more suited to the maritime surveillance role than pure jet or reciprocating engine aircraft. It is primarily for these reasons that most of the major nations of the world operate turboprop aircraft rather than jets for military maritime surveillance purposes.

A review of operational surveillance systems (Section 7.3) indicates that the most effective minimum aircraft package would include a 360-degree long range sea surveillance radar and a comprehensive ELINT system. Normal crew would consist of two pilots, two equipment operators, and one or two observers, one of whom might act as tactical coordinator. The radar and ELINT equipment will weigh about 600 pounds depending on specific options. With an allowance of 200 pounds per crew member plus an extra 200 pounds for miscellaneous equipment that may be carried, mission payload will be about 1400 pounds. This payload and the associated space requirement is well within the range offered by a variety of moderately-priced turboprop aircraft. The aircraft itself should be pressurized, to permit operation directly over the high terrain encountered in Papua New Guinea, and air conditioned, both for crew comfort on long missions and to maximize the operational life of the surveillance equipment.

Range and speed requirements are more difficult to specify, and some assumptions regarding mission objectives, profiles and operational constraints must be made. The Papua New Guinea DFZ covers an area of approximately 750,000 square nautical miles. Ideally one might wish to search this entire area every day. However, if the objective is to deter illegal fishing activity, then complete once-a-day coverage should not be required. As a general rule, 20% coverage should be sufficient. That is, if the master of an unlicensed vessel knows that a surveillance aircraft flying random search patterns is covering the entire DFZ within a five-day period and he has one chance in five of being intercepted, he will be unlikely to risk loss of his vessel at these odds.

Traditionally, few nations have actually carried out search missions at this level of intensity. This may be attributed to the fact that, until recently, sea surveillance missions were required to be flown at altitudes of 3,000 feet or less due to limitations in radar operational performance and reliance on visual contact. At these altitudes and operating with standard radar systems, the effective detection range for moderately-sized targets would be approximately 35 nm, providing instantaneous coverage of an area of some 220 square nm, or about 0.03% of the Papua New Guinea DFZ. This limited area coverage means that a great number of search lines must be flown, which in turn indicates a need for larger aircraft with long endurance capability. This is reflected in the search pattern proposed by one major manufacturer of large aircraft (Figure 15). This typical pattern would permit inspection of 40% of the DFZ each week, with about 75 to 80 flight hours required.

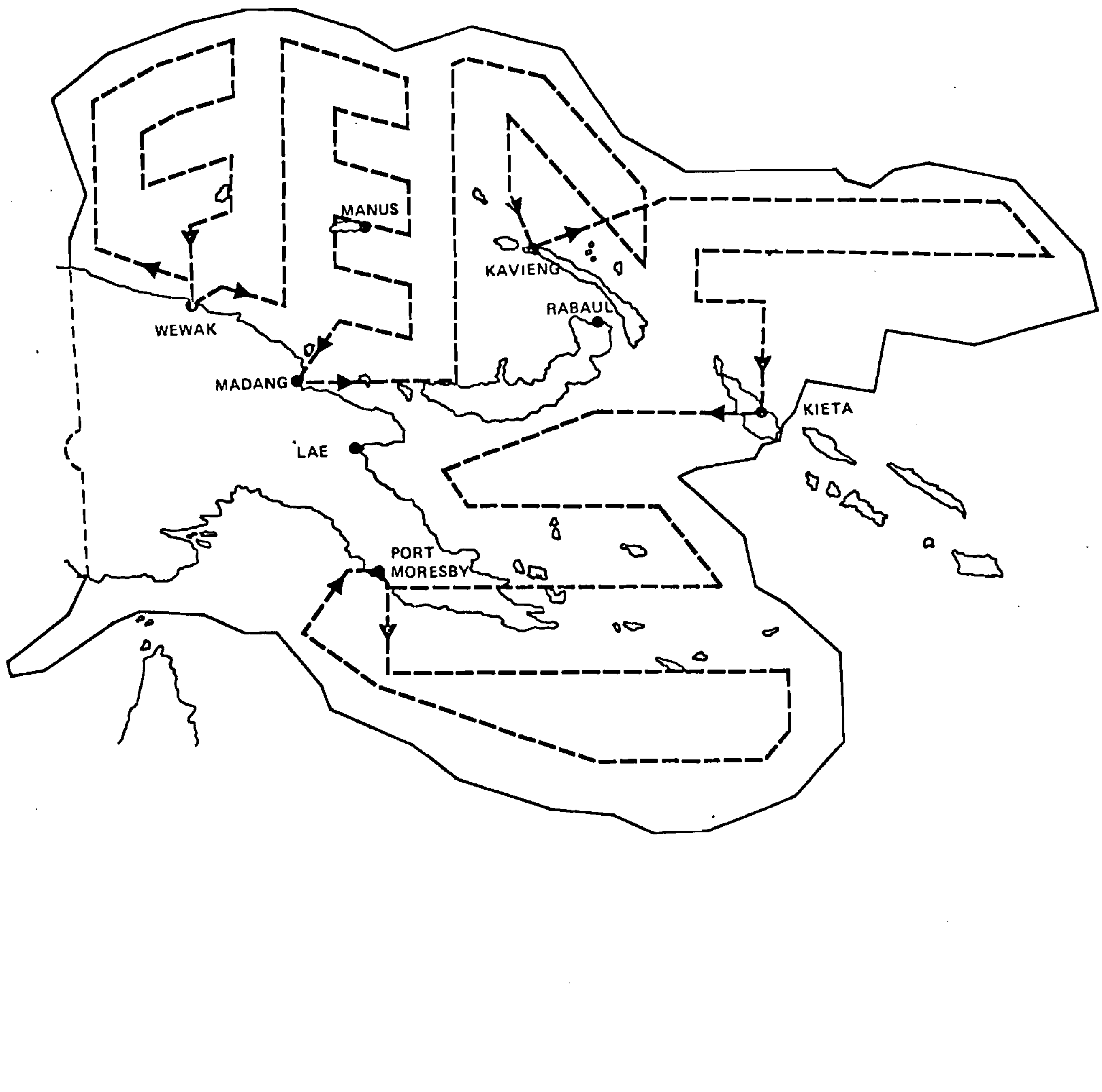


Figure 15: TYPICAL LOW-ALTITUDE SEARCH PATTERN FOR AIRCRAFT WITH STANDARD EQUIPMENT

Significant advantages accrue, in terms of area covered per unit time, if the search aircraft can be operated effectively at higher altitudes. With the combination of advanced sea surveillance radar and ELINT systems recommended here, search aircraft can operate efficiently in the 10,000 to 25,000 foot altitude range. As shown in Figure 16, at an altitude of 10,000 feet the radar coverage area increases to 31,400 square nm, or more than 140 times that possible at 3,000 feet. When combined with ELINT capability, the instantaneous area coverage increases to 196,350 square nm, nearly 900 times the standard radar coverage at low altitude. This increased efficiency means that 100% of the DFZ can now be covered in less than one-third the time otherwise required to cover only 40% of the area. A typical pattern is presented in Figure 17. If the operational altitude is increased to 25,000 feet, then, as shown in Figure 18, 70% of the total DFZ might be covered in a single flight of approximately eight hours.

The significance of these performance figures is that smaller, less complex, and less expensive aircraft may now serve equally well for sea surveillance purposes. Given the electronic surveillance package specified here, a search aircraft with 1,500 nm range capability would be adequate. With the appropriate equipment, an aircraft of this type could also be used to provide a surveillance service to other island groups. A typical high altitude mission (Figure 19) could cover a major portion of the Western South Pacific area, including Micronesia, the Gilbert Islands, Tuvalu, Fiji, New Hebrides, the Solomons and Papua New Guinea, in a four-day period, flying less than eight hours per day.

There are several relatively small turboprop aircraft available whose size, performance, and price would seem to make them viable candidates for the sea surveillance role. Six of these, together with two jet aircraft included for comparison purposes, are summarized briefly in Figures 20 and 21. "Average equipped" prices range from a low of $769,000 for a Rockwell Turbo Commander 690B to a high of $1,464,145 for a Sweringen

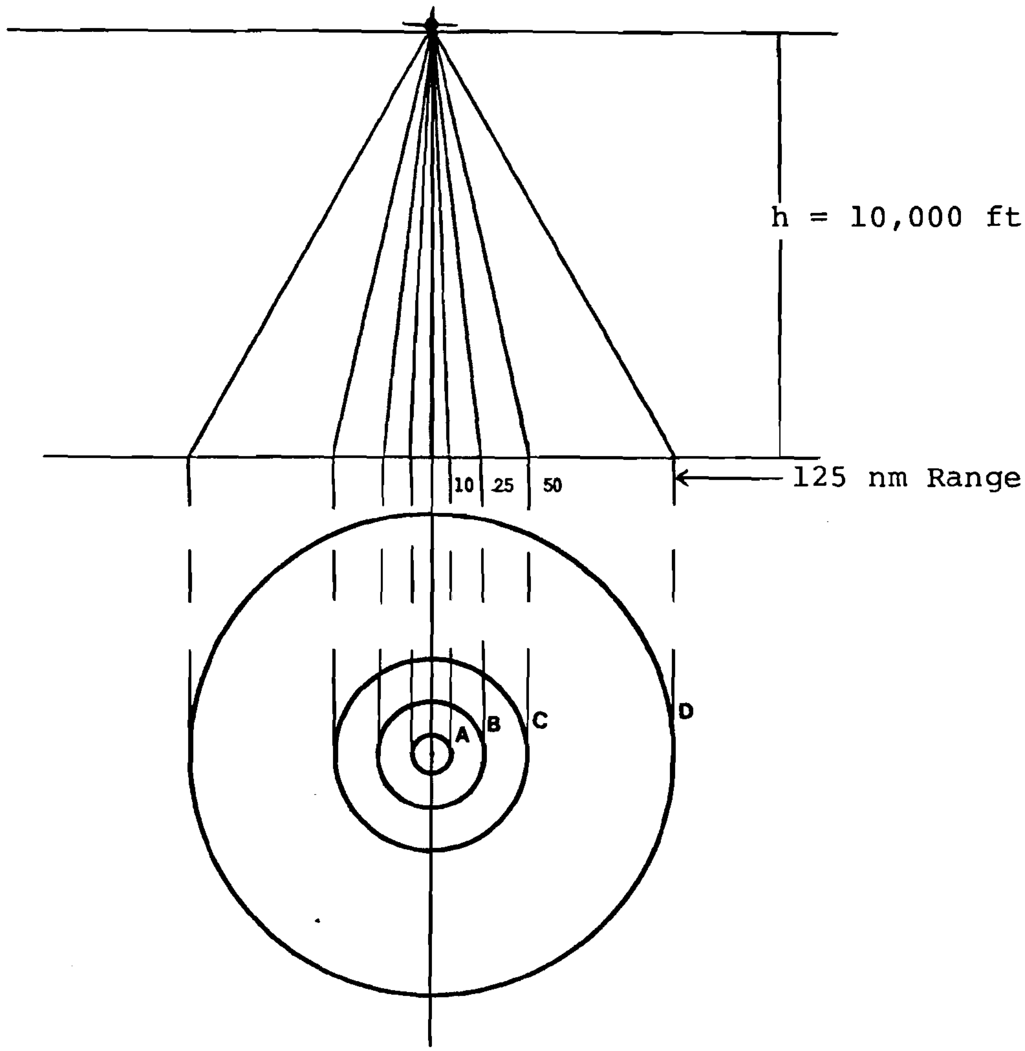


Figure 16: DETECTION RANGE AND AREA COVERAGE FOR ALTERNATIVE SYSTEMS
($150\ m^2$ Target; 10,000 ft Altitude; Sea State 2)

	Range (nm)	Diameter (nm)	Area (nm^2)
A. Visual Search[1]	10	20	1,250
B. Weather Radar[2]	25	50	7,850
C. Sea Surveillance Radar[3]	50	100	31,400
D. ELINT System[4]	125	250	196,350

[1] Daytime only, good visibility condition.

[2] Bendix RDR-1400 type system; day-night.

[3] APS-128A with frequency agility; day-night.

[4] Day-night operations. Requires operating radar system on target.

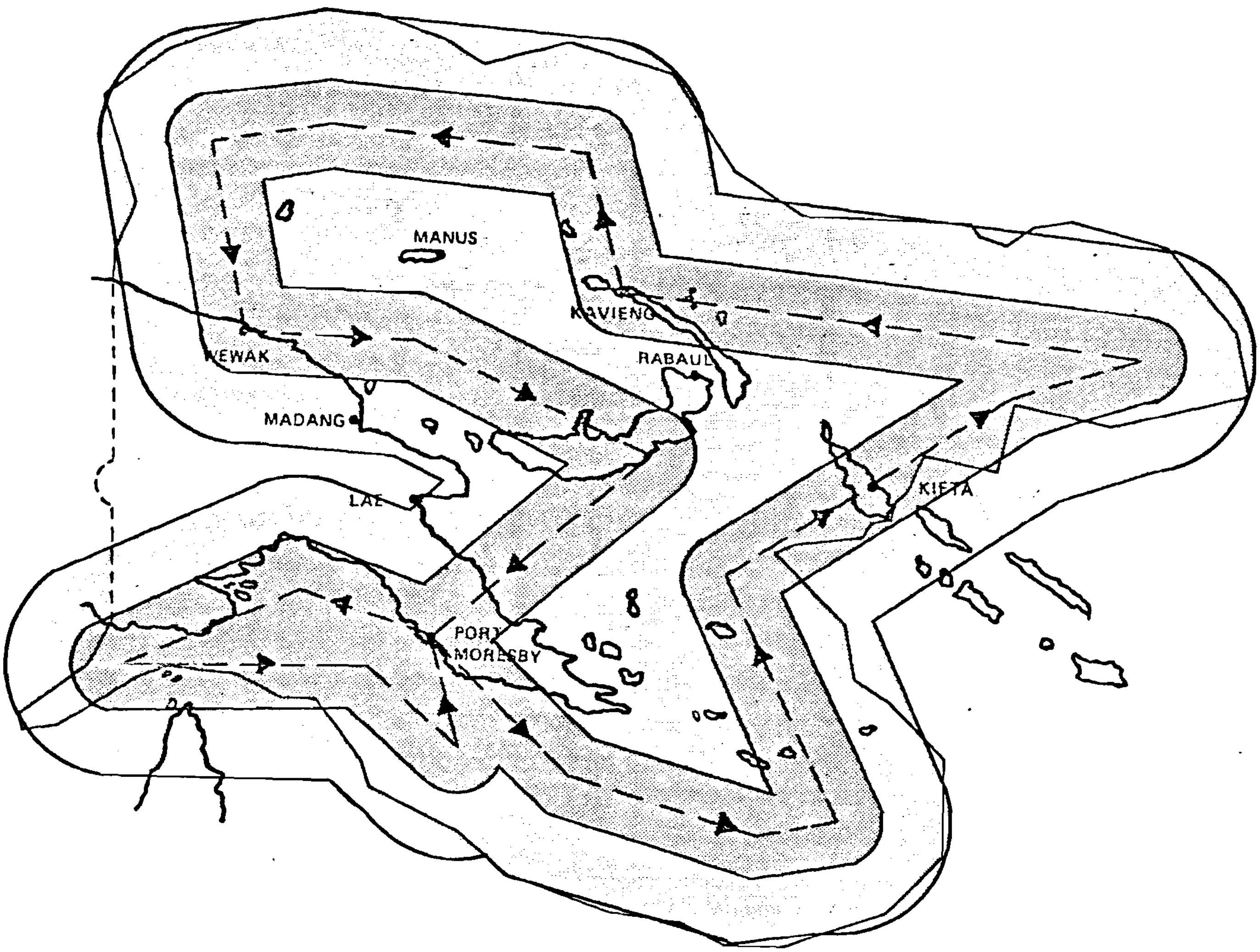


Figure 17: SEARCH PATTERN AND AREA COVERAGE
(150 m^2 target; 10,000 foot altitude; 24 search hours)

RADAR

ELINT

100% of the DFZ

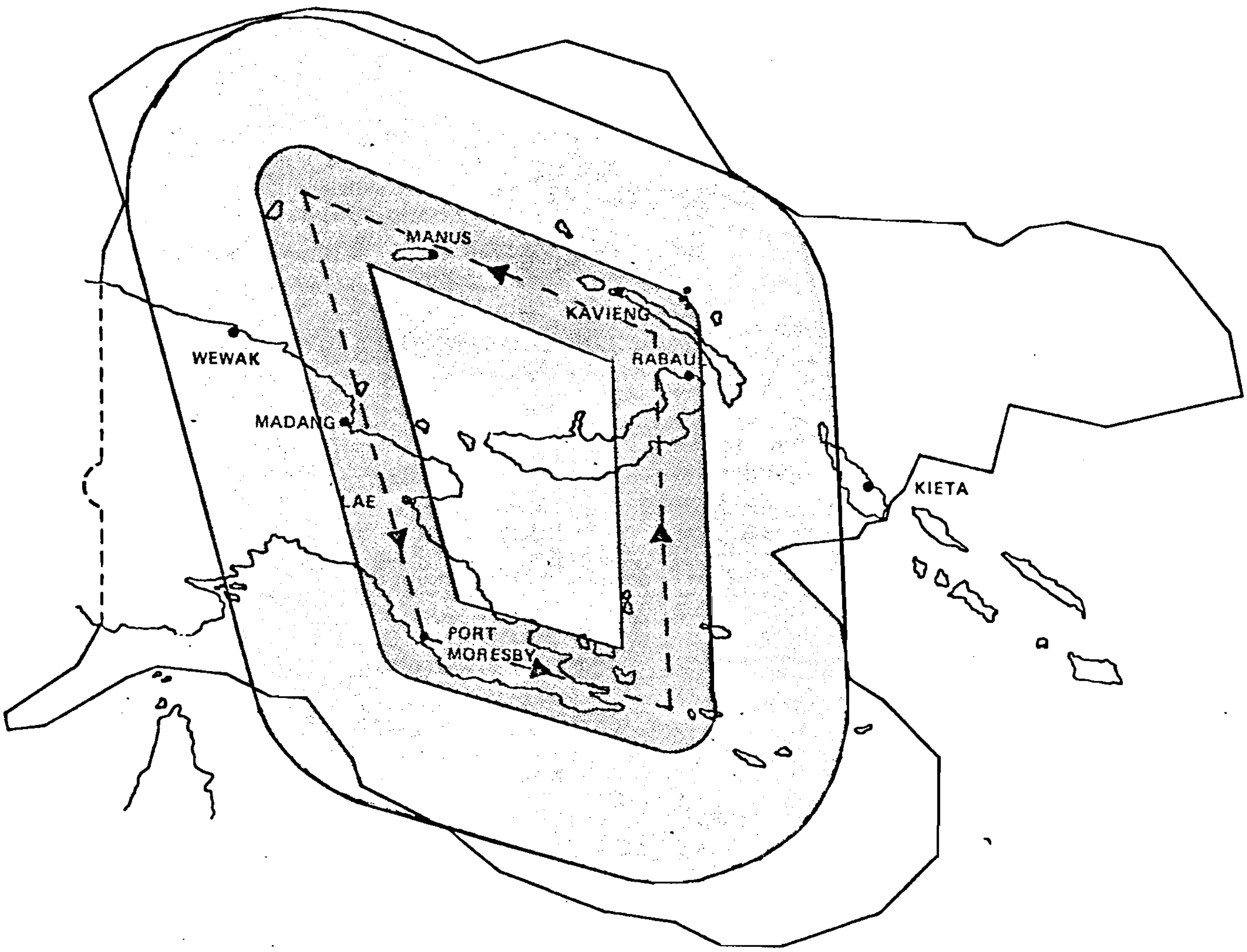


Figure 18: MAXIMUM RANGE SINGLE FLIGHT COVERAGE
(150 m^2 target; 25,000 feet altitude; 8.2 search hours)

RADAR

ELINT

70% of the DFZ

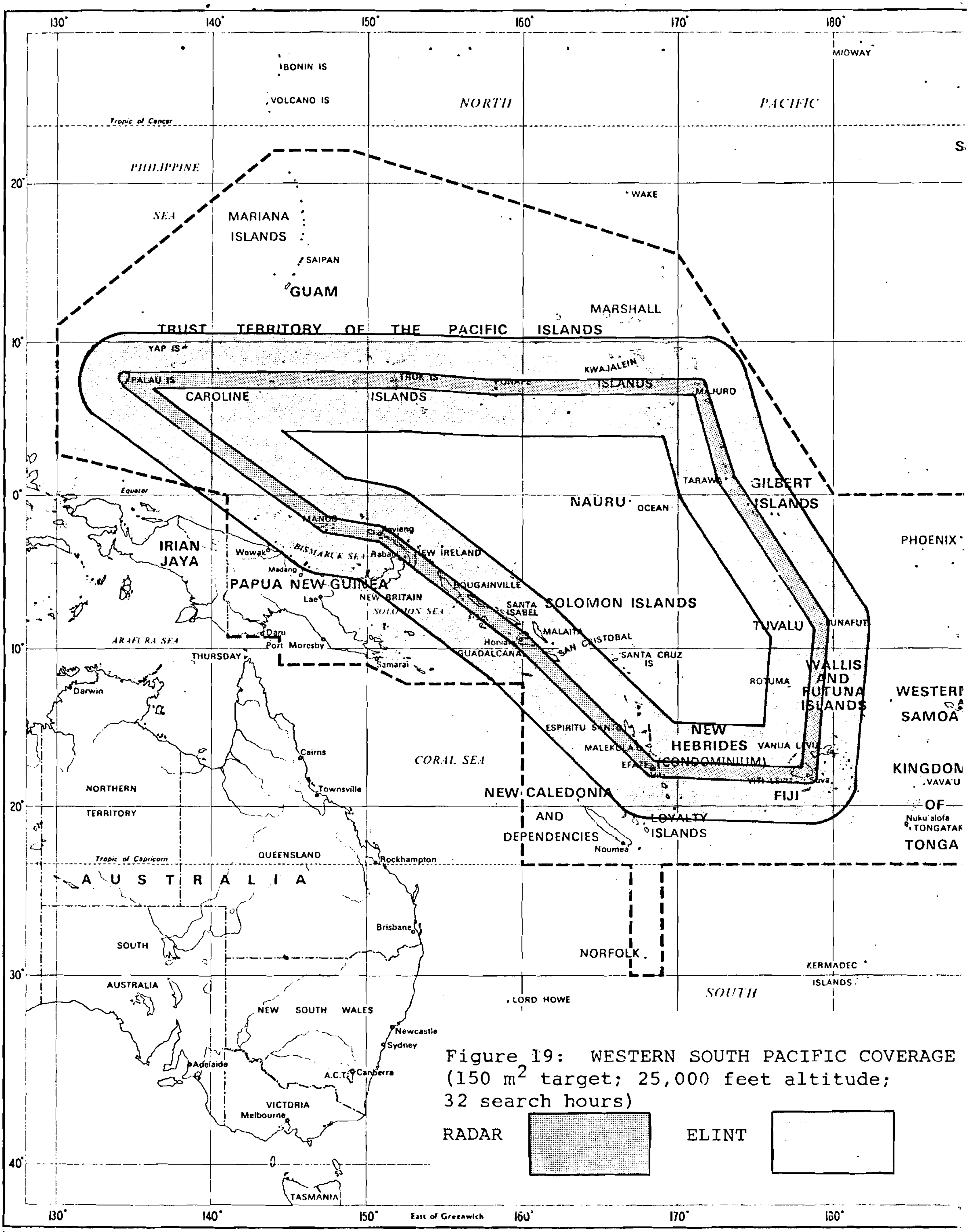
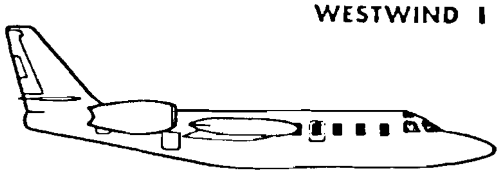


Figure 19: WESTERN SOUTH PACIFIC COVERAGE
(150 m^2 target; 25,000 feet altitude;
32 search hours)

RADAR ELINT

WESTWIND I

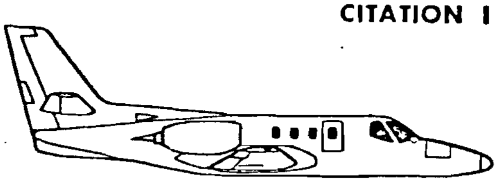


☐ The Jet Commander, a "soft" competitor in its first configuration, is the ancestor of Israel Aircraft's Westwind I. The Garrett fanjets and increased fuel capacity translate into transcontinental range, while the roomy cabin has space for seven to 10 seats and an enclosed lavatory.

1979 Standard price	$2,375,000
Estimated average equipped price	$2,420,425
Engines	Gar TFE 731-3, 3,700 lbs each
Length	52 ft 3 in
Height	15 ft 10 in
Seats	9/12
Wingspan	44 ft 10 in
Wing area	308.3 sq ft
Wing aspect ratio	6.5
Max ramp weight	23,000 lbs
Max takeoff weight	22,850 lbs
Standard empty weight	12,390 lbs
Max useful load	10,610 lbs
Zero fuel weight	16,000 lbs
Max landing weight	19,000 lbs
Wing loading	74.1 lbs/sq ft
Power loading	3.09 lbs/lb

Max usable fuel	1,400 gals/9,380 lbs
Max rate of climb	4,000 fpm
Ceiling (certificated)	45,000 ft
Max pressurization differential	9 psi
8,000-ft cabin altitude @	45,000 ft
SE rate of climb	1,190 fpm
SE best rate of climb airspeed	150 kts
SE climb gradient	476 ft/nm
SE ceiling	25,000 ft
Max speed	470 kts
Normal cruise @ 41,000 ft	430 kts
Fuel flow @ normal cruise	1,407 pph
Endurance @ normal cruise (no reserve)	6.7 hrs
Stalling speed, clean	113 kts
Stalling speed, flaps/gear down	91 kts
Turbulent air penetration speed	230 kts

CITATION I

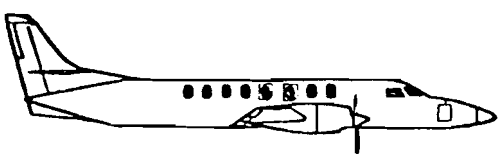


☐ The Citation I, Cessna's smallest business jet, is designed for efficient, economical operation. The production run for the next two years is sold out. Pilots like the docile handling—unlike that of most jets, the wings are not swept back—and neighbors like the low noise levels.

1979 Standard price	$1,245,000
Estimated average equipped price	$1,310,000
Engines	P&WAC JT15D-1A, 2,200 lbs each
Length	43 ft 6 in
Height	14 ft 4 in
Seats	8
Wingspan	47 ft 1 in
Wing area	278.5 sq ft
Wing aspect ratio	7.83
Max ramp weight	12,000 lbs
Max takeoff weight	11,850 lbs
Standard empty weight	6,560 lbs
Max useful load	5,440 lbs
Zero fuel weight	8,400 lbs
Max landing weight	11,350 lbs
Wing loading	42.5 lbs/sq ft
Power loading	2.7 lbs/lb

Max usable fuel	564 gals/3,807 lbs
Max rate of climb	2,680 fpm
Ceiling (certificated)	41,000 ft
Max pressurization differential	8.5 psi
8,000-ft cabin altitude @	41,000 ft
SE rate of climb	800 fpm
SE best rate of climb airspeed	147 kts
SE climb gradient	340 ft/nm
SE ceiling	21,000 ft
Max speed	354 kts
Normal cruise @ 35,000 ft	352 kts
Fuel flow @ normal cruise	967 pph
Endurance @ normal cruise (no reserve)	4.4 hrs
Stalling speed, clean	93 kts
Stalling speed, flaps/gear down	83 kts
Turbulent air penetration speed	180 kts

MERLIN IVA

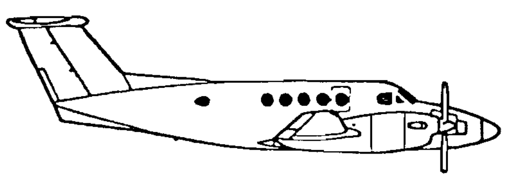


☐ The long Merlin IVA is an executive version of the popular Metroliner commuter airplane. The cigar-shaped fuselage, which seats up to 20 passengers in the Metroliner configuration, seats only 12 to 15 in the IVA. This leaves a spacious cabin with room for a toilet, and the IVA becomes a comfortable miniairliner.

1979 Standard price	$1,275,000
Estimated average equipped price	$1,464,145
Engines	Gar TPE 331-30-303G, 840 shp each
Length	59 ft 4 in
Height	16 ft 7 in
Seats	12/15
Wingspan	46 ft 3 in
Wing area	277.5 sq ft
Wing aspect ratio	7.71
Max ramp weight	12,600 lbs
Max takeoff weight	12,500 lbs
Standard empty weight	8,200 lbs
Max useful load	4,300 lbs
Zero fuel weight	NA
Max landing weight	12,500 lbs
Wing loading	45 lbs/sq ft

Power loading	7.4 lbs/hp
Max usable fuel	554 gals/3,712 lbs
Max rate of climb	2,400 fpm
Ceiling (service)	26,300 ft
Max pressurization differential	7 psi
8,000-ft cabin altitude @	32,400 ft
SE rate of climb	650 fpm
SE best rate of climb airspeed	133 kts
SE climb gradient	293 ft/nm
SE ceiling	13,500 ft
Max speed	263 kts
Normal cruise @ 25,000	250 kts
Fuel flow @ normal cruise	454 pph
Endurance @ normal cruise (no reserve)	8.3 hrs
Stalling speed, clean	98 kts
Stalling speed, flaps/gear down	86 kts
Turbulent air penetration speed	NA

SUPER KING AIR



☐ The Beech King Air turboprops have consistently sold well since the first Model 90 appeared in 1964. Not always the fastest in their class, the King Airs have been popular on the basis of a roomy, comfortable cabin, quality construction and good flying habits. The Super King Air is currently the reigning monarch of the Beech fleet.

Max and cruise speeds at 11,000 lbs.

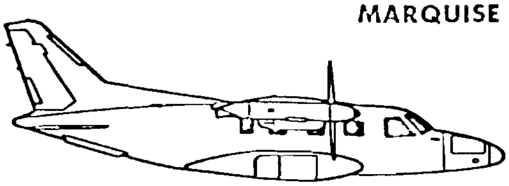
1979 Standard price	$1,174,000
Estimated average equipped price	$1,340,000
Engines	P&WAC PT6A-41, 850 shp each
Length	43 ft 9 in
Height	15 ft
Seats	8/15
Wingspan	54 ft 6 in
Wing area	303 sq ft
Wing aspect ratio	9.8
Max ramp weight	12,590 lbs
Max takeoff weight	12,500 lbs
Standard empty weight	7,437 lbs
Max useful load	5,153 lbs
Zero fuel weight	10,400 lbs
Max landing weight	12,500 lbs
Wing loading	41.3 lbs/sq ft
Power loading	7.4 lbs/hp

Max usable fuel	544 gals/3,645 lbs
Max rate of climb	2,868 fpm
Ceiling (certificated)	35,000 ft
Max pressurization differential	6 psi
8,000-ft cabin altitude @	27,360 ft
SE rate of climb	938 fpm
SE best rate of climb airspeed	122 kts
SE climb gradient	363 ft/nm
SE ceiling	19,150 ft
Max speed	289 kts
Normal cruise @ 24,000 ft	275 kts
Fuel flow @ normal cruise	598 pph
Endurance @ normal cruise (no reserve)	5.5 hrs
Stalling speed, clean	99 kts
Stalling speed, flaps/gear down	75 kts
Turbulent air penetration speed	171 kts

Figure 20: CANDIDATE SURVEILLANCE AIRCRAFT

BEST AVAILABLE COPY

MARQUISE

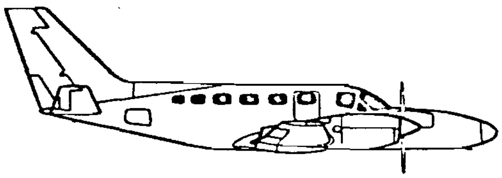


☐ The stretched Mitsubishi, formerly known as the MU2-N, has become the Marquise with the addition of more powerful engines (the same used on the shorter Solitaire). A higher gross weight and room for an extra row of seats reduces the performance below the Solitaire's, but it still remains at the top of its class.

1979 Standard price	$1,095,000
Estimated average equipped price	$1,125,000
Engines	Gar TPE 33-10-501M, 715 hp each
Length	39 ft 5 in
Height	13 ft 8 in
Seats	9/11
Wingspan	39 ft 2 in
Wing area	178 sq ft
Wing aspect ratio	7.71
Max ramp weight	11,625 lbs
Max takeoff weight	11,575 lbs
Standard empty weight	7,650 lbs
Max useful load	3,975 lbs
Zero fuel weight	9,950 lbs
Max landing weight	11,025 lbs
Wing loading	65 lbs/sq ft
Power loading	8.1 lbs/hp

Max usable fuel	403 gals/2,700 lbs
Max rate of climb	2,675 fpm
Ceiling (certificated)	31,000 ft
Max pressurization differential	6 psi
8,000-ft cabin altitude @	28,000 ft
SE rate of climb	675 fpm
SE best rate of climb airspeed	145 kts
SE climb gradient	280 ft/nm
SE ceiling	18,200 ft
Max speed	309 kts
Normal cruise @ 20,000 ft	296 kts
Fuel flow @ normal cruise	592 pph
Endurance @ normal cruise (no reserve)	4.6 hrs
Stalling speed, clean	100 kts
Stalling speed, flaps/gear down	76 kts
Turbulent air penetration speed	191 kts

CONQUEST

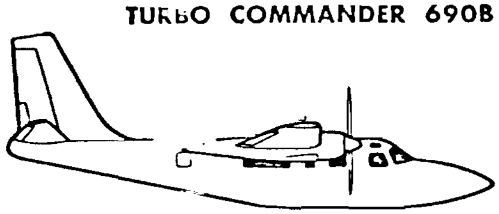


☐ After steadfastly maintaining that it would not build a turboprop, Cessna had a change of heart and introduced the Conquest in 1977. The airplane is designed for high-altitude operation; it is also at home on soft and short fields. The high aspect-ratio wing is of bonded construction and the Fowler flaps are of rigid honeycomb.

1979 Standard price	$937,000
Estimated average equipped price	$995,000
Engines	Gar TPE 331-8-401S, 635 shp each
Length	39 ft
Height	13 ft 1 in
Seats	11
Wingspan	49 ft 3 in
Wing area	253 sq ft
Wing aspect ratio	9.5
Max ramp weight	9,925 lbs
Max takeoff weight	9,850 lbs
Standard empty weight	5,589 lbs
Max useful load	4,336 lbs
Zero fuel weight	8,100 lbs
Max landing weight	9,360 lbs
Wing loading	38.8 lbs/sq ft
Power loading	7.9 lbs/hp

Max usable fuel	475 gals/3,182 lbs
Max rate of climb	2,435 fpm
Ceiling (certificated)	33,000 ft
Max pressurization differential	6.3 psi
8,000-ft cabin altitude @	33,000 ft
SE rate of climb	715 fpm
SE best rate of climb airspeed	120 kts
SE climb gradient	357 ft/nm
SE ceiling	21,380 ft
Max speed	279 kts
Normal cruise @ 28,000 ft	271 kts
Fuel flow @ normal cruise	372 pph
Endurance @ normal cruise (no reserve)	8.5 hrs
Stalling speed, clean	89 kts
Stalling speed, flaps/gear down	74 kts
Turbulent air penetration speed	167 kts

TURBO COMMANDER 690B

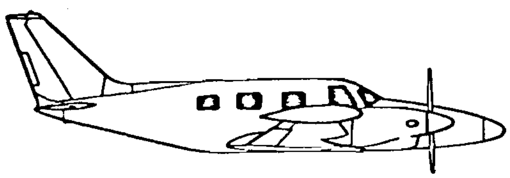


☐ The Commander 690B is the latest of the Rockwell twin turboprops, a series that was first produced in 1965. The 690B is an improved version of the 690A: it has reduced noise levels and increased performance and payloads. The standard price quoted is for a fully-equipped IFR airplane.

1979 Standard price	$769,000
Estimated average equipped price	NA
Engines	Gar TPE331-5-251, 700 shp each
Length	44 ft 4 in
Height	14 ft 9 in
Seats	7/10
Wingspan	46 ft 7 in
Wing area	266 sq ft
Wing aspect ratio	8.2
Max ramp weight	10,375 lbs
Max takeoff weight	10,325 lbs
Standard empty weight	6,195 lbs
Max useful load	4,180 lbs
Zero fuel weight	8,750 lbs
Max landing weight	9,675 lbs
Wing loading	38.8 lbs/sq ft
Power loading	7.4 lbs/hp

Max usable fuel	384 gals/2,573 lbs
Max rate of climb	2,821 fpm
Ceiling (service)	32,800 ft
Max pressurization differential	5.5 psi
8,000-ft cabin altitude @	23,000 ft
SE rate of climb	878 fpm
SE best rate of climb airspeed	115 kts
SE climb gradient	462 ft/nm
SE ceiling	19,600 ft
Max speed	297 kts
Normal cruise @ 22,000 ft	285 kts
Fuel flow @ normal cruise	523 pph
Endurance @ normal cruise (no reserve)	4.9 hrs
Stalling speed, clean	82 kts
Stalling speed, flaps/gear down	77 kts
Turbulent air penetration speed	170 kts

CHEYENNE II



☐ The Cheyenne II, Piper's first turboprop, is almost a Pressurized Navajo with turbines and tip tanks. Its downspring pitch control made the term stability augmentation system familiar to a lot of pilots. The market success of this airplane perhaps explains why Piper is content with turboprops in the "jet age."

1979 Standard price	$635,890
Estimated average equipped price	$804,155
Engines	P&WAC PT6A-28, 620 shp each
Length	34 ft 7 in
Height	12 ft 8 in
Seats	8
Wingspan	42 ft 7 in
Wing area	229 sq ft
Wing aspect ratio	7.95
Max ramp weight	9,050 lbs
Max takeoff weight	9,000 lbs
Standard empty weight	4,976 lbs
Max useful load	4,074 lbs
Zero fuel weight	7,200 lbs
Max landing weight	9,000 lbs
Wing loading	39.3 lbs/sq ft
Power loading	7.3 lbs/hp

Max usable fuel	382 gals/2,559 lbs
Max rate of climb	2,800 fpm
Ceiling (service)	31,600 ft
Max pressurization differential	5.5 psi
8,000-ft cabin altitude @	25,000 ft
SE rate of climb	660 fpm
SE best rate of climb airspeed	113 kts
SE climb gradient	350 ft/nm
SE ceiling	14,600 ft
Max speed @ 11,000 ft	283 kts
Normal cruise @ 11,000 ft	283 kts
Fuel flow @ normal cruise	438 pph
Endurance @ normal cruise (no reserve)	6.6 hrs
Stalling speed, clean	86 kts
Stalling speed, flaps/gear down	75 kts
Turbulent air penetration speed	177 kts

Figure 21: CANDIDATE SURVEILLANCE AIRCRAFT

BEST AVAILABLE COPY

Merlin IVA. The Beech Super King Air 200 and the Cessna Conquest 441 are presently available in "Maritime Surveillance" models. Rockwell now produces a new model Jetprop Commander 840 (similar to the 690B pictured) with a significantly extended range and higher useful load and a maritime version has been designed. The Mitsubishi Marquise is reportedly available in a maritime conversion, but no supporting data is available at the present time. The Piper Cheyenne II is available in a maritime surveillance model that features a Bendix RDR 1300 radar system. No design work has been done to install a sea surveillance radar of the AN/APS-128 type, but it would appear that the aircraft could be modified to carry such a system.

At the present time, Beech and Cessna would appear to be the leading contenders for the maritime surveillance aircraft role, as both have built and modified such aircraft. The Rockwell Commander 840 and Mitsubishi Marquise should definitely be examined in more detail if only because of their high-wing design. Final selection between these aircraft should be delayed pending decision regarding the specific surveillance systems to be carried, power requirements, number of crew stations and similar considerations.

The Nomad 22B presently operated by the PNG Defence Force is not recommended for the <u>primary</u> sea surveillance role. With extra fuel tanks installed, the aircraft does not have sufficient remaining payload capacity to accomodate the recommended surveillance systems, operators, observers, air conditioning, and similar equipment. The Nomad 22L "Search Master" model, although better equipped for this role, still offers performance that is substantially below that of its competitors for the high altitude surveillance mission. This does not, however, mean that the present Nomad 22B fleet should not be used in sea surveillance mission support. The aircraft could play a very useful role in low altitude sweeps against targets such as the illegal "clam boats", which do not carry radar and are difficult to detect from high altitude. Similarly, if a vessel seen to be illegally fishing within the DFZ moves beyond the 200-mile limit before it can be intercepted on the surface, the doctrine of "hot pursuit" will only hold if the vessel has been followed and kept under constant observation by the surveillance aircraft. Under these conditions, multiple aircraft may be required to maintain a rotating watch on the vessel until it can be intercepted and boarded.

8.1 Estimated Costs for Maritime Surveillance Aircraft

Aircraft costs vary widely as a function of equipment options. Avionics and other standard options may represent 25% of the total purchase price. Options desired in a "maritime surveillance" aircraft, such as an extended-range fuel system, upgraded navigation and radio equipment, observation windows, and modified or heavy-duty wings may add another 30% or more. To this must be added the costs of the surveillance sensor systems themselves, together with their installation costs. These installation costs will vary substantially as a function of the particular sensor system configuration and aircraft selected. Decisions regarding these items are properly part of a detailed design study effort. Until such an effort is completed, any cost estimate must be treated as rough order-of-magnitude numbers only.

The 1979 "average equipped price" for a basic Beech Super King Air 200 was $1,340,000. The "maritime surveillance" model of this aircraft, including sensor systems, installation and modification, will cost an estimated $2,800,000 in 1981.

It seems reasonable then to assume that an equipped maritime surveillance aircraft for Papua New Guinea will cost between $2 million and $3.5 million U.S. dollars by 1981, exclusive of spares.

9.0 RECOMMENDATIONS AND CONCLUSIONS

This study has concluded that surveillance of Papua New Guinea's Declared Fishing Zone using advanced technology is feasible given present system constraints and budget limitations. Potential advantages of such surveillance include protection of the country's national interest, more efficient enforcement of national laws, more effective management of the country's fishery resources, increased revenues from licensing agreements, and expansion of the scientific data base.

Various techniques are applicable to the surveillance problem. Cooperative vessels may be monitored with use of the TIROS-N ARGOS Data Collection System. An alternative to this technique is the TRANSIT/OMEGA navigation system with a SSB digitial data relay. Detection and surveillance of non-cooperative vessels will require an airborne capability. A dedicated maritime surveillance aircraft with surface search radar and an ELINT capability is recommended.

Maintenance of a reaction or enforcement force is a necessity if the overall system is to work. Detection alone will not suffice. There must be a capability to pursue and capture offenders. The surveillance system will assist in logical and efficient deployment of the reaction forces and will guide these forces to specific offenders.

Specific recommendations necessary to effect these general conclusions follow.

9.1 Cooperative Targets

The PNG Government should immediately initiate an application for permission to use the ARGOS system. Upon receipt of permission, an operational system design should be finalized. An initial complement of PTT's should be purchased and installed on the fishing vessels. A receiving station should be purchased and set up for an initial system test. Training programs for system operation and maintenance should be established.

Peripheral oceanographic data should be collected concomitant with collection of vessel location. The Fisheries Department should specify the types of data desired. Selection of specific sensors and required interface should be included in a detailed design study prior to PTT purchase.

9.2 Non-Cooperative Targets

Detection of non-cooperative targets will require an airborne capability. A dedicated maritime surveillance aircraft should be outfitted with two major sensor systems, a surface search radar and an electronic intelligence radar signal monitoring syem. Recommended radar systems include the Litton AN/APS-504(V)-2 and the AIL (Cutler Hammer) AN/APS-128.

In addition, the surveillance aircraft should be outfitted with an ARGOS Platform Interrogator and Field Test Set. This will allow airborne verification of cooperative vessels and a check of proper PTT operation. Also, cooperative vessels should be outfitted with a radar beacon compatible with the recommended surface search radar. This beacon will enhance remote airborne differentiation between cooperative and non-cooperative targets.

9.3 Maritime Surveillance Aircraft

Based on a brief analysis of available aircraft which could be compatible with both the operational requirements of the mission and the recommended sensor systems, a list of candidate aircraft has been prepared. The leading contenders include the Beechcraft Super King Air 200, the Cessna Conquest 441, the Rockwell Turbo Commander 840, and the Mitsubishi Marquise. Regardless of choice, these aircraft will require modification to accept appropriate radomes or sensor pods. "Package" modifications presently available with certain of these aircraft do not include key elements that will be required in Papua New Guinea.

In addition to the dedicated aicraft, the present fleet of Defence Force Nomad aircraft should be maintained. They can provide a needed low-altitude low-speed surveillance capability.

9.4 Data Coordination and Management

Implementation of the total recommended surveillance system will rapidly generate large amounts of data. Some of this data will require immediate reaction, for example, non-cooperative target intercept data. The other data will continually accumulate and will require efficient organization and storage for later use. To illustrate, assume 50 vessels linked to the system, each collecting five parameters of oceanographic data plus location (latitude, longitude). Each day, this system will generate 2,450 unique pieces of data.

In order to avoid becoming smothered in data, an operational plan must be developed. Staffing must be sufficient to keep up with the system. An organized storage and retrieval system is a necessary requisite. In order to take advantage of the information in this data, a preliminary data analysis plan is also highly recommended.

Interception of non-cooperative targets will require close communication between surveillance aircraft and pursuit vessels. It is strongly recommended that a 24 hour/day DFZ Command Center be established to coordinate and control communication and data flow. This Center could also house the ARGOS receiving station and coordinate cooperative vessel data flow. The "operational plan" referred to above should include an analysis of DFZ Command Center organization and operation.

9.5 Remote Sensing Data

Remote sensing data from many government and commercial sources may be of great value to fisheries scientists and oceanographers in Papua New Guinea. Efforts should be made to train these people in this technology and its utilization.

9.6 Operational Design Study

The technology recommended herein is proven and off-the-shelf. However, considerable specific design will be necessary to properly tailor the available hardware to the PNG application. This is true for all aspects of the system, including the PTT's, the oceanographic sensor interfaces, the receiving station, the airborne sensor selection and interface, aircraft modifications and Command Center organization. An operational design study should be completed prior to any hardware purchase. This study should provide detailed operational specifications for all systems. These specifications could be directly input to future purchase documents or requests for bids.

9.7 Pilot Project

Rather than proceeding directly to a full-scale surveillance system monitoring location of all fishing vessels in PNG's waters, it is recommended that PNG proceed first with a Pilot Project on a smaller scale. This Pilot Project could outfit a maximum of perhaps 30 vessels with PTT's, establish the recommended reference transmitters, and instrument some rafts. The Pilot system should then be operated for perhaps one year to iron out any operational difficulties which may arise. After that time, the system can go fully operational.

10.0 FUTURE DIRECTION - A PILOT PROJECT APPROACH

Implementation of the recommendations contained in this report will require extensive effort and effective technical leadership. Consideration must be given to design of the <u>total</u> system. This includes installation, operation, maintenance, training, analysis, and reaction as well as the more obvious hardware configuration and design.

Implementation of a system to monitor <u>all</u> fishing vessels utilizing PNG waters will be a complex and expensive operation. Prior to final commitment to such a system, it would be prudent to test the system on a smaller scale. Such a test would allow one to experience the real-life operational problems that might appear with this prototype system and to properly design means to circumvent them in a final operational system. In the long run, this phased approach would increase the chances of success of the entire concept. It would also decrease the likelihood of costly mistakes.

As presently envisioned, a Pilot Project of this sort would have a minimum of eight separate and distinct tasks. In actuality, these eight tasks will have to be performed regardless of whether PNG proceeds with a small scale test or a full scale system. The eight tasks include final selection of approach and techniques, design of operational specifications, formation of purchase specifications, purchase of hardware and services, design and construction of command center, hardware installation and checkout, operational system test, and training of personnel. At the conclusion of such a project, a decision could be made whether to proceed. If so, the full scale program can be implemented with changes, suggested by the Pilot Project, integrated into the final design.

A brief description of these eight tasks follows.

10.1 Final Section of Approach and Techniques

This feasibility study has presented various alternative approaches. The first step is to select an approach which is to be followed. Major hardware types and components must be specified. If the ARGOS system were selected, these hardware types might include specific oceanographic sensors. For the airborne system, type of aircraft, type of radar, and specific components of the ELINT system would have to be selected..

10.2 Operational and Purchase Specifications

Detailed specifications which could later be inserted in the purchase documents would be outlined. These specifications would include system interface, packaging, size and weight, power, and reliability requirements.

In conjunction with the appropriate PNG contracting office, purchase specifications would be drawn up. These would include the operational specifications as well as requirements for warranty, installation, maintenance, documentation, spare parts, training, and delivery.

10.3 Operational Plan

An initial operational plan must be developed. It must specify, in detail, all scheduling aspects of the program, including hardware delivery, installation, test, and operation. It must specify the type of staff required and select appropriate individuals. It must organize and coordinate data flow and reaction policies.

10.4 Purchase of Hardware

The purchase specifications would be used as a guide for the purchase of the hardware. Technical support may be required for review of any potential contractor's bid.

10.5 Command Center

A location must be chosen for the Command Center. It must be constructed so as to accomodate the appropriate receiving or monitoring station. In addition, it must have reliable communications facilities linking it to all surface and air surveillance and enforcement craft. It must have capabilities for storage and retrieval of data and should have appropriate means of plotting data to facilitate tactical command decisions. Staffing levels must be specified for the facility.

10.6 Hardware Installation and Check-out

Upon delivery of hardware, it must be installed and checked out. For the receiving station, this should be performed by the contractor supplying the hardware. For the PTT's, it will be done by PNG personnel. Aircraft systems should be installed and checked out by a major aircraft modification subcontractor or by the supplier of the aircraft.

10.7 Operational System Test

The system should be operated for a period of one year. During that time, operational procedures must remain flexible. Various different procedures should be tested and their results documented. Procedures for handling and analyzing data must be confirmed during this period.

10.8 Training of Personnel

During the one year system test, various training courses must be held for PNG personnel. These must include courses in system operation, system maintenance, and data analysis.

10.9 Full System Implementation

At the end of the one year system test, a decision will be made whether the system should proceed to full operation. At that time, PNG will have all necessary capabilities to implement and operate the full system.

11.0 SELECTED REFERENCES

American Institute of Aeronautics and Astronautics, Inc., 1977, A Collection of Technical Papers, AIAA/AMS/AGU/EEE/MTS/SEG Conference on Satellite Applications to Marine Technology, New Orleans, Louisiana.

Cavanaugh, F.A., 1976, Application of High Altitude Surveillance Aircraft to Future Coast Guard Mission Objectives, Final Report, Office of Research and Development, U.S. Coast Guard, Washington,D.C.

Couchman, R.L., 1978, An Overview of Alternative Techniques for Determining Positions at Sea, with Emphasis on Applicability of Potential Use for Positioning Buoys, Final Report, Office of Research and Development, U.S. Coast Guard, Washington, D.C.

Fisheries Division, 1977, Surveillance Manual 1977, Department of Primary Industry, Papua New Guinea.

Fisheries Division, 1978, Fisheries Research Annual Report, Department of Primary Industry, Papua New Guinea.

Johnson, K., ed., 1963, Modern Fishing Gear of the World, Vol. 2, FAO, Rome.

Kearney, R.E., 1975, The Prospects for Fisheries Development in Papua New Guinea.

Kearney, R.E., 1975, Skipjack Tuna Fishing in Papua New Guinea, 1970-1973, Marine Fisheries Review.

Lewis, A.D. and B. R. Smith, 1977, A Brief Guide to the Tunas and Billfish of Papua New Guinea, 2nd PNG National Game Fish Titles, Finchhaven, April 8-10, Papua New Guinea.

Madrid, C.R., ed., 1978, The Nimbus 7 User's Guide, Goddard Space Flight Center, National Aeronautics and Space Administration, Washington, D.C.

Mueller, E.J., Kuegler, G.K., and Willman, C.E., 1975, Analysis of the Potential Application of Space Telecommunications Systems to U.S. Coast Guard Missions, Final Report, Office of Operations and Office of the Chief of Staff, U.S. Coast Guard, Washington, D.C.

Munro, I.S.R., 1967, The Fisheries of New Guinea, Department of Agriculture, Stock and Fisheries, Port Moresby, New Guinea.

Murphy, 1973, Fishery Development Problems in Southeast Asia Island Area, Oceania.

Office of International Affairs, 1978, Papua New Guinea Fisheries Agreement with Japan, F43/BB,IFR-78/147, U.S. Department of Commerce, Washington, D.C.

Office of Technology Assessment, 1977, Establishing a 200-Mile Fisheries Zone, Working Papers, Congress of the United States, Washington, D.C.

Papua New Guinea, 1979, Statement by Papua New Guinea at the Twentieth Session of the FAO Conference, Rome, November.

Pownall, P.C., 1974, Fisheries of Papua New Guinea, Canberra.

Schwalb, A., 1977, The TIROS-N/NOAA A-G Satellite Series, National Environmental Satellite Service, National Oceanic and Atmospheric Administration, Washington, D.C.

Service ARGOS, 1978, User's Guide, Satellite-Based Data Collection and Location System, Centre National D'Etudes Spatiales, Toulouse, France.

Smith, B.R., 1974, An Appraisal of the Live Bait Potential and Handling Characteristics of the Common Tuna Bait Species in Papua New Guinea. Tuna Bait Workshop, June 4-6, Honolulu, Hawaii.

Sonnenberg, G.J., 1978, Radar and Electronic Navigation, 5th Edition, Newnes-Butterworth's, London.

South China Seas Fisheries Development Coordination Program, 1977. Development Potential of Selected Fishery Products in the Regional Member Countries of the Asian Development Bank, Vol. 2, Fishery Country Profiles, SCS/DEV/76/11, App. 1, FAO, Manila, Philippines.

South Pacific Commission, 1975, Country Statements, Eighth Regional Technical Meeting on Fisheries, Noumea, New Caledonia.

Takashiba, A., 1972, Report on Fisheries Project in Papua New Guinea.

Wankowski, J.W.I. and Lindholm, R.Y., 1979, The Papua New Guinea Tuna and Bait Fisheries, 1978 and 1979, Fisheries Division, Port Moresby, Papua New Guinea.

Wilson, M.H., and West, G.F., 1975, The Present Status of the Papua New Guinea Tuna Fishery, SPC Eighth Regional Technical Meeting on Fisheries, Noumea, New Caledonia.

Wilson, P.T., 1979, Fisheries Newsletter, July, Papua New Guinea.

APPENDIX A

EXAMPLES OF AVAILABLE AIRBORNE AND SPACEBORNE PHOTOGRAPHY AND IMAGERY

Included in this appendix are various examples of current remote sensing photographs and images available from either U. S. Government sources or from commercial firms. As explained in the body of this report, most of these types of data are inapplicable to the specific problem of regional reconnaissance of fishing vessels. However, the reconnaisance system, as recommended, will also gather certain types of oceanographic data which will be used in research on stock assessment, stock prediction, and location of fish schools. Many of the techniques described in this appendix can contribute complementary data which may provide a valuable adjunct to that gathered by the reconnaissance system.

The addresses of agencies through which imagery and photography may be ordered are as follows:

Aerial Photography, Skylab, Landsat

EROS Data Center
U. S. Geological Survey
Sioux Falls, South Dakota 57198

TIROS-N, CZCS, SEASAT

Satellite Data Services Branch
Environmental Data and Information Service
National Atmospheric and Oceanic Administration
World Weather Building
5200 Auth Road
Camp Springs, Maryland 20233

Japanese GMS

Meteorological Information Center
Japan Weather Association
Kaiji Center Building
4-5 Koji-machi, Chiyoda-ku, Tokyo
100 Japan

Aerial Photography

Aerial photography, using either black and white panchromatic, black and white infrared, natural color, or color infrared film, may provide valuable information on water color, water clarity (turbidity), current patterns, pollution, ships, and in some rather rare cases, actual schools of fish. The spatial resolution of most aerial photographs is more than sufficient to not only detect vessels, but, in most cases, to determine their type. Various different film types accentuate different features. Natural color films accentuate turbidity. Certain water-penetrating films accentuate bottom features. Color infrared films accentuate vegetative or chlorophyll-containing features.

Photo A-1 is a color infrared photo of a current interface in the Gulf of Mexico. Color infrared film senses radiation in the invisible near-infrared portion of the spectrum, that part having wavelengths slightly longer than the human eye can see. The red areas of the photo represent a high reflection of near-infrared, indicative of high chlorophyll. As can be seen in the photo, a concentration of planktonic detritus has accumulated along the interface between the two rather separate water masses.

Photo A-2 is a natural color aerial photo of a massive oil spill from a blown-out oil well in the Gulf of Mexico. The slick can be clearly seen and mapped. Surrounding the well is a string of containment barges.

Photo A-3 is a false color infrared photo taken from Skylab using the S190B Earth Terran Camera. From an altitude of 234 nautical miles, the S190B, having an 18-inch focal length lens, took photos using three different types of film, a high resolution natural color, a high resolution black and white, and a color IR. Photo A-3, taken with the color IR film, has a ground resolution of 150 feet and covers much of the island of Flores in Indonesia. Photo coverage from Skylab was very limited in the South Pacific. No more missions of a similar nature are planned.

Photo A-1: FALSE COLOR INFRARED AIRPHOTO: CURRENT INTERFACE GULF OF MEXICO

BEST AVAILABLE COPY

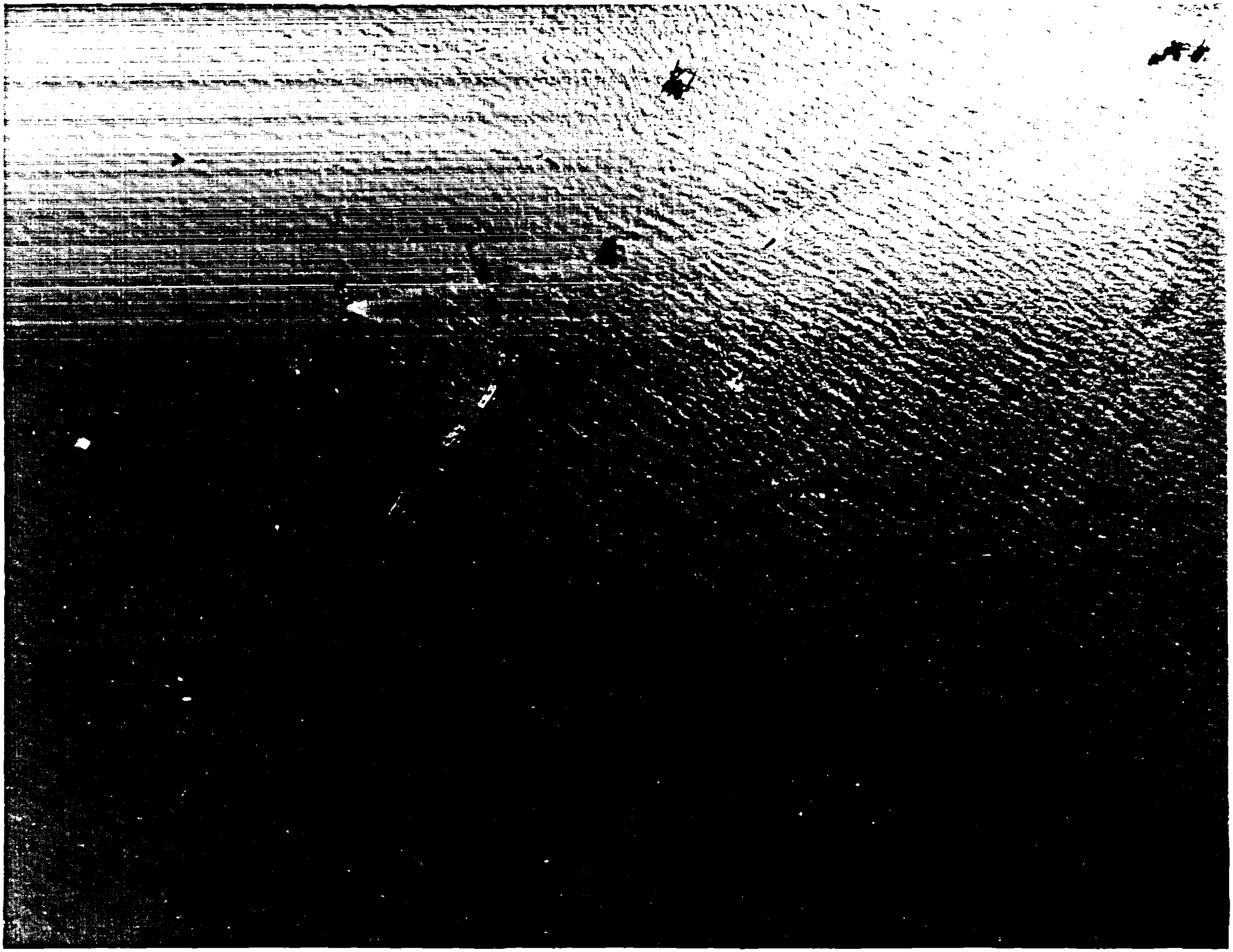


Photo A-2: NATURAL COLOR AIRPHOTO: GULF OF MEXICO OIL SPILL

BEST AVAILABLE COPY

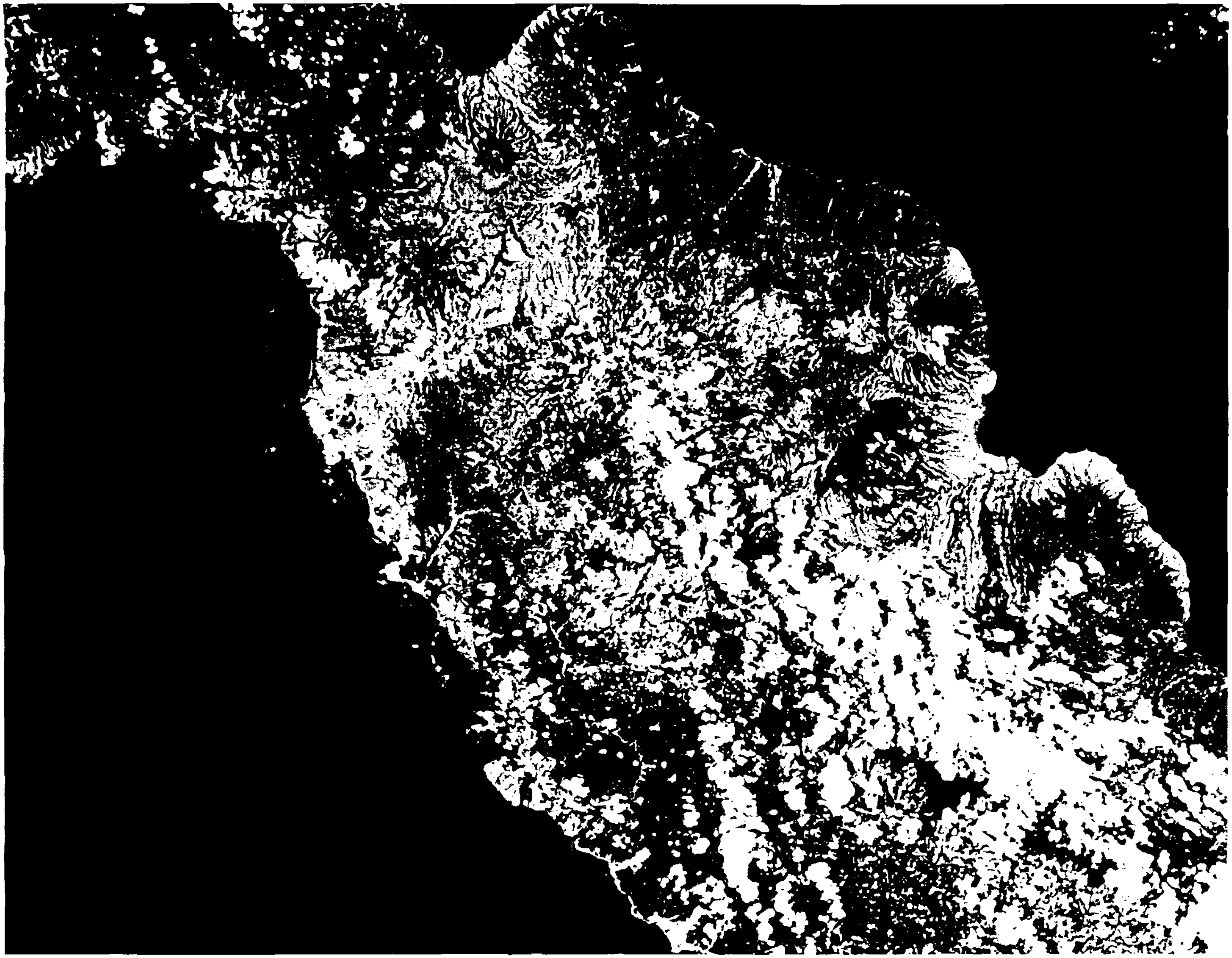


Photo A-3: SKYLAB COLOR INFRARED: PHOTOGRAPH OF ISLAND OF FLORES, INDONESIA

BEST AVAILABLE COPY

Landat

In 1972, ERTS-1 was launched. It was the first attempt to use a satellite as a data collection platform oriented toward earth resources. In 1975, ERTS-2 was launched. It was essentially a duplicate of ERTS-1 and was designed to replace ERTS-1 which had already exceeded its design lifetime by about 200%. Since then, both systems have been renamed Landsat. In 1978, Landsat 3 was launched. Since then, Landsat 1 failed leaving only two satellites presently operating. Each Landsat satellite makes 14 orbits a day viewing a 185 kilometer (115-mile) wide strip of earth. In this orbit, it gives global coverage once every 18 days. With the two satellites, coverage is possible once every 9 days. Every equatorial crossing occurs at approximately the same local time each day - about 9:30 AM, and this holds for all parts of the world, the spacecraft crossing any particular place at about 9:00-10:00 AM local time each day.

At the equator, the centers of successive strips are spaced 2,800 km apart, so that 14 such strips may be observed around the world every day. The orbit is adjusted so that a strip observed on one given day, in one given location, advances westward by about 170 km on the next day. In this fashion, the spacecraft sensors view the entire world between 80°N and 80°S once every 18 days. However, limited power, data transmission and, above all, data-processing capacity prevent acquisition of images over the entire world during every 18-day period. Thus, contiguous images are acquired every 18 days only over the North American continent.

The Landsat payload includes these major elements:

1. Return Beam Vidicon (RBV) Television Cameras - These three cameras view the same 185 x 185-km (115 x 115-mi) square area in three different spectral bands: green, red, and near-infrared.
2. Multispectral Scanner Subsystem (MSS) - The MSS returns images in four spectral bands: green, red, and two

near-infrared bands. The MSS scans horizontally along the orbital track. During ground processing, frames equivalent to the 185-km square scenes imaged by the RBV are constructed.

3. Data Collection System (DCS) - The DCS is a communications system, not remote-sensing experiment. It collects information from some 150 remote, unattended, instrumented ground platforms and relays the information to NASA ground stations for delivery to the users.

Data from the RBV and MSS are distributed in the form of film images or machine-sensitive digitized data on magnetic tape. Informaton from the data collection platforms is in digital form only.

The Multispectral Scanner (MSS) is a line-scanning device which uses an oscillating mirror to simultaneously scan the terrain passing beneath the spacecraft. The scanner produces four synchronous images, each at a different wave band. The wavelength ranges of each band are:

Band 4 (green)	0.5 to 0.6 micrometers
Band 5 (lower red)	0.6 to 0.7 micrometers
Band 6 (upper red-lower infrared)	0.7 to 0.8 micrometers
Band 7 (infrared)	0.8 to 1.1 micrometers

Band 7 is the best for land-water discrimination. Band 5 is best for showing topographic and cultural features, such as drainage patterns, roads, and towns. Band 4 sometimes discriminates, qualitatively, the depth and/or turbidity of standing bodies of water. Band 6 shows the best tonal contrasts that reflect various land use practices; it also gives maximum land-water contrast.

Data from the MSS can be obtained in several different formats. Black and white prints, transparencies, or negatives can be obtained for each of the four spectral bands. Photo A-4 is a copy of a band 7 (near-infrared) image of San Francisco Bay. Scale is approximately 1:1,000,000.

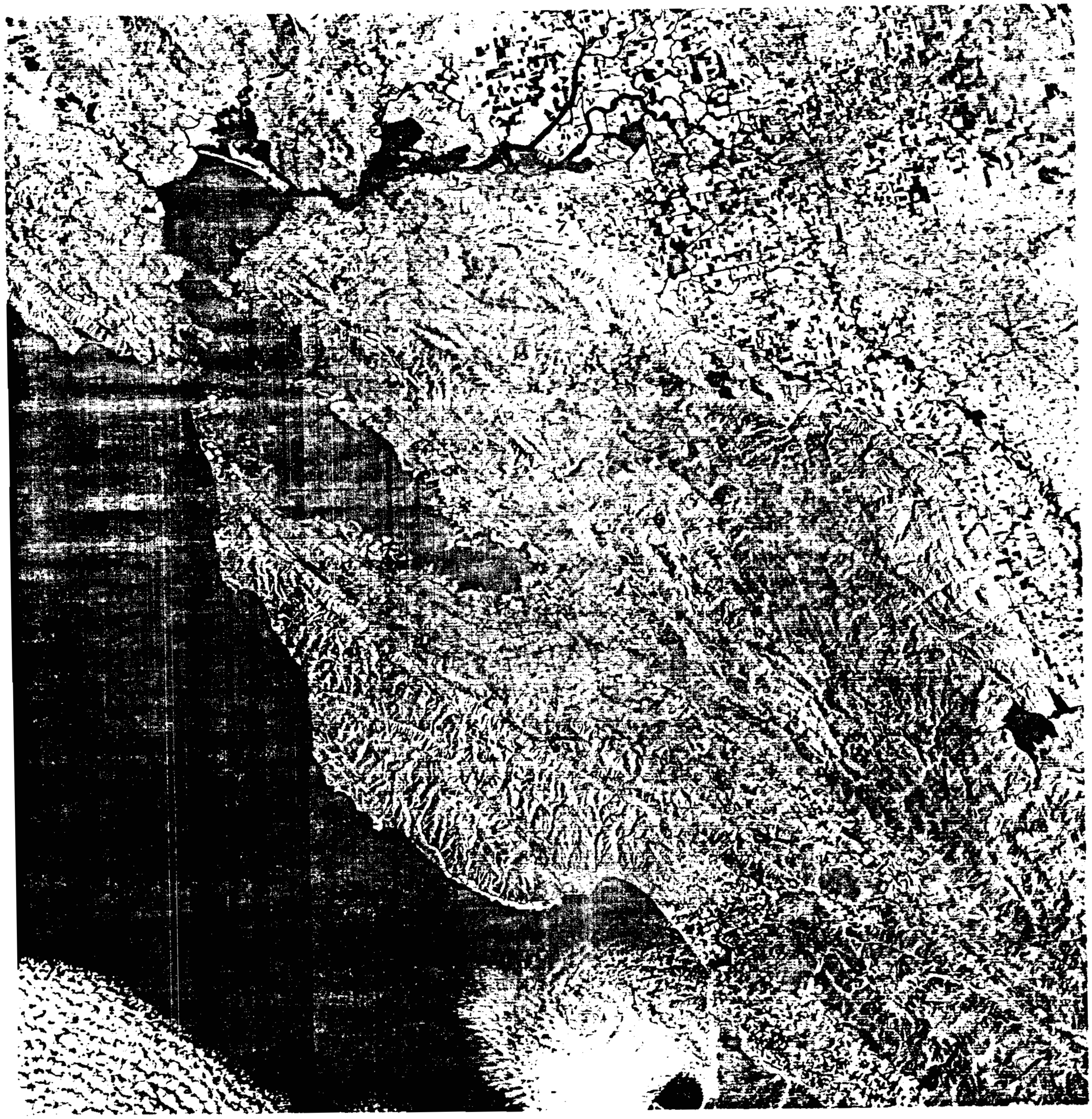


Photo A-4: LANDSAT BAND 7 IMAGE
SAN FRANCISCO BAY

Several bands can be represented simultaneously on a color composite. Three of the four bands (commonly 4, 5, 7) are printed through three colored filters to provide an image similar to a false color IR photo. As with color IR film, high IR reflectance shows up red on these composites.

Photos A-5 and A-6 are false color composites of a 1:250,000 scale MSS image of Papua New Guinea. Photo A-5 covers part of Table Bay on the south coast of the island east of Port Moresby. Photo A-6 covers Collingwood Bay near Tufi. Of particular interest are the sediment plumes entering the ocean from several rivers.

As mentioned earlier, Landsat has a relatively poor spatial resolution as compared to airphotos. It is this limitation plus the fact of infrequent (once every nine days) coverage that restricts Landsat as a candidate for vessel surveillance. As an example of the resolution limitations of Landsat, Photos A-7, A-8, and A-9 have been prepared.

Photos A-7 and A-8 are prints of airphotos taken by the NASA U-2 reconnaissance aircraft from an altitude of approximately 65,000 feet. Photo A-7, taken in 1974, was obtained with a 36" lens using Panatomic-X high resolution film. Original scale of the photo was approximately 1:24,000. Of particular interest in the photo are the many ships lying at anchor. This is part of the mothballed U. S. Merchant Marine fleet of WWII. Average length of these ships is approximately 450 feet. Photo A-8, taken in 1975, was obtained with a 12" lens using black and white infrared film. The scale of the original photo was 1:65,000. It has been enlarged to match the scale of Photo A-7. Photo A-9 is an enlarged portion of the Landsat image found in Photo A-4. It has been enlarged to an approximate scale of 1:24,000. The blurred white blotches are the rows of ships. Landsat has a spatial resolution of only about 256 feet. Thus, the length of each ship is covered in only two resolution elements. A single ship of 450 feet length probably could not be distinguished from noise in the system.

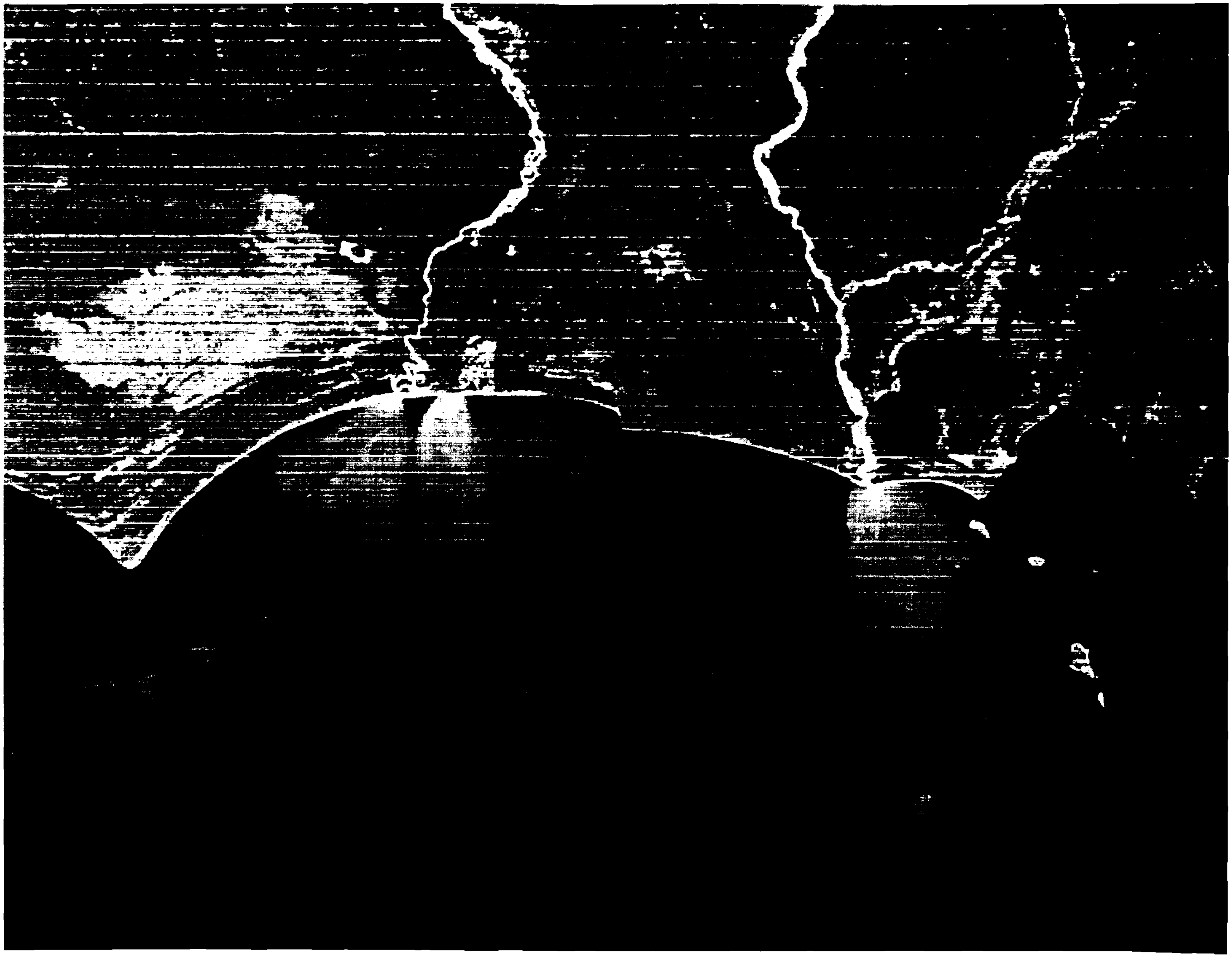


Photo A-5: LANDSAT FALSE COLOR COMPOSITE: SOUTH COAST OF PAPUA-NEW GUINEA

BEST AVAILABLE COPY

Photo A-6: LANDSAT FALSE COLOR COMPOSITE: NORTH COAST OF PAPUA-NEW GUINEA

BEST AVAILABLE COPY

162

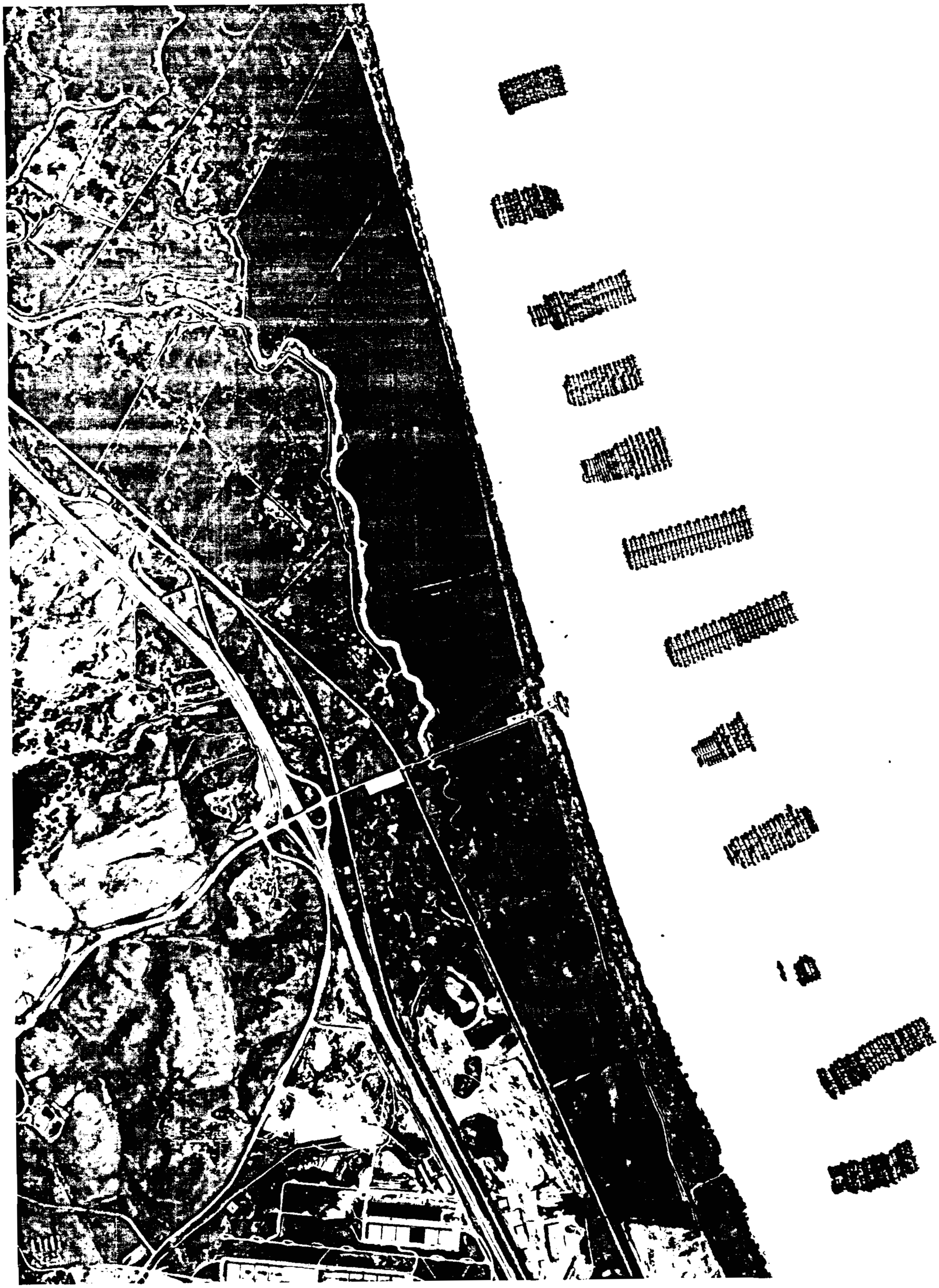


Photo A-7: U-2 AERIAL PHOTOGRAPH
36" LENS, PANATOMIC-X FILM
SCALE = 1:24,000

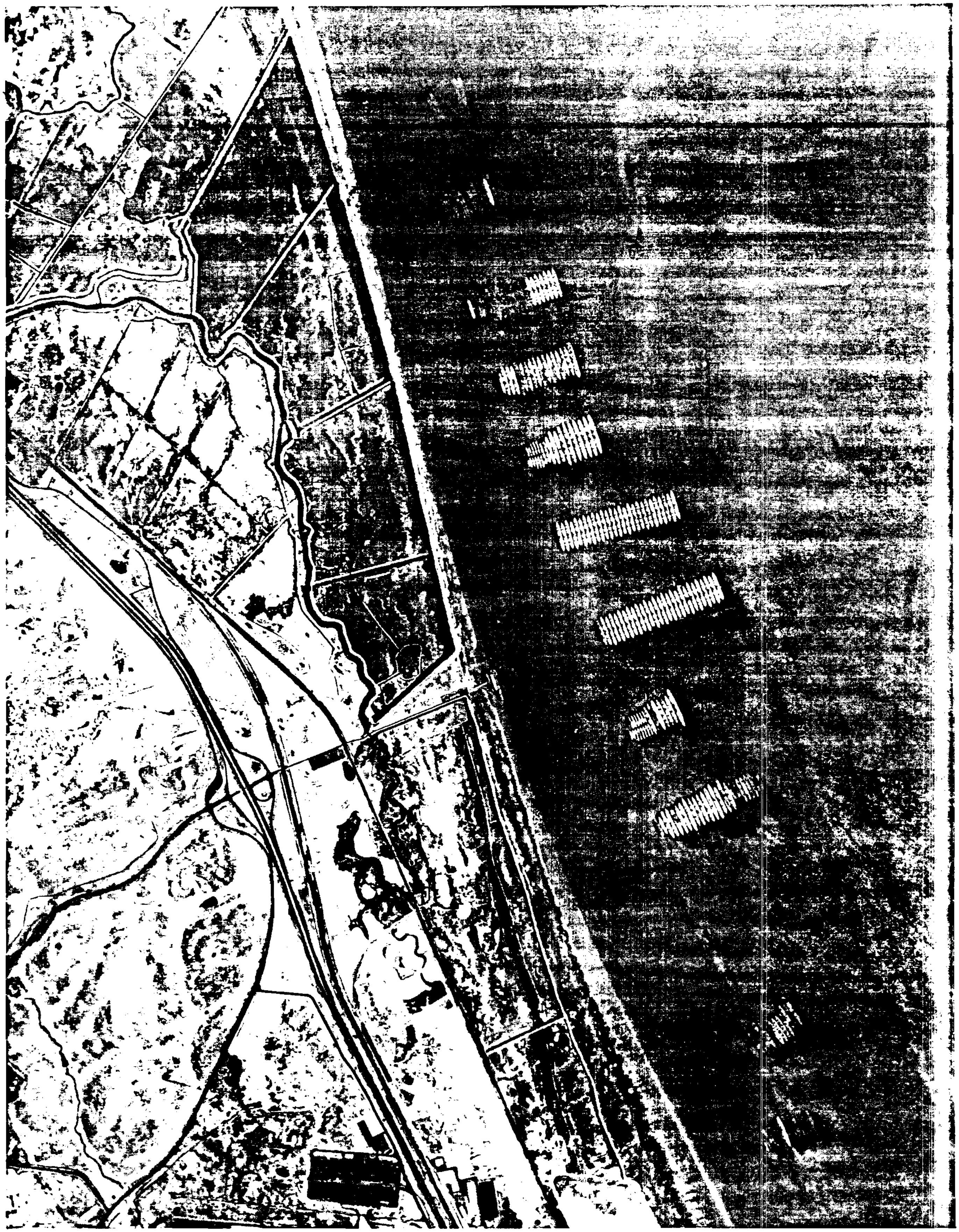


Photo A-8: U-2 AERIAL PHOTOGRAPH
12" LENS, B/W INFRARED FILM
SCALE = 1:24,000

164

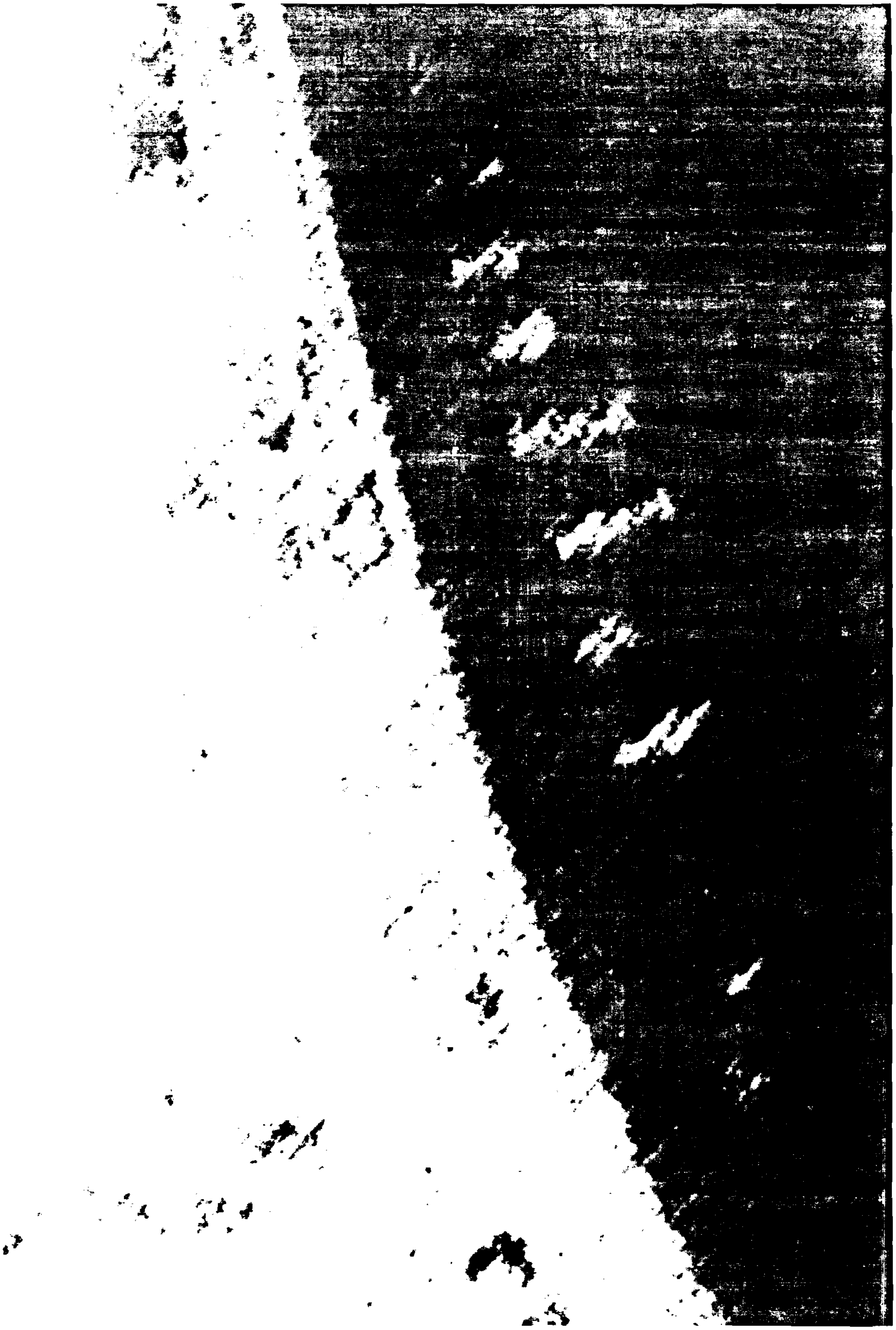


Photo A-9: LANDSAT BAND-5 ENLARGEMENT
SCALE = 1:24,000

Coastal Zone Color Scanner (CZCS)

The Coastal Zone Color Scanner (CZCS) is the first instrument devoted to the measurement of ocean color and flown on a spacecraft. Although instruments on other satellites have sensed ocean color, their spectral bands, spatial resolution, and dynamic range were optimized for land or meteorological use. In the CZCS, every parameter is optimized for use over water to the exclusion of any other type of sensing. The signal-to-noise ratios in the spectral channels sensing reflected solar radiance are higher than those required in the past. These ratios need to be high because the ocean is such a poor reflecting surface that the majority of the signal seen by the reflected energy channels at spacecraft altitudes is backscattered solar radiation from the atmosphere rather than reflected solar energy from the ocean. The CZCS thermal channel utilizes the 10.5 μm to 12.5 μm region used on many other thermal mappers. This CZCS channel is unique, however, since it is registered with the reflected solar energy bands and has the same spatial resolution.

The CZCS is intended primarily as a tool for determining the content of water. It is well known that the content of water, be it organic or inorganic particulate matter or dissolved substances, affects its color. Ocean water, containing very little particulate matter, scatters as a Rayleigh scatterer with the well known deep purple or bluish color of the ocean. As particulate matter is added to the water, the scattering characteristics are changed and the color is changed. Phytoplankton, for instance, have specific absorption characteristics and normally change the water to a more greenish hue although some phytoplankton, such as the various red tide, can change the water to colors such as red, yellow, blue-green, or mahogany. By sensing the color with very high signal-to-noise ratios, the CZCS provides a mechanism for analyzing that color for the content of the water. Inorganic particulate matter in water, such as the terrigenous outflow from rivers, has a different color from organic material typically brownish in color but sometimes varying with red.

By conducting measurements over a large area in a short period of time, the CZCS allows oceanographers to view the ocean as never seen before from ships. As an example, in one two-minute data segment, the CZCS covers approximately 1.3 million square kilometers of the ocean surface allowing examination, nearly simultaneously, on a scale never before accomplished. Measurements on this scale allow oceanographers to determine such things as the standing stock of phytoplankton and its distribution in various fishing areas and, potentially, to assess the ability of that area to support a standing stock of fish. In addition to examining the existing fisheries, the CZCS will be used to look for new areas of potential fish production around the globe.

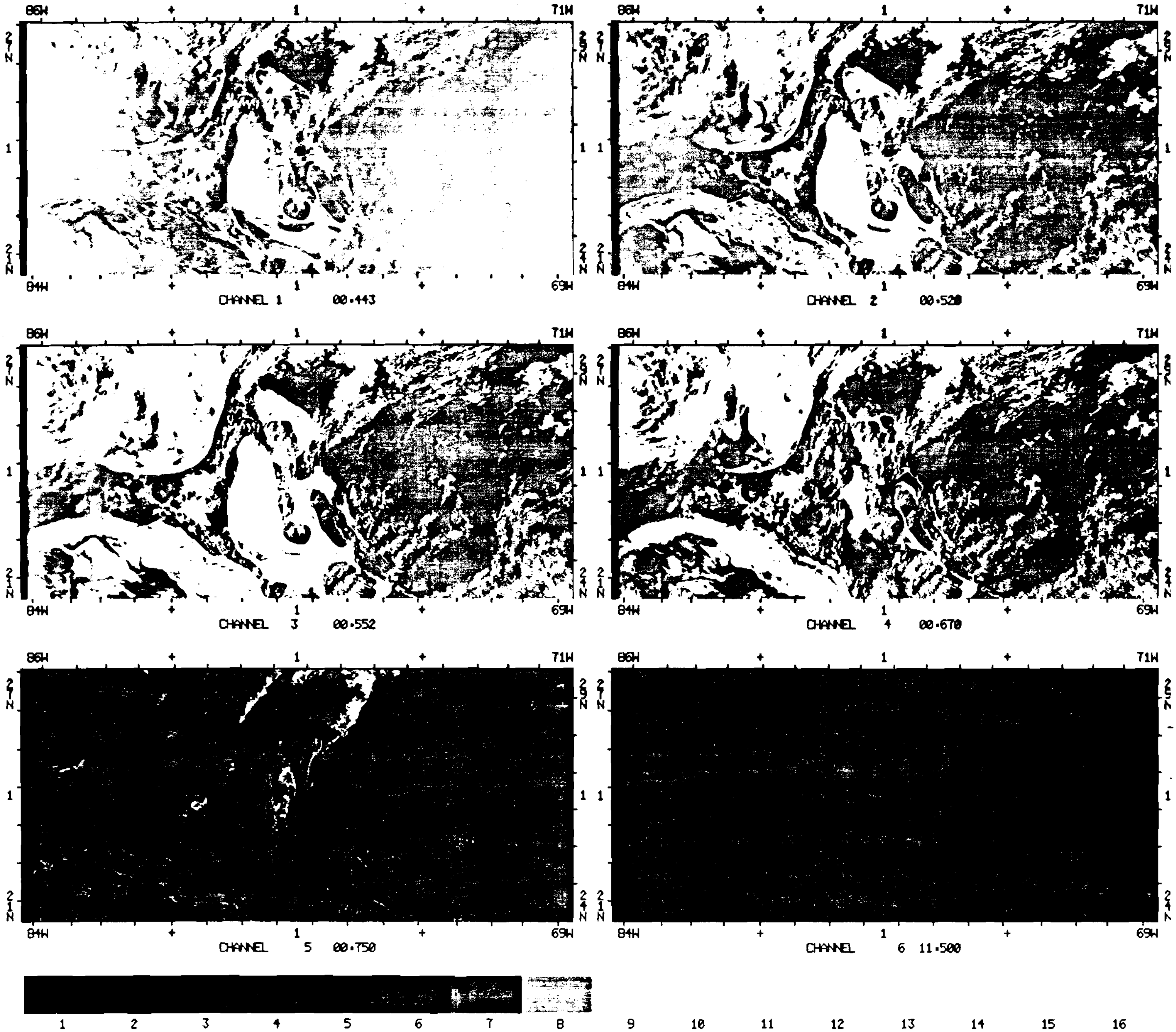
The CZCS has six channels, sensing radiation in blue, green, yellow, red, far red, and thermal infrared bands. The spectral bandwidths of the channels are as follows:

Channel	Micrometers
1	0.433 - 0.453
2	0.510 - 0.530
3	0.540 - 0.560
4	0.660 - 0.680
5	0.700 - 0.800
6	10.5 - 12.5

Photo A-10 illustrates an example of the six channels of data. These images cover an area comprising southern Florida, Cuba, and the Bahamas. Channel 6, the thermal band, was inoperative on this pass. Photos A-11 and A-12 show enlargements of a portion of Channels 5 and 2 of the image.

NIMBUS 7 CZCS

ORBIT 517 30NOV78 164016 TO 164216 GMT GAIN 1-4=3 THRESHOLD OFF TILT ANGLE 0.00
GRID CENTER DATA: 164116 GMT 25N 77W SUN EL 43 AZ 175 ROLL 0.5 PITCH -0.1 YAW 0.4



GRAY SCALE KEYED TO TABLE 3 IN REFERENCE MANUAL
ALGORITHMS 00 00 00 00 00 00 00 00 00 00
963 SCAN LINES PROCESSED, 000 WITH ERRORS

F742040 ZQ001201

Photo A-10: COASTAL ZONE COLOR SCANNER DATA FROM NIMBUS-7

168

Photo A-11: COASTAL ZONE COLOR SCANNER - CHANNEL 5
SOUTHERN FLORIDA AND BAHAMAS

Photo A-12: COASTAL ZONE COLOR SCANNER - CHANNEL 2
SOUTHERN FLORIDA AND BAHAMAS

Airborne Thermal Infrared Scanners

Certain portions of the EM spectrum cannot be recorded directly on photographic film. Other means must be used to detect and record the information from these wavelengths. Various detectors have been devised to respond to this radiation. In order to create a photo-like display of this information (an "image"), numerous optical-mechanical scanning systems are used.

All scanners create an image by successive collection of discrete data elements in two dimensions and then reconstitution of the data in the same format. Radiation is usually optically collected by a narrow field-of-view telescope and focused onto a detector. Different detectors exist for sensing radiation of many different wavelengths. Thus, a scanner may be used to create images of UV, visible, near IR, thermal IR, or other data. The detector converts the radiation to an electrical impulse which then may be used to modulate a visible light source focused onto photographic film or to create a record on magnetic tape.

One of the most popular type of scanners for remote sensing is the thermal infrared scanner. Utilizing a special detector (commonly mercury cadmium telluride, lead tin telluride or indium antimonide) which must be cryogenically cooled (usually with liquid nitrogen or helium), it can produce an image of the reflected and/or emitted heat of the terrain. Most thermal IR scanners operate in the 3-5 micron or 8.5-13.5 micron wavelength regions as these are the only portions of the IR spectrum in which the atmosphere is "transparent"; i.e., atmospheric "windows".

Photos A-13 and A-14 are examples of imagery produced by a thermal infrared line scanner. These images are actually "mapping" the heat emitted or reflected by the water and land. They can be calibrated such that absolute temperatures may be obtained. Photo A-13 shows a hot water discharge into cooler bay water. Photo A-14, taken at 2300 hours, shows a small boat harbor. Since these images correspond to heat, they can be

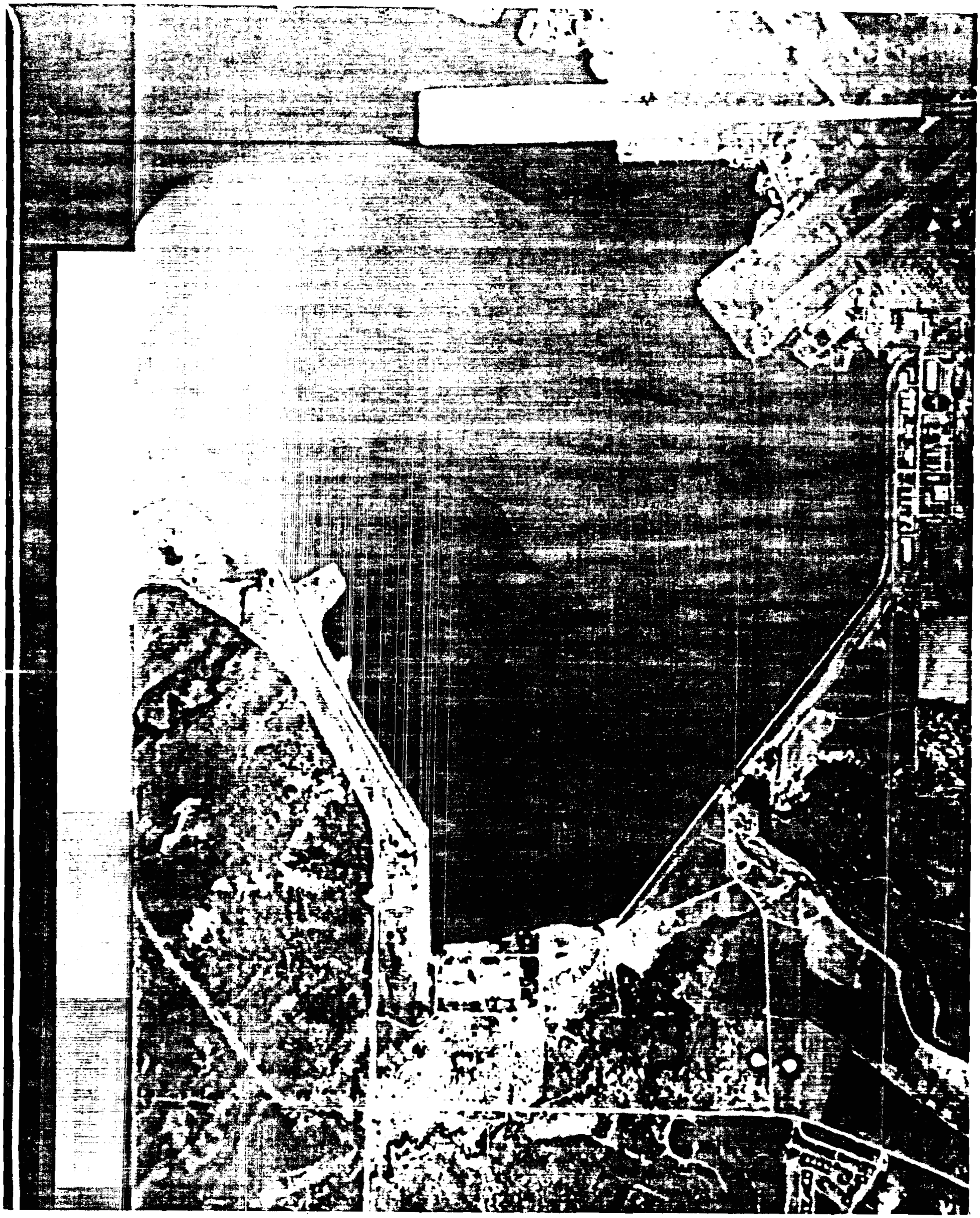


Photo A-13: THERMAL INFRARED IMAGE - HOT WATER DISCHARGE
WHITE = HOT
BLACK = COLD

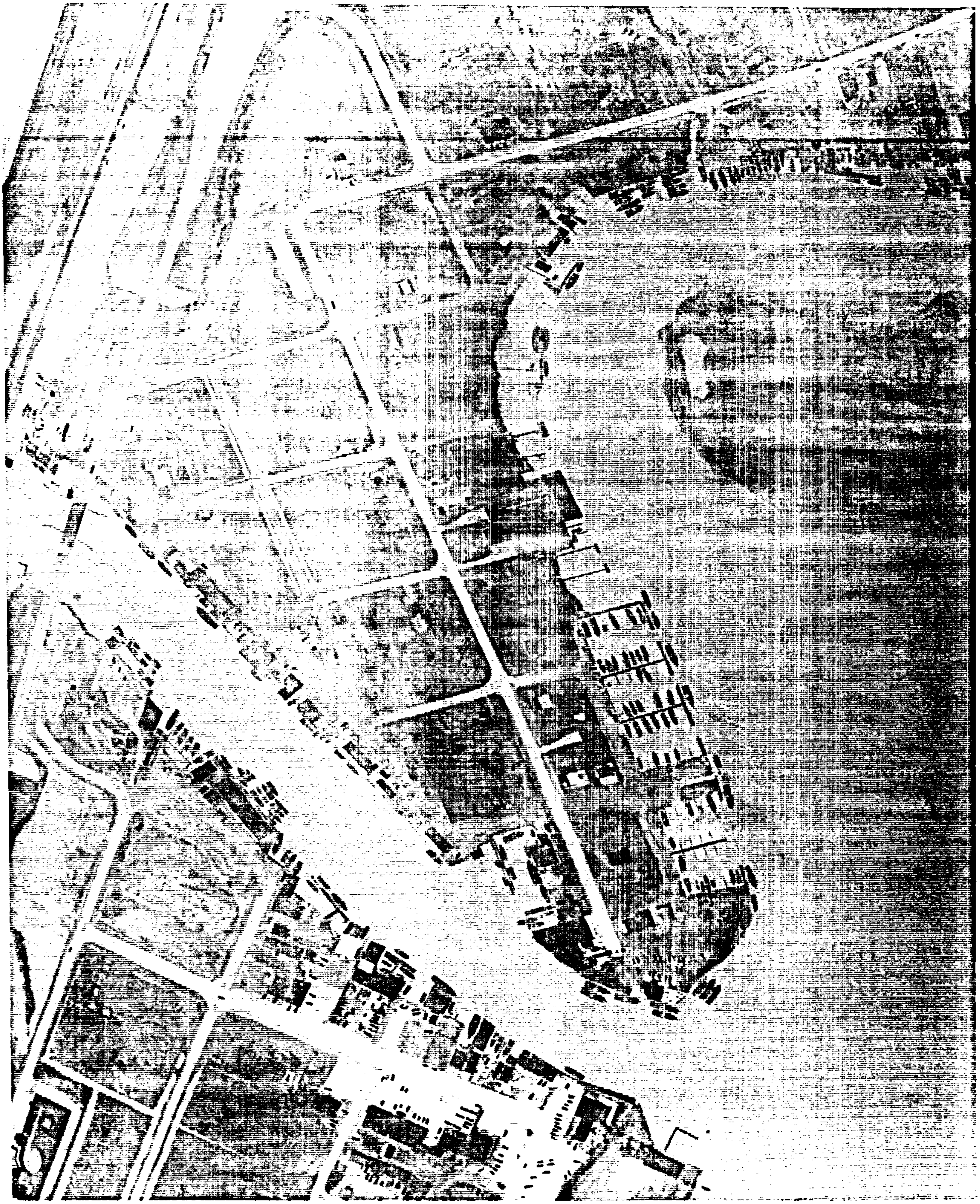


Photo A-14: THERMAL INFRARED IMAGE - SMALL BOAT HARBOR
WHITE = HOT
BLACK = COLD

obtained at night as well as in the daylight, thus providing a certain advantage for a surveillance system.

TIROS-N Advanced Very High Resolution Radiometer (AVHRR)

The Advanced Very High Resolution Radiometer (AVHRR) for TIROS-N is a four-channel scanning radiometer, sensitive to visible/near IR and infrared (IR) radiation. The instrument channelization has been chosen to permit multispectral analyses which may provide improved determination of hydrologic, oceanographic, and meteorological parameters. The four channels detect radiation in the following wavelength regions:

Channel	Micrometers
1	0.55 - 0.68
2	0.725 - 1.10
3	3.55 - 3.93
4	10.5 - 11.5

The visible (0.5 μm) and visible/near IR (0.9 μm) channels can be used to discern clouds, land-water boundaries, snow and ice extent, and when the data from the two channels are compared, an indication of ice/snow melt inception. The IR channels can be used to measure cloud distribution and to determine temperature of the radiating surface (cloud or surface). Data from the two IR channels can be incorporated into the computation of sea surface temperature. By using these two data sets, it is possible to remove an ambiguity introduced by clouds filling a portion of the field-of-view.

Photo A-15 is a worldwide mosaic of all AVHRR standard resolution visible (Channel 1) scenes collected for 29 September 1979. Photo A-16 is a single strip image from the AVHRR. It covers an area from the South Pole to Japan. Photos A-17 and A-18 are high resolution visible (Channel 1) and infrared

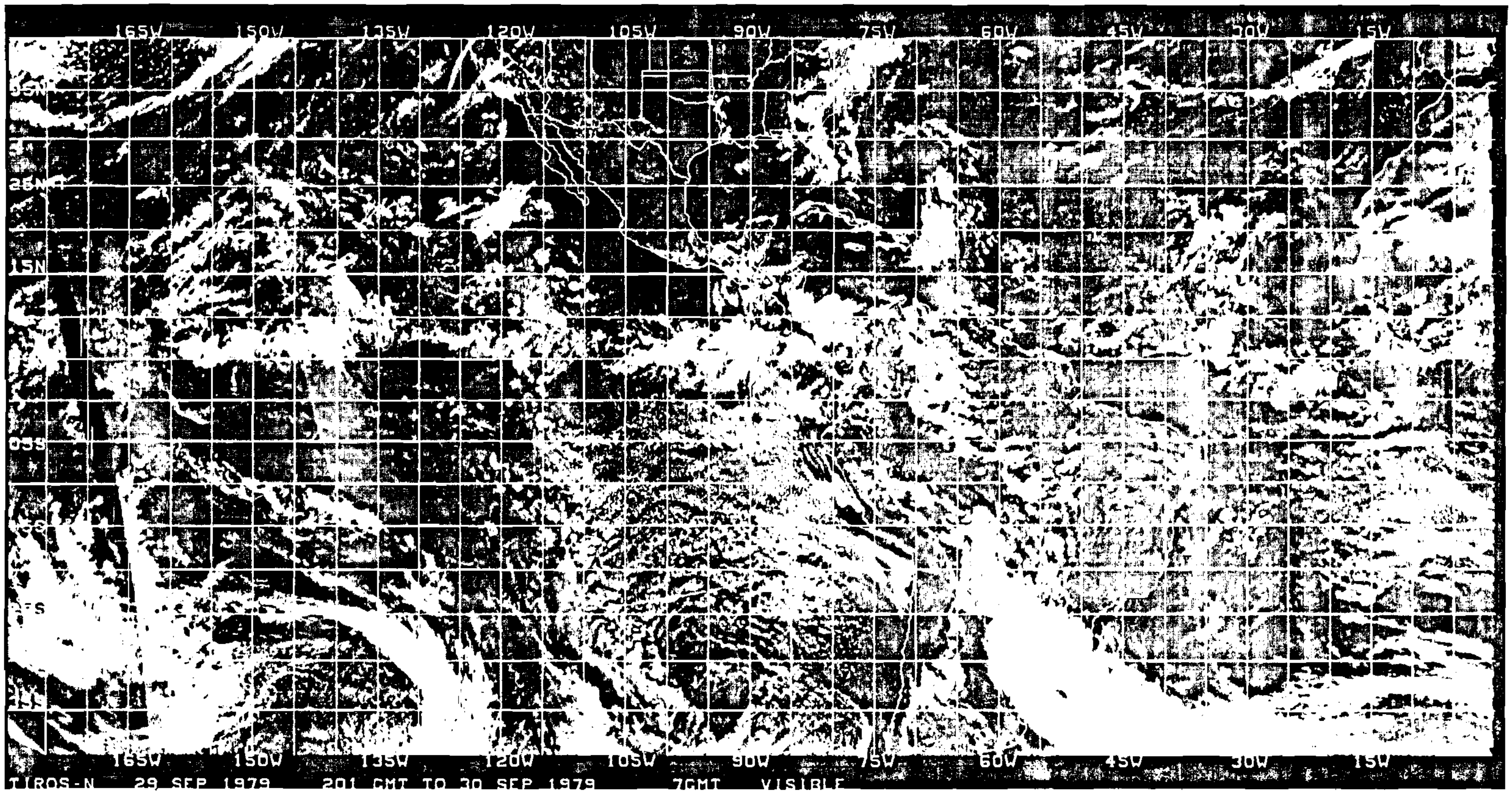


Photo A-15: WORLD MOSAIC - 29 SEPTEMBER 1979
VISIBLE BAND
TIROS-N AVHRR

175

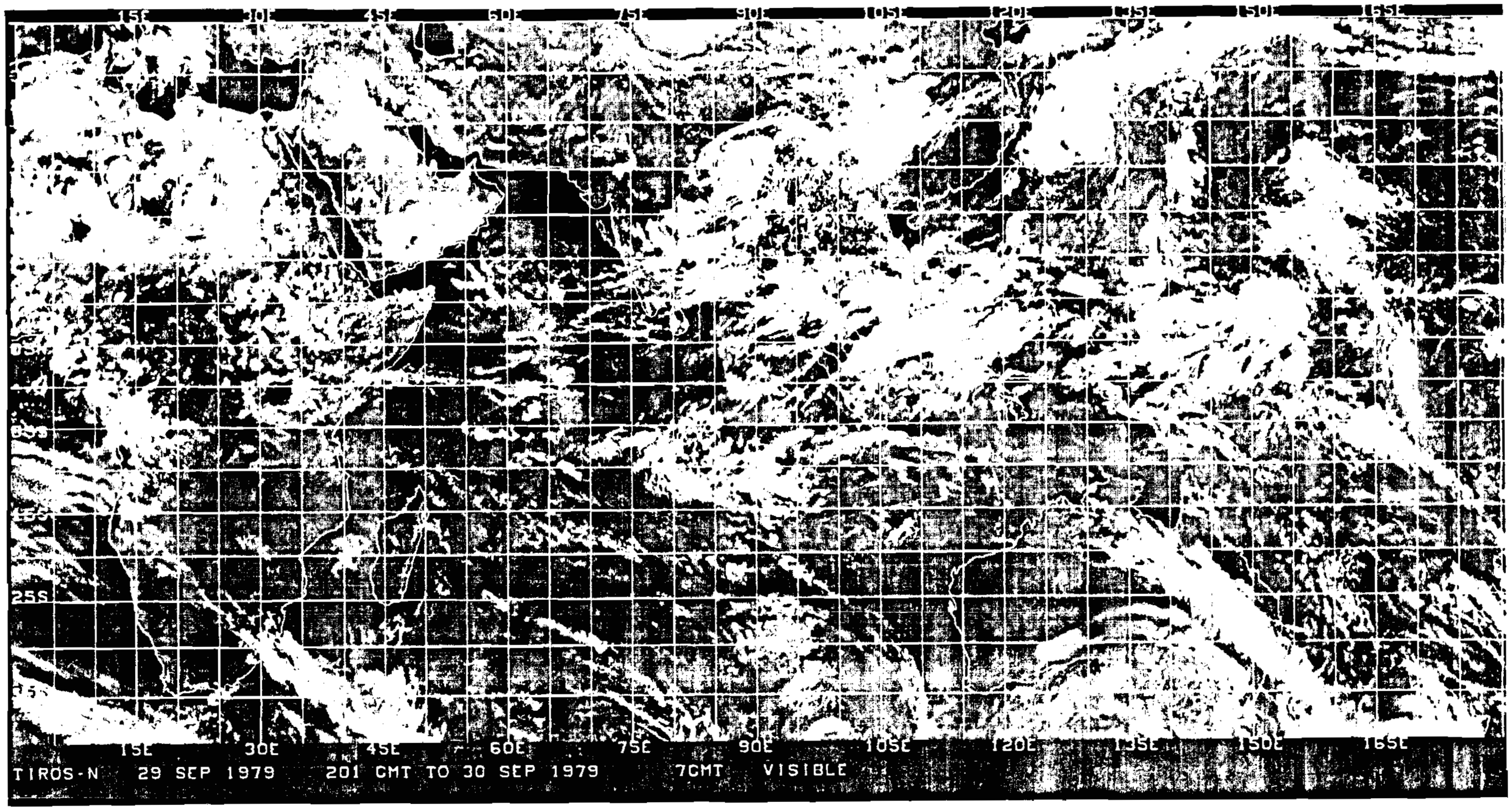


Photo A-15 Continued: WORLD MOSAIC - 29 SEPTEMBER 1979
VISIBLE BAND
TIROS-N AVHRR

176

Photo A-16: VISIBLE BAND - STANDARD RESOLUTION
TIROS-N AVHRR
(Advanced Very High Resolution Radiometer)

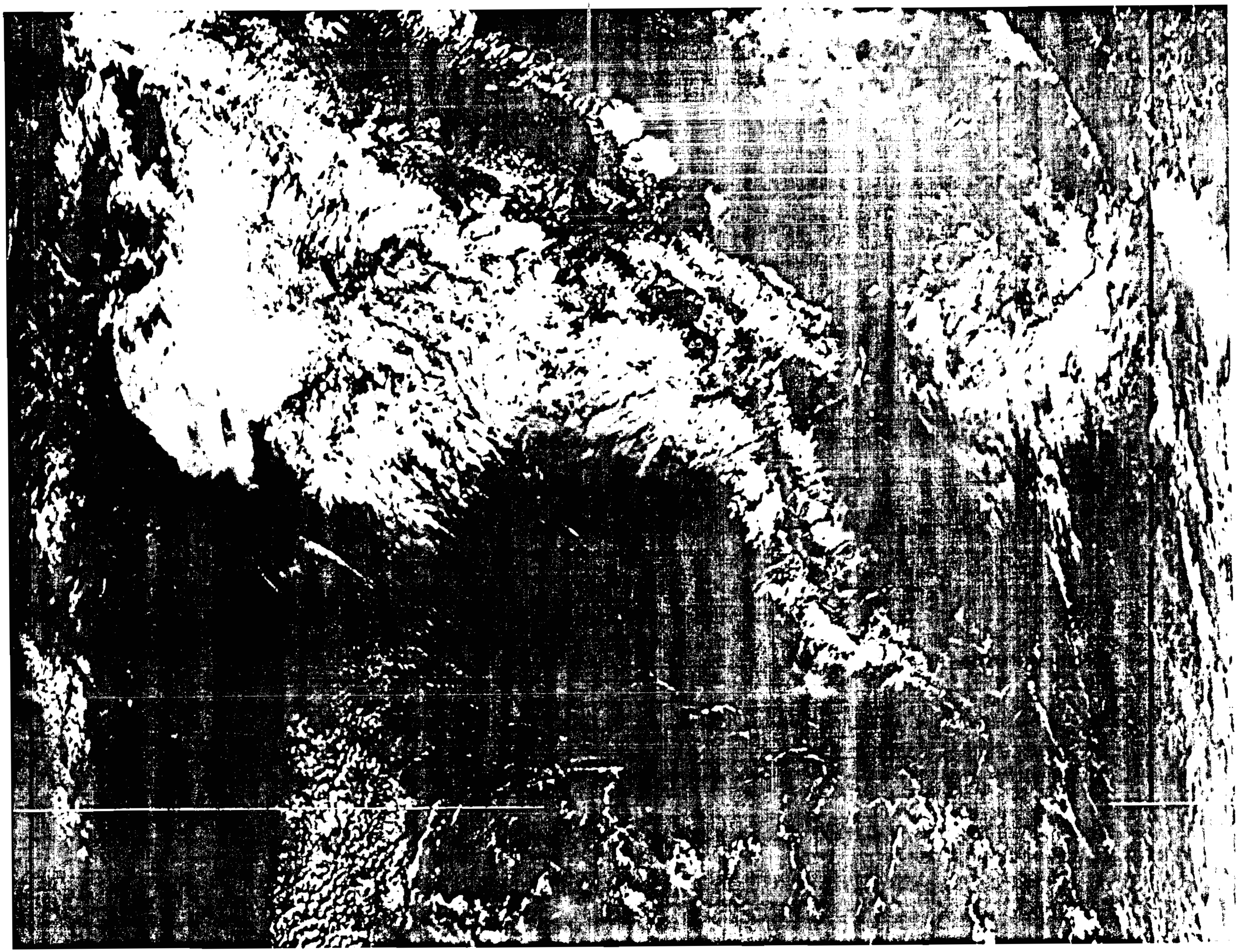


Photo A-17: VISIBLE BAND - HIGH RESOLUTION
TIROS-N AVHRR
(Advanced Very High Resolution Radiometer)

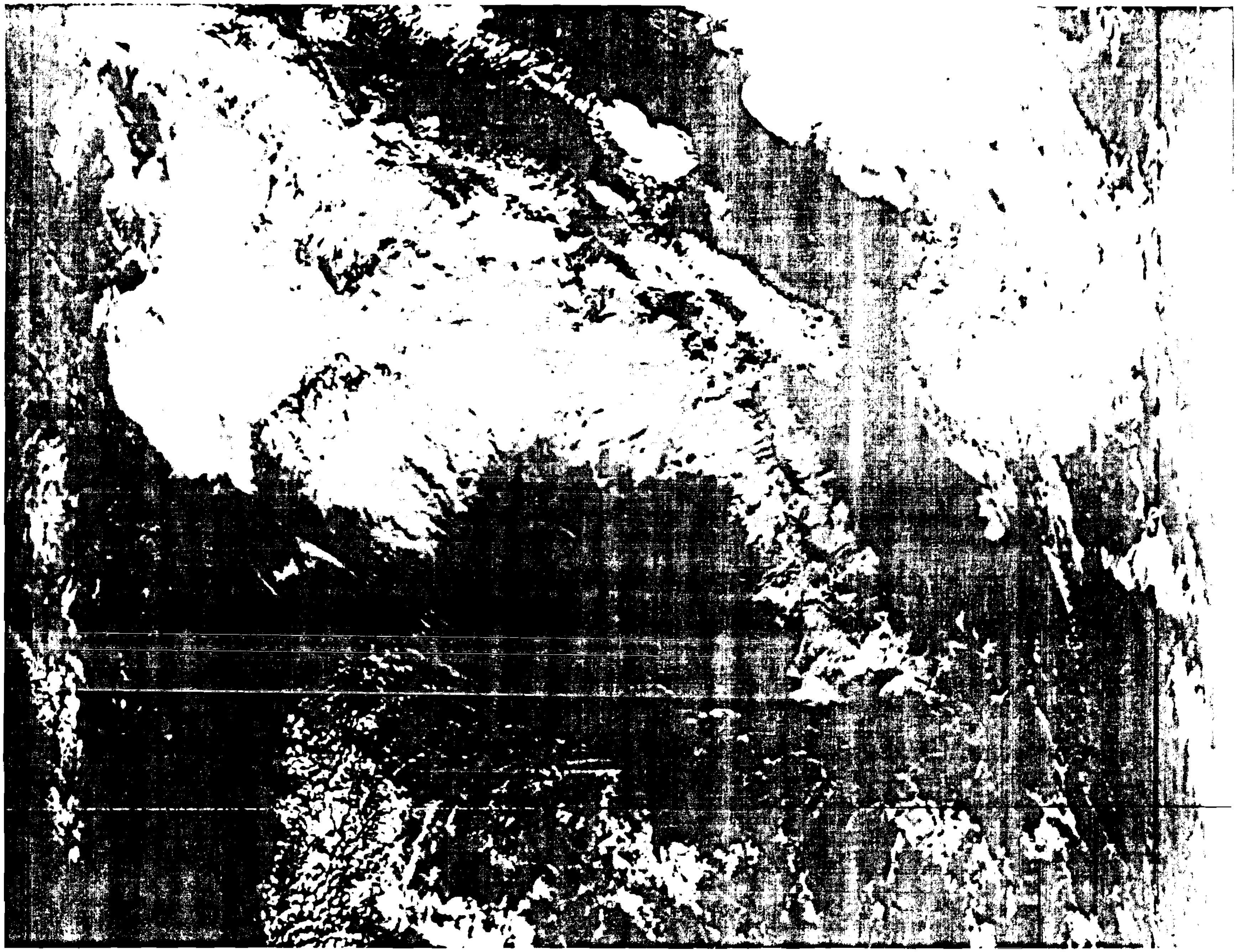


Photo A-18: THERMAL IR BAND - HIGH RESOLUTION
TIROS-N AVHRR
(Advanced Very High Resolution Radiometer)

(Channel 4) images, respectively. They cover the same area surrounding Papua New Guinea for 17 September 1979.

Japanese GMS Visible and Infrared Spin-Scan Radiometer (VISSR)

The Geostationary Meteorological Satellite (GMS) program was initiated by the Japan Meteorological Agency in 1971. The GMS collects images of the Western Pacific, Asia and Oceania day and night with the Visible and Infrared Spin-Scan Radiometer (VISSR). The pictures are disseminated to user stations in the GMS communication area in facsimile format via the onboard transponder in S-band. The communication system relays meteorological and oceanographic observation data from ships, buoys, weather stations, etc. to a central processing center in Japan.

The objective of the GMS program is to perform the following missions in relation with the Global Atmospheric Research Program (GARP) experiment and also to improve meteorological services, domestic and international. The missions are:

1. Imaging earth surface by use of VISSR.
2. Relaying of meteorological data observed by ships, buoys, weather stations, etc. to the Data Processing Center (DPC) in Japan.
3. Relaying of processed image and meteorological data for facsimile reproduction at Medium and Small Scale Data Utilization Station (MDUS and SDUS).
4. Monitoring of solar activity by counting the incoming solar protons, alpha-particles and electrons.

The GMS was launched from Cape Canaveral, Florida, USA in the middle of 1977. The final station in the synchronized orbit is 140°E. The spacecraft is spinning at a rate of 100 rpm with the spin axis parallel to the earth's polar axis.

The VISSR obtains images in both the visible and thermal IR bands. The visible band is 0.50 - 0.75 micrometers and the IR is 10.2 - 12.8 micrometers. Ground resolution is 1.25 kilometers in the visible and 5.0 kilometers in the IR. Photo A-19 is an IR image of PNG taken by the VISSR on 14 June 1978. The borders of land masses have been inserted by computer.

SEASAT Synthetic Aperture Radar (SAR)

In 1978, the National Aeronautics and Space Administration (NASA) launched SEASAT-A, the first satellite dedicated primarily to measurement of the characteristics of the ocean surface. It was also the first satellite to make extensive use of microwave sensors. With the exception of the synthetic aperture radar (SAR), the sensors provided global coverage (excluding the extreme polar regions) on a 36-hour repetitive cycle. With these instruments, SEASAT provided global coverage of such parameters as:

1. significant wave height,
2. ocean currents,
3. surface wind speed and direction, and
4. sea surface temperature.

In addition, the SAR provided information (over restricted areas) on ice characteristics and movement, and on wave length and direction. Because of orbit characteristics, SAR coverage was most effective in high latitudes. It was used on other ocean regions, and for observation of land areas as well. It was possible to detect internal waves and to develop a better understanding of ocean circulation.

SEASAT-A carried five instruments to be used for ocean monitoring. These are a compressed pulse altimeter, a microwave scatterometer, a synthetic aperture radar (SAR), a scanning multichannel microwave radiometer (SMMR), and a visible and infrared radiometer (V/IR).

Photo A-19: INFRARED BAND
JAPANESE GEOSYNCHRONOUS METEOROLOGICAL SATELLITE (GMS)

The SAR is an instrument which had not previously flown in a satellite. It provided all-weather imagery of ocean features; i.e., ice fields, icebergs and leads, slicks, wave and current patterns, and coastal conditions. Resolution is 25 meters over a 100-km swath, 230 to 330 km off nadir. The SAR, operating at 1.275 GHz (22-cm wavelength), is capable of penetrating clouds and nominal rain. It had its own data recording system and a very high data rate. Because of this, it was operated only while within line-of-sight of those tracking stations that are equipped to receive and record its data. Conversions of the radar measurements to imagery were not provided in real time, but rather considerable time after time of measurement.

Unfortunately, late in 1978, the SEASAT SAR system failed. From that time on, no SAR imagery was gathered. No imagery was ever collected over PNG. However, the outstanding success of the data which was collected has encouraged the hope that similar systems may again be launched and that such data may eventually become an operational reality.

Photos A-20 and A-21 are examples of SEASAT SAR imagery. Their general appearance is very similar to SAR imagery obtained from aircraft. Vessels and their wakes may be seen on each image, but not identified. Various interacting wave patterns are also clearly evident.

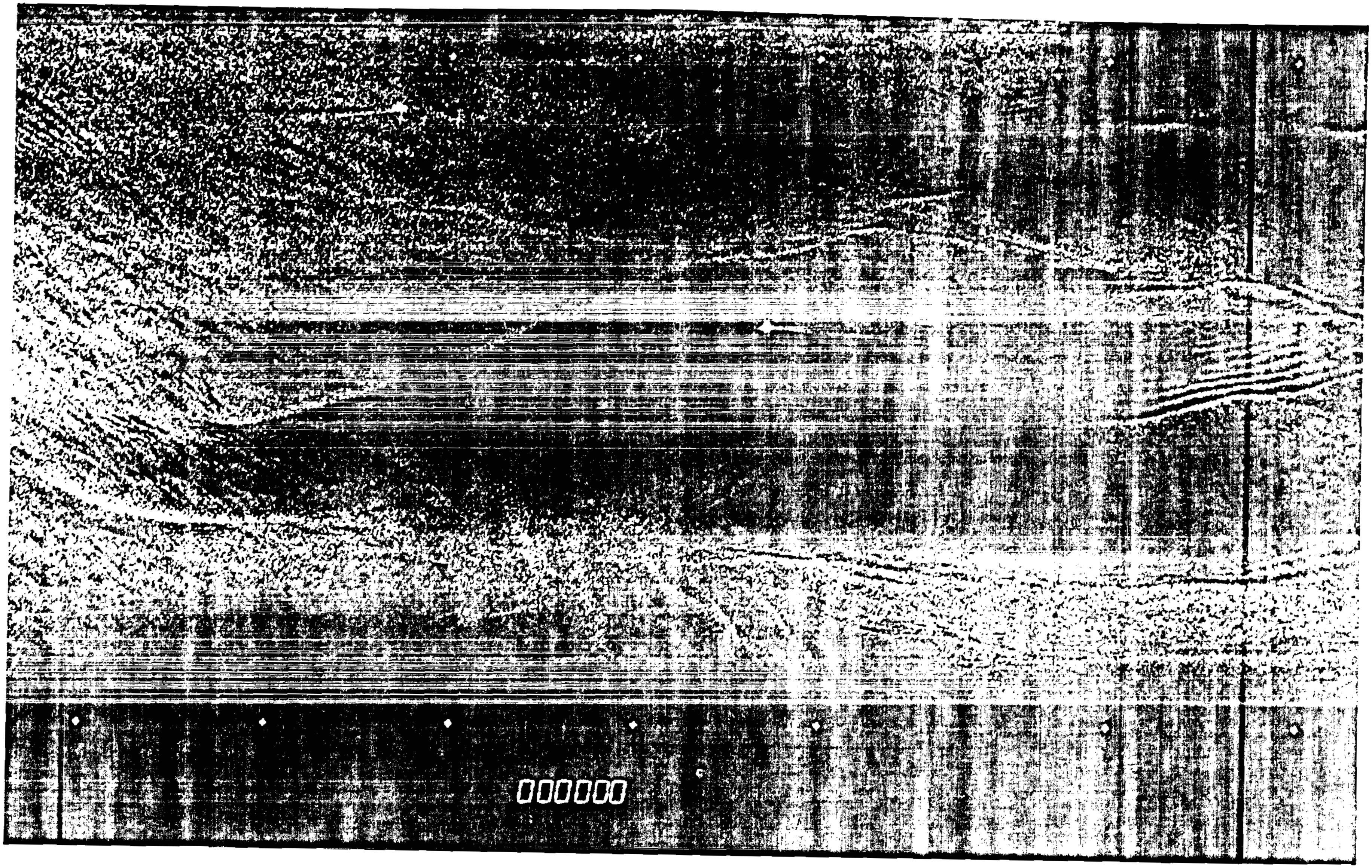


Photo A-20: SEASAT SYNTHETIC
APERTURE RADAR

Photo A-21: SEASAT SYNTHETIC
APERTURE RADAR

APPENDIX B-1

TECHNICAL DESCRIPTION
TIROS-N ARGOS DATA COLLECTION SYSTEM

General Introduction

In 1978, NASA successfully launched a third generation, operational, polar orbiting, environmental satellite system called TIROS-N. In 1979, an identical sysem, funded and launched by NOAA, was placed in orbit. This satellite, called NOAA-6, is the first of seven scheduled NOAA environmental satellites, which in addition to TIROS-N, comprise an operational system guaranteed to remain in use through the mid to late 1980s. It is intended that two satellites will be in orbit and operational at any given time.

The TIROS-N series of satellites is a cooperative effort of the United States (NOAA and NASA), the United Kingdom, and France. As has been true in the past, NASA has funded the development and launch of the first flight satellite (TIROS-N); subsequent satellites are being procured and launched by NASA using NOAA funds. The operational ground facilities including the Command and Data Acquisition (CDA) stations, the Satellite Control Center, and the data processing facilities (with the exception of the Data Collection System (DCS) processing facility) are being procured, funded and operated by NOAA. The United Kingdom, through its Meteorological Office, Ministry of Defense, is providing a Stratospheric Sounding Unit, one of three sounding instruments for each satellite. The Centre National d'Etudes Spatiales (CNES) of France is providing the DCS instrument for each satellite and the facilities necessary to process and make available to users the data obtained from this system. The Centre d'Etudes de la Meteorologie Spatiale (CEMES) of France is providing ground facilities for receipt of sounder data during the blind orbit periods.

The primary environmental sensors for these satellites are:

1. A TIROS Operational Vertical Sounder (TOVS). The TOVS is a three instrument system consisting of:
    a. The High Resolution Infrared Radiation Sounder (HIRS/2)

    b. The Stratospheric Sounding Unit (SSU)

    c. The Microwave Sounding Unit (MSU)

2. The Advanced Very High Resolution Radiometer (AVHRR)

3. The Space Environment Monitor (SEM) data will also be included in the HRPT and beacon transmissions. The SEM consists of three separate instruments and a data processing unit. The components are:

    a. The Total Energy Detector (TED)

    b. The Medium Energy Proton and Electron Detector (MEPED)

    c. The High Energy Proton and Alpha Detector (HEPAD)

4. The Data Collection System (DCS): a random access system to acquire data from fixed and free-floating terrestrial and atmospheric platforms. Platform location will be possible by ground processing of the Doppler measurements of carrier frequencies. Data collected from each platform will include identification, as well as environmental measurements. These data are also included in the HRPT and beacon transmissions.

Figure B-1 schematically illustrates the design and layout of the TIROS-N/NOAA-6 satellite series.

<u>Spacecraft Orbit Parameters</u>

The TIROS-N satellite series has been designed to operate in a sun-synchronous orbit at 833 + 90 km (450 + 50 n.mi.). Two nominal altitudes have been chosen: 833 km (450 n.mi.) and 870 km (470 n.mi.). The choice between nominal altitudes will be made to keep the orbital periods of two operational satellites in similar orbits sufficiently different so that they do not both view the same point on the Earth at the same time each day. Each satellite completes approximately 14 orbits/day with a 101 minute period. Each satellite crosses the equatorial plane at a fixed time (local solar time) each day. These times are: satellite I - 15 h (ascending node) and 3 h (descending node); satellite II - 19h30 and 7h30. See Figure B-2. This characteristic is important from the user's viewpoint since, from one day to the

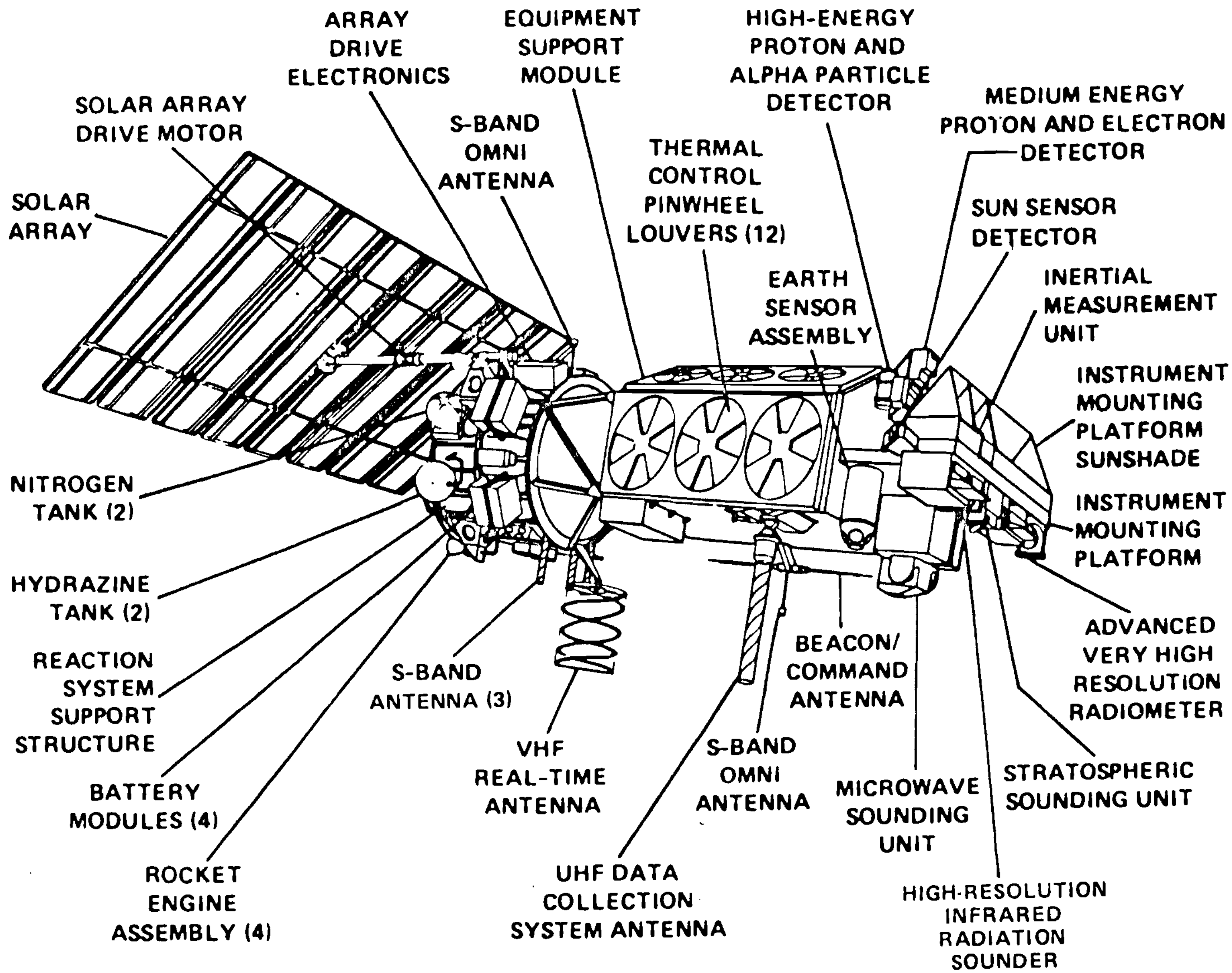
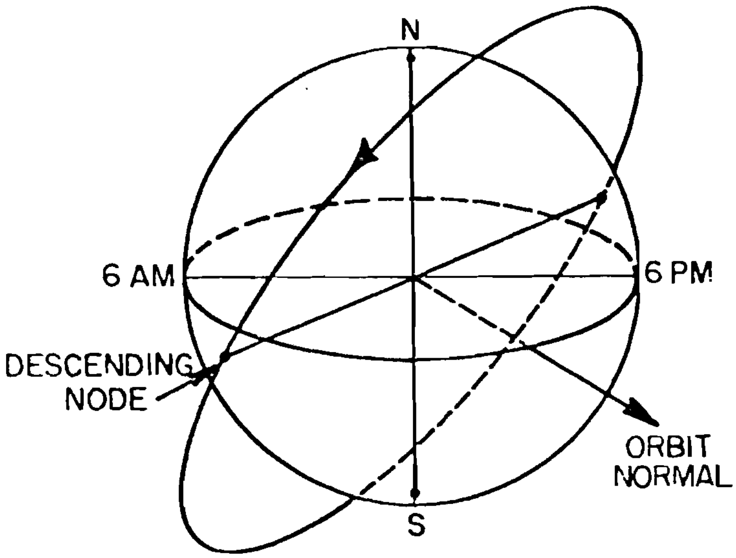
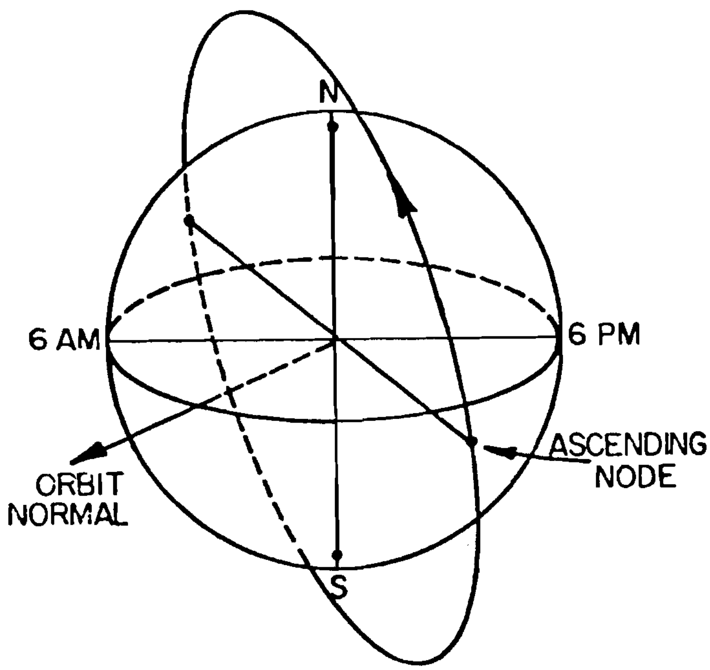


Figure B-1: TIROS-N SPACECRAFT



AM DESCENDING NODE ORBIT



PM ASCENDING NODE ORBIT

Figure B-2: TIROS-N/NOAA EQUATOR CROSSING TIMES next, a given platform comes within a satellite's coverage at the same time (local solar time).

At any given moment, each satellite "sees" all the platforms located within a circle 5,000 km in diameter. As the satellite orbits, the ground track of this circle corresponds to a swath 5,000 km in width encompassing the Earth. At each orbit, this swath covers both the North and South Poles (polar orbits). For a given satellite, the swath is displaced by 25 (i.e., 2,800 km) at the Equator as a result of the rotation of the Earth.

For any given point on Earth, the number of passes overhead varies as a function of the latitude of the point. Figure B-3 delineates the number of passes in a 24-hour period as a function of latitude. These data are for a nominal two-satellite system. The following are taken into account in its construction:

1. A satellite is considered to be "visible" when more than 5 degrees above the horizon.
2. The fact that at higher latitudes a single platform might be simultaneously received by the two satellites is not taken into account.

ARGOS Data Collection System (DCS)

The Data Collection and Location System (DCS) for TIROS-N has been designed, built, and furnished by the Centre National d'Etudes Spatiales (CNES) of France, who refer to it as the ARGOS Data Collection and Location System. The ARGOS provides a means for obtaining environmental (e.g., temperature, pressure, altitude, etc.) data from, and locating, fixed or moving platforms. Location information, where necessary, may be computed by differential doppler techniques using data obtained from the measurement of platform carrier frequency as received on the satellite. When several measurements are received during a given contact with a platform, location can be determined. The environmental data messages sent by the platform will vary in

Latitude	Cumulative Visibility Time Over 24 Hours (Minutes)	Number of Passes in 24 Hours Minimum	Mean	Maximum	Mean Pass Duration (Minutes)
± 0°	80	6	7	8	
±15°	88	8	8	9	
±30°	100	8	9	12	
±45°	128	10	11	12	10 Min.
±55°	170	16	16	18	
±65°	246	21	22	23	
±75°	322	28	28	28	
±90°	384	28	28	28	

Figure B-3: SATELLITE PASSES AS A FUNCTION OF LATITUDE length depending on the type of platform and its purpose. The ARGOS (DCS) system consists of three major components:

1. Terrestrial platforms
2. On-board instrument
3. Receiving station and processing center.

The terrestrial platforms may be developed by the user to meet his particular needs so long as it meets the interface criteria defined by CNES. Before being accepted for entry into the system, the platform design must be certified as meeting these criteria. By international agreement, entry into the system is limited to platforms requiring location service or for those situated in polar regions out of the range of the DCS on geostationary satellites. Officially, CNES controls access to the system. Permission to use the system must be obtained by making application to CNES. Appendix B-2 describes procedures for obtaining access to the system and Appendix B-3 contains a Program Application Form.

The on-board instrument is designed to receive the incoming platform data, demodulate the incoming signal, and measure both the frequency and relative time of occurrence of each transmission. The on-board system consists of three modules: the power supply and command interface units, the signal processor, and the redundant receiver and search units. Figure B-4 shows the basic relationship of the component modules.

Platform signals are received by the receiver, search units at 401.65 MHz. Since it is possible to acquire more than one simultaneous transmission, four processing channels (called Data Recovery Units (DRU)) operate in parallel. Each DRU consists of a phase lock loop, a bit synchronizer, doppler counter, and a data formatter. After measurement of the doppler frequency, the sensor data are formatted with other internally generated data and the output transferred to a buffer interface with the

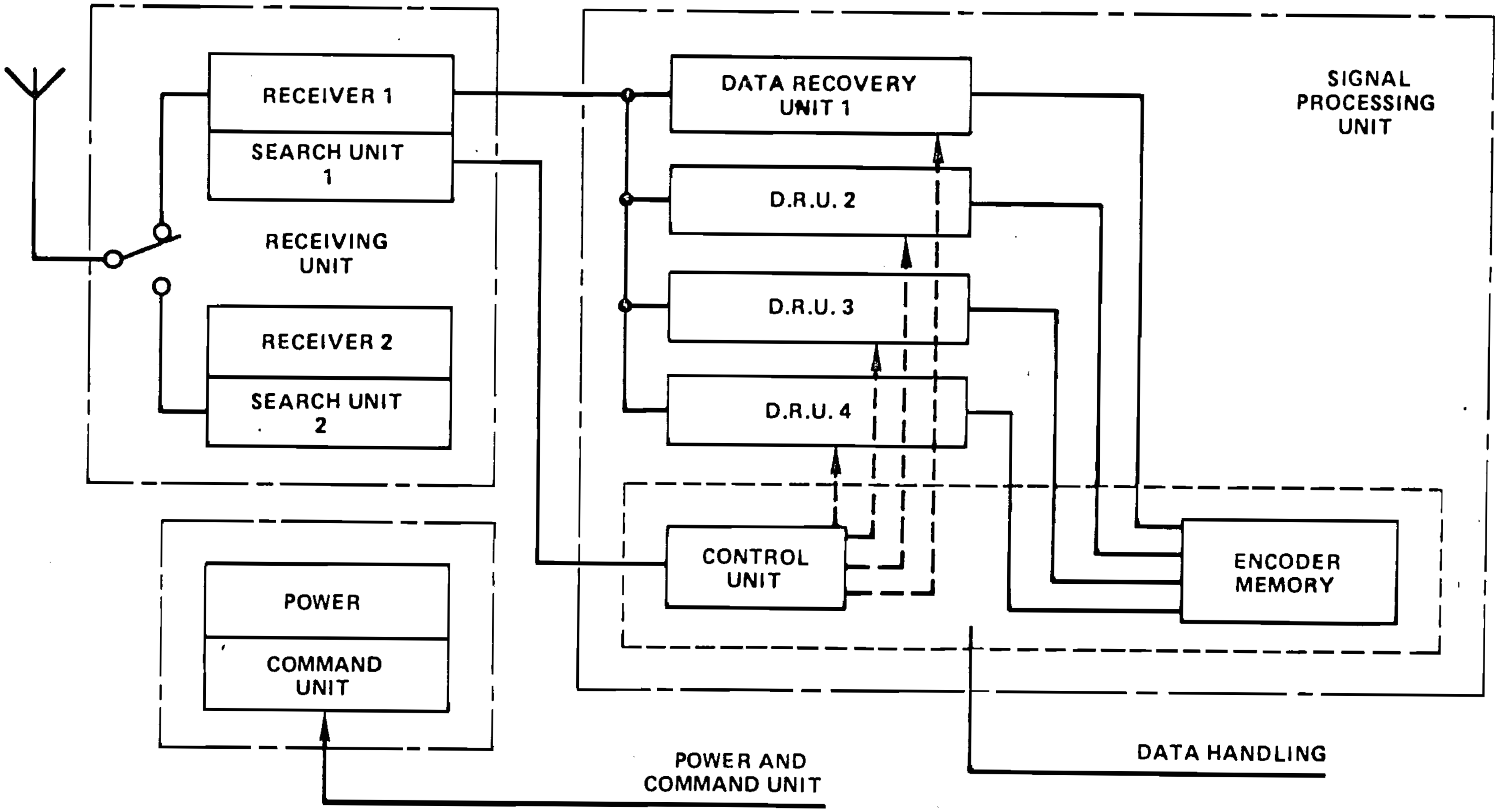


Figure B-4: DATA COLLECTION SYSTEM/ARGOS COMPONENT MODULES

194

spacecraft data processor (TIP). The DCS output data rate is controlled to 720 bits per second.

Data from the DCS are included with that from the low bit rate instruments within the TIP. After receipt of the stored data at the central processing facility, the DCS information is decommutated and sent to the CNES, ARGOS processing center in Toulouse, France. At the processing center, the DCS data are received by and stored in a small computer and then transferred to a large computer where processing is completed. Resulting outputs are sent to system users and are retained on magnetic tape for archive purposes. Data provided by the processing center of CNES are subject ot a tariff. Appendix B-4 outlines the present tariff structure. An additional user option is to purchase and operate his own receiving station. Details are included later in this appendix.

Platform Transmitter Terminals

The Platform Transmitter Terminals (PTT), or beacons as they are commonly called, can be manufactured by any organization. They are basically radio transmitters which transmit a string of digital data to the spacecraft receiver. This data is repeatedly transmitted every 40 to 60 seconds in a burst which lasts between 200 and 760 milliseconds. Following are required transmission characteristics.

Nominal Carrier Frequency

The nominal frequency for ARGOS PTTs is:

$$f_o = 401.650 \text{ MHz} \pm 1.2 \text{ kHz}$$

Permissible drift due to aging is $\pm$ 2 kHz

Short-Term Stability (100 ms)

For "location" platforms:

$$\left|\frac{\Delta f}{f_o}\right| \leq 10^{-9}$$

For fixed platforms:

$$\left|\frac{\Delta f}{fo}\right| \leq 2.10^{-9}$$

Medium-Term Stability (20 min)

For "location" platforms:

$$\left|\frac{\Delta f}{f_o}\right| \leq 10^{-8}$$

For fixed platforms:

$$\left|\frac{\Delta f}{f_o}\right| \leq 10^{-7}$$

Long-Term Stability (2 hours)

$$\left|\frac{\Delta f}{f_o}\right| \leq 10^{-6}$$

Message Structure

Unmodulated Carrier	Modulated Carrier (Time: T_2)					
	Bit synchronization	Format synchronization	Initialization	Number of Groups of 32 bits	Identification	Sensor Data
T_1 = 160.0 ± 2.5 ms	15 bits (=1)	8 bits (00010111)	1 bit (=1)	4 bits	20 bits	Nx32 bits (1 N 8)

Unmodulated carrier time:

T = 160.0 ± 2.5 ms (which corresponds to 64 ± 1 bit periods)

Modulated carrier duty cycle: T_2

Minimum duty cycle: 200.0 ± 2.5 ms (corresponding to 32 bits)

Maximum duty cycle: 760.0 ± 9.5 ms (corresponding to 8 blocks of 32 bits each)

The modulated carrier time may adopt certain intermediate values, but only in steps of 80 $\pm$ 1 ms corresponding to a 32-bit block).

Modulation type: PCM Biphase L

Transmission duty cycle: $T_3 = T_1 + T_2$

360 $\pm$ 5 ms $\leq$ T $\leq$ 920 $\pm$ 12 ms

Repetition period: T_R

The repetition period, T_R, is variable as follows:

- Between 40 and 60 seconds, for "location" platforms
- Between 60 and 200 seconds for data-collection-only platforms

Coding

- 4 bits to encode number of 32-bit data block
- Identification code: 20 bits
  - 14 bits for the platform number
  - 6 bits for bit error detection
- Sensor data:
  - Variable (in 32-bit steps) between 32 and 256 bits
  - Sensor data encoding: refer to the chapter entitled "Data Processing"

Bit rate:

Nominal bit rate: $f_b = 400 \pm 5$ bps

These characteristics are summarized in Figure B-5.

Several companies presently manufacture, as off-the-shelf items, these PTTs. Two of the leaders in this field are Polar Research Laboratory, Inc. and Handar, Inc. Appendix B-5 contains information on their product lines.

Carrier frequency	401.650 MHz
Aging (during life)	±2 KHz
Short term stability (100 ms)	$1{:}10^9$ (platform requiring location) $1{:}10^8$ (platform not requiring location)
Medium term stability (20 min)	:0.2 Hz/min (requiring location)
Long term (2 hr)	:±400 Hz
Power out: 34.8 dBm (3w) nominal	
Range during transmission (stability)	:0.5 db
Antenna: Vertical linear polarization	
Message length: 360 ms to 920ms	
Repetition period for message:	40-60 sec (requiring location) 60-200 sec (not requiring location)
Data sensors: 4-32 eight-bit sensors for environmental data	
Total number of platforms:	4,000 global 459 within view

Figure B-5: ARGOS PLATFORM CHARACTERISTICS

ARGOS Random Access Reception and Location Capabilities

The only communications links between users' platforms and the satellites are one-way platform-to-satellite uplinks. Messages from platforms within a satellite's coverage zone appear at the input to the onboard receiver in a random fashion. Message separation in time is obtained through the asynchronization of transmissions and the use of different repetition periods. Message separation in frequency is achieved as a result of the different Doppler shifts in the carrier frequency transmitted by the various platforms. In the event of a number of messages reaching the receiver input simultaneously, up to four can be acquired provided they are separated in frequency.

The probability of message acquistion during a satellite pass is given by the formula:

$$1 - (1 - Pe)^N$$

where N is the number of messages transmitted by the platform while within the satellite's coverage, and Pe is the elementary probability of message acquisition. N is given by the pass duration divided by the platform's transmission repetition period. Pe is a function of: the number of transmissions received per second by the onboard receiver (i.e., Pe is a function of both the number of platforms simultaneously within the satellite's coverage and of their repetition periods), and the duration of each message.

Numerous simulation tests with the ARGOS onboard equipment package have provided useful data concerning the variation of Pe as a function of λe (the number of transmissions per second "seen" by the satellite) subject to the assumption that all messages last 360 ms (which corresponds to 4 platform sensors, each generating an 8-bit word).

By specifying the platform repetition periods, a correlation can be established between the number of transmissions received per second and the number of platforms that are simultaneously visible at a given time.

Figure B-6 illustrates the probability of message acquisition for both 3 and 4 operating processing units.

The location of each platform is determined solely by measuring the Doppler effect on the carrier frequency of in-coming messages (the transmitting frequency being fixed and the same for all platforms).

Each measurement made by the satellite corresponds to a field of possible positions of the platform under consideration. This field takes the form of a cone with the satellite as its apex, the satellite velocity vector $\vec{V}$ as the axis of symmetry and apex half-angle θ, where θ is such that:

$$\cos\theta = \frac{c}{V} \cdot \frac{Fd}{F_o}$$

where:

c = speed of light

V = satellite velocity

F_o = platform transmission frequency

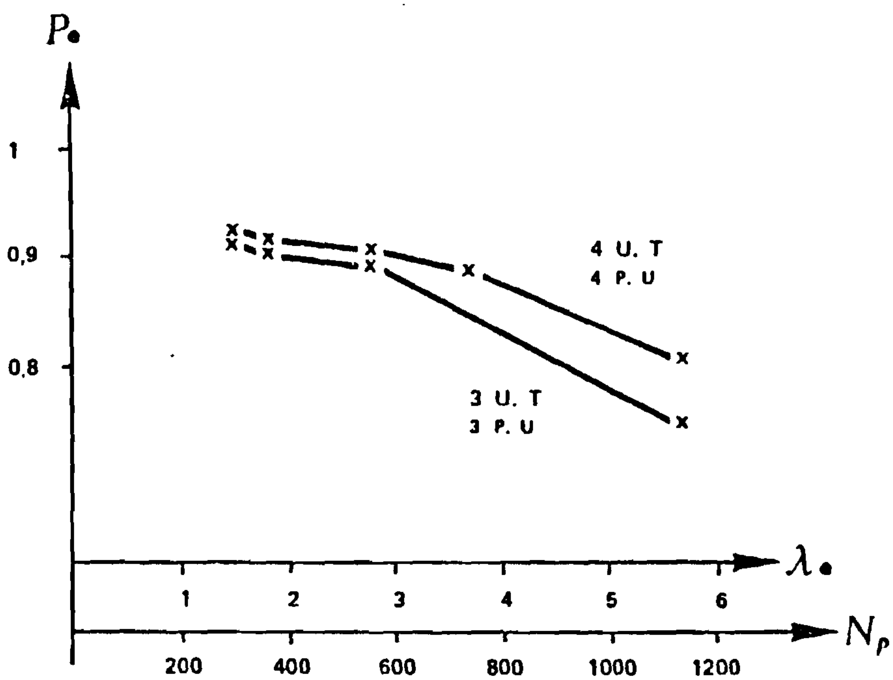
Fd = frequency of message received by the satellite.

The altitude of the satellite being assumed to be known, the intersection of several of these cones (each corresponding to a separate measurement) with the altitude sphere yields the solution.

The main errors that can be considered as inherent in the ARGOS system are:

- Errors in the position of the satellite along its orbit. A special network of "position determination" stations has been set up to minimize this type of error. Thanks to this network, the satellites' positions can be determined to within 300 m along the orbit and within 150 m along the other two axes. Further refinement can be obtained by

200



P• - ELEMENTARY PROBABILITY

λ• - NUMBER OF MESSAGES PER SECOND

N_p - NUMBER OF PLATFORMS (with T_R = 200 S) SIMULTANEOUSLY VISIBLE

Figure B-6: PROBABILITY OF MESSAGE ACQUISITION

201

placing independent reference beacons in a network covering the general area of interest. These beacons have a known location and pass an ID code to the satellite in the same manner as a PTT. By working backward from their "calculated location", one can determine precisely the location of the satellite.

- Errors in the time at which each Doppler measurement is made.
- Errors concerning the number of messages received during a pass over a given platform; this number being used in the calculation to determine the platform location.

The minimum number of messages is 5. Taking into account the mean pass duration and the probability of acquiring each message, the repetition period of platforms that are destined to be located should be between 40 and 60 seconds.

The system can be characterized by giving the accuracy of location for a "near perfect" platform. This means a platform such that:

a. the altitude is known,
b. its speed is constant between satellite passes,
c. its oscillator is highly stable (i.e., stable to 2.10^{-9} over 20 minutes).

The corresponding accuracy, determined by simulation studies, is given in the table below.

Accuracy of Position Determination	Accuracy of Speed Determination	
0.7 km	0.25 m/sec	at 1σ, i.e., in 68% of all cases
2 km	0.75 m/sec	at 3σ, i.e., in 99% of all cases

ARGOS Receiving Station

All data received from PTTs by the satellite are simultaneously stored on an on-board tape recorder for later retransmission and retransmitted immediately by a VHF link at 136,770 or 137,770 Mcs (depending on the satellite) which is thus modulated at 8320 bits/second. The signal transmitted to the ground contains all the data from ARGOS on-board equipment; the radiated power is of the order of 250 mW. For applications requiring a real-time capability, use of an independent receiving station is recommended over use of the French Data Center because of inherent delays in the latter.

Inexpensive receivi g stations can be purchased from several manufacturers. Appendix B-6 contains information on one such system, that produced by Old Dominion Systems, Inc.

A receiving station is made up of several components. They include:

- Directable VHF antenna system
- VHF receiver
- Bit and frame synchronization
- Decommutator
- Microcomputer
- Terminal

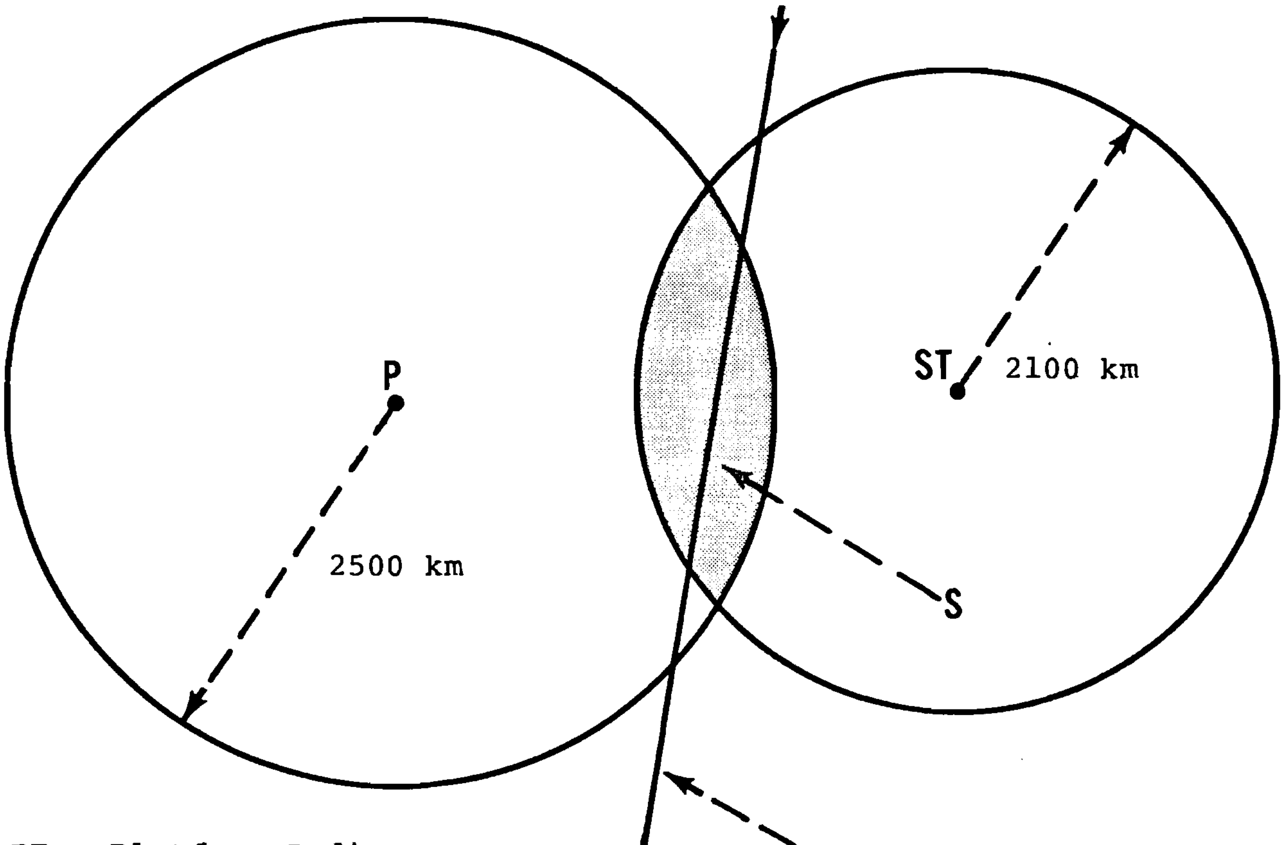
The range of operation of the PTT/satellite/receiving station system may be calculated as follows. The satellite sees all the points located within a cone tangential to the globe and the apex of which is the satellite itself and the vertex half angle 63° (altitude 830 km). The intersection of the cone with the globe is a circle with a radius of 3000 km. The displacement "of this point" due to that of the satellite in orbit is called the path of the satellite on the earth.

In the same way a platform on the Earth sees any point located above its horizon (angle of sight 0°). Because of radioelectric propagation problems, one rather considers the visibility envelope related to a minimum angle of sight of 5°. The locus of visible points is then a cone, the apex of which is the platform, and the vertex half-angle equal to (90-5°). The globe "orbital" portion (radius 7,400 km: Earth radius + satellite altitude) within this cone is the locus of all the satellite positions seen by the platform. If this portion of a sphere is projected onto the surface of the Earth one defines the "platform-satellites visibility circle". The platform sees a satellite whenever the path of the latter on the Earth goes through this "visibility circle". For a minimum link angle of sight of 5°, the radius of this circle is 2500 km.

The "receiving station - satellite visibility circle" is defined in the same way. In this case, the minimum link angle of sight is 10° because of the low power transmitted by the satellite. Under these conditions the circle radius is 2100 km. The VHF receiving station sees a satellite and can therefore receive transmissions whenever the satellite path cuts across the station visibility circle. Direct reception of PTT signals by the VHF receiving station is possible if the satellite can simultaneously see the platform and the receiving station (Figure B-7), or if the respective visibility circles define a common area on the Earth S. The platform and the station are linked when the path of a satellite cuts across this common area. The link duration is obviously proportional to the length of path within the common area S.

204

Minimum Elevation Angle	Platform Transmitter Terminal	5°
	Receiving Station	10°



PF = Platform Radius

ST = Receiving Station Radius

S = Area over which satellite can relay platform transmission to receiving station

Satellite Path

Figure B-7: SATELLITE POSITION FOR PTT SIGNAL RECEPTION

APPENDIX B-2

ACCESS TO THE ARGOS SYSTEM

ACCESS TO THE ARGOS SYSTEM

BEST AVAILABLE COPY

DECEMBER 1978

The documents making up the "ARGOS Access File" are sent in two mailings. The first contains :

- the PROGRAM APPLICATION form.

The other documents are forwarded to the user as soon as the completed PROGRAM APPLICATION form has been received by Service ARGOS.

-oOo-

CONTENTS

Name :

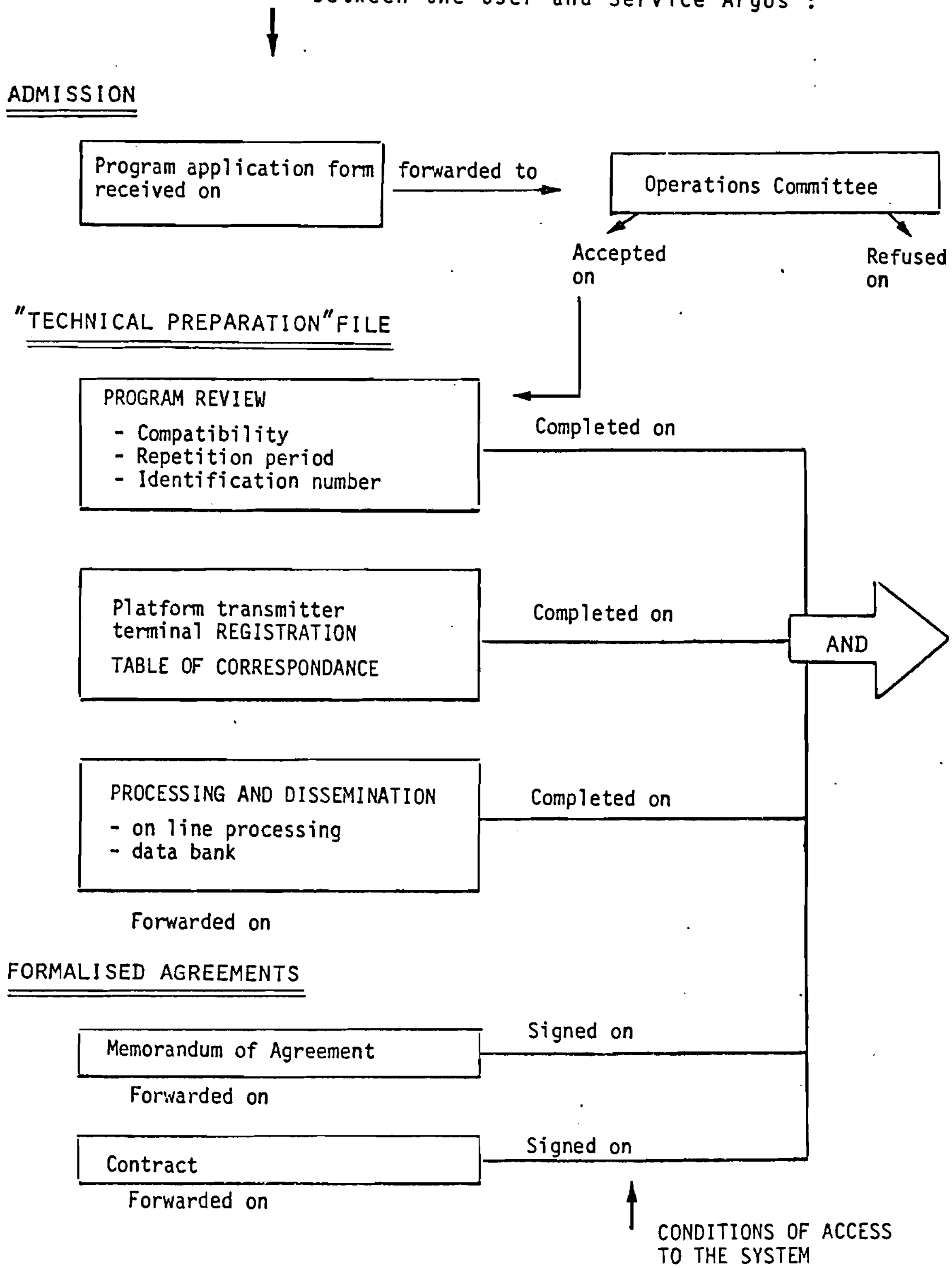
Country :

Program . :

Experiment :

SITUATION OF
"ARGOS ACCESS FILE" AT :

Documents which have to be exchanged between the User and Service Argos :



Copie

Courrier départ

210

INTRODUCTION

Access to the ARGOS system is a three-phase procedure : program application and approval, technical preparation, and formalized agreements.

- Program application and approval

  The ARGOS system can only be used for applications (projects, programs, experiments, etc.) concerned with environmental data collection.

  Following a review of the application made by a user, approval will be granted if the above condition is clearly satisfied.

- "Technical Preparation" file

  The "Technical Preparation" file constitutes a means of information exchange between the user and Service ARGOS.

  Such an exchange is a necessary preliminary to the entry of any program into the system. The purpose of this exchange is to enable users to specify their exact needs and to give Service ARGOS the opportunity to specify the system's capabilities of meeting these needs.

- Formalized agreements

  This, the last phase of the admission procedure involves the signing of various undertakings by both the user and Service ARGOS. This phase also includes the formal recognition of the rules of operation of the system.

  Two documents may be signed :
  - a Memorandum of Agreement (MOA), and
  - a contract.

  Access to the system will be granted when agreement has been reached on all of the above points (see figure 1).

1 - PROGRAM APPLICATION AND APPROVAL

1.1 - Conditions of Program Approval

The ARGOS system can only be used for applications concerned with environmental data collection. Environmental data are defined as measurements of physical, chemical, or biological properties of the water, earth, or atmosphere including space.

The APPROVAL of a program application corresponds to the checking that these conditions are satisfied.

The user is required to supply a sufficiently detailed description of the proposed program and to return a completed Program Application form. These documents are to be forwarded to Service ARGOS who, in turn, submits them to the Operations Committee for approval. (*)

NOTE : Applications not directly concerned with environmental data collection may be approved, provided that :

- the application does not last more than 6 months,
- the Program Application is examined by the Operations Committee according to a special procedure and ultimately accepted.

APPROVAL PRIORITIES

Program Applications will be approved by the Operations Committee according to the following priorities :

First priority

Platforms used for environmental data collection that cannot be accommodated by any system other than ARGOS.

(*) All U.S. applicants are requested to send a duplicate copy of their application questionnaire to the following address :

Mr DOUGLAS MAC CALLUM, Chief, Data Collection & Direct Broadcast Br.
SATELLITE SERVICE DIVISION, MAIL STOP G - NOAA / NESS -
Room 711 World Weather Building - WASHINGTON D.C. 20233 -

Second priority

Platforms used for environmental data collection but from which results could be obtained by means other than the ARGOS system. This category covers platforms that could be accommodated by geostationary satellites.

Third priority

Platforms used for data collection and location programs that are not directly concerned with the environment but which satisfy the requirements listed above under the sub-heading "NOTE".

These priorities will be used for the selection of experiments wherever there is a risk of system saturation (see "Technical Preparation" file, under Program Review).

1.2 - Program Application

1.2.1 - General

Users should submit Program Applications at the earliest possible date. This is important since, in certain cases, the application may have to be submitted to the Operations Committee for special review and may, as a result, be somewhat delayed.

Furthermore, there is always a certain risk that approval might not be granted by the Committee.

Thus, it is in the user's interests not to undertake any actions that might lead to user commitments, before notification has been received of program APPROVAL.

1.2.2 - Filling out the Program Application form

The request for the admission of a program is made by completing and returning the Program Application form.

This form is used directly for all processing formalities and, in particular, for submissions to the Operations Committee; it should thus be filled out most carefully.

Program Application forms may be filled out in either the French or English language.

2 - TECHNICAL PREPARATION FILE

The entry into the system of one or more platforms involves the exchange of a certain amount of technical information between the user and Service ARGOS.

This exchange takes place as detailed below.

2.1 - Program Review

2.1.1 - Compatibility with the ARGOS system

A detailed description of the proposed user program is required to enable Service ARGOS to determine the compatibility between the program and the ARGOS system.

Despite the large capacity of the ARGOS system, there may be some risk, in certain geographical zones, of the platform density reaching a level that may compromise system performance.

Each user program will thus be examined on the basis of data provided concerning :

- the geographical distribution of the platforms to be deployed,
- the planned number of platforms,
- the functions required of the ARGOS system, i.e. data collection and/or platform location. (Note, this is equivalent to specifying the message repetition period of each platform).

This information is then used, along with that already available concerning other platforms to be deployed in the same area, to determine the number of messages per second that will reach the satellite when the zone comes within the satellite's coverage.

This study is thus used to determine whether there is any risk of performance degradation due to saturation.

If there is a risk of performance degradation, approval cannot be granted. An estimate of the date by which approval may be possible is communicated to the user.

If there is no risk of performance degradation, access to the system can progress normally.

2.1.2 - Repetition periods

This study is also used to allocate a message repetition period to each platform. This period, T_R, will fall within the following ranges :

- 40 to 60 seconds if platform location is required,
- 100 to 200 seconds if data collection is the only required function.

The value (or values) selected are proposed to the user.

2.1.3 - ARGOS identification numbers

The ARGOS identification numbers (ID N°) required to ensure that each platform is correctly identified and processed are communicated to users by Service ARGOS.

216

2.1.4 - "Program Review" form

Upon reception of the Program Application form, Service ARGOS undertakes the review of the proposed program.

The results of this review (program compatibility with the ARGOS system, repetition periods, identification numbers) are recorded on the "Program Review" form. If the Program Application is approved by the Operations Committee, the Program Review form is forwarded to the user along with the notification of approval.

2.2 - PTT Deployment Preliminaries

2.2.1 - PTT registration

Each platform transmitter terminal, or PTT (appropriately identified by the manufacturer's name, the type and serial number), must be registered with Service ARGOS before being introduced into the system.

To register a PTT, the user must send the standard format data sheet supplied by the manufacturer with each unit to Service ARGOS. The section of the data sheet to be filled out by the user must, of course, be completed appropriately.

In particular, the user must specify the anticipated operating temperature range of the electronics throughout the proposed program. Obviously, this temperature range must fall entirely within the range for which CERTIFICATION was granted.

The antenna used with the PTT must be of the same type as that for which CERTIFICATION was granted.

217

2.2.2 - "Table of Correspondence"

The user must prepare a table detailing the correspondence between the ARGOS identification numbers allocated for the program and the manufacturer's serial number for each PTT to be deployed. This "table of correspondence" must reach Service ARGOS before the program in question actually becomes operational.

2.3 - Processing and Dissemination of Results

Following the above-described exchange of information and the completion of the "data processing and dissemination" file, Service ARGOS should normally be in possession of all the information necessary for carrying out the tasks requested by the user. The so-called "data processing and dissemination" file is divided into two parts:

- one concerning on-line processing and dissemination,
- the other concerning off-line processing and dissemination.

2.3.1 - On-line processing and dissemination

The on-line part of the data processing file contains documents specifying :

- the user's on-line processing requirements and the modes and means of on-line data dissemination,
- the results to be stored in the ARGOS data bank.

2.3.2 - Off-line processing and dissemination

The off-line part of the data processing file contains documents specifying :

- the tasks to be performed on data stored in the data bank,
- the periodicity with which results are to be forwarded to the user,
- the type of support medium (magnetic tape, microfiche, etc.).

3 - FORMALIZED AGREEMENTS

This, the third and last phase of the program application and approval procedure involves the signing of two documents by the user and Service ARGOS.

3.1 - Memorandum of Agreement (MOA)

The memorandum of agreement (MOA) will detail all rules, and their limitations, governing system operation and define the role and undertakings of each party.

The MOA can, however, be negotiated between the user and Service ARGOS. The document will be signed by both parties when agreement has been reached on all points.

3.2 - Contract

A contract will be prepared concerning all services for which users are to be charged.

The contract will indicate both the amounts due for services and the conditions of payment (now in preparation).

APPENDIX B-3

ARGOS SYSTEM PROGRAM APPLICATION

A R G O S

PROGRAM APPLICATION FORM

P R O G R A M   A P P L I C A T I O N

The Program Application form may be filled out in English or French. The completed form should be forwarded to :

Service ARGOS
Centre Spatial de Toulouse
18, avenue E. Belin
31055 Toulouse Cedex
France

BEST AVAILABLE COPY

DECEMBRE 1978

(*) All U.S. applicants are requested to send a duplicate copy of their application questionnaire to the following address :

Mr DOUGLAS MAC CALLUM, Chief, Data Collection & Direct Broadcast Br.
SATELLITE SERVICE DIVISION, MAIL STOP G - NOAA / NESS -
Room 711 World Weather Building - WASHINGTON D.C. 20233 -

ARGOS

N° :

(assigned by Service ARGOS)

PROGRAM APPLICATION FORM

Program :

This program is approved

This program is not approved

Priority :

Observations :

Date :

Co-Chairman Co-Chairman

222

I - <u>IDENTIFICATION</u> of the Program Director (1) or the person responsible for relations with Service ARGOS

Surname and first name :

Job function within the organization or company :

Organization or company :

Department :

Address :

II- <u>IDENTIFICATION</u> of the Program — Where applicable specify both the NAME of the program and your references

(1) If there is more than one address or contact, kindly give all relevant details.

III - PROGRAM APPLICATION (2)

III.1 - DESCRIPTION OF PROGRAM (3)

(2) or EXPERIMENT APPLICATION or PROJECT APPLICATION.

(3) This description must be sufficiently detailed to enable Service ARGOS to determine the aims and the main characteristics, these elements being essential for the approval or rejection of the program application.

III.2 - ADDITIONAL INFORMATION

- Type of program (x) :
  - . experimental
  - . lead-up to an operational program
  - . operational
  - . other

- Date of start of program :

- Date of end of program :

- Types of platforms to be used (x) :
  - . fixed
  - . buoys
  - . balloons
  - . other

- Number of platforms :

- Geographical zone covered by the program (4) :

- Program requirements (x) :
  - . location (with minimal data collection) only
  - . data collection only
  - . data collection and platform location

- Physical parameters to be measured and number of sensors per platform (5) :

(x) : Delete as necessary.

(4) : Please fill out this section most carefully; certain geographical zones may be subject to saturation.

(5) : Please fill out this section most carefully.

IV - PLATFORM TRANSMITTER TERMINALS (PTTs)

. Name of manufacturer

. Type of PTT selected

IMPORTANT :

All information given on this form will be used for the program REVIEW.

The aims of the program review are :

- to check the compatibility of the proposed program and the ARGOS system,
- to propose the message repetition period (or periods),
- to allocate ARGOS identification numbers.

APPENDIX B-4

CNES TARIFF RATES

CENTRE NATIONAL
D'ÉTUDES SPATIALES

DATA COLLECTION AND PLATFORM LOCATION SYSTEM

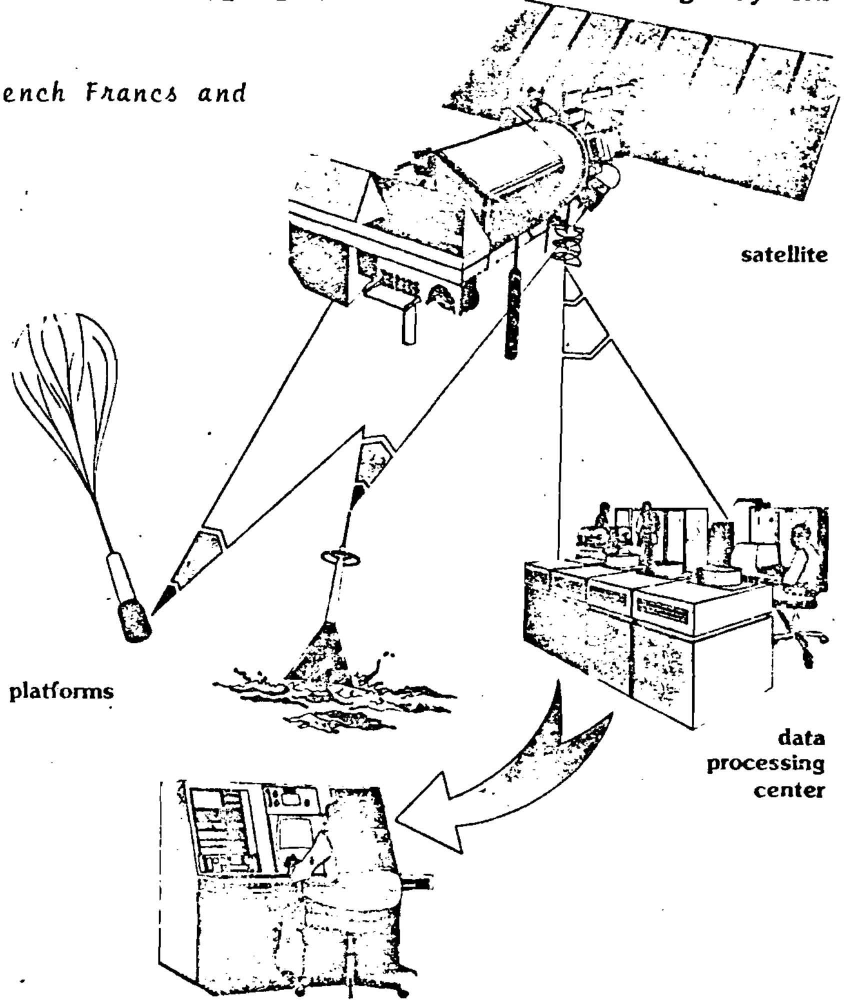
TARIFFS

(All tariffs are given in French Francs and exclusive of taxes)

Basic technical data concerning the ARGOS system and upon which the new tariffs are based, are briefly summarized below.

For more detailed information, refer to the ARGOS System User's Guide and to the detailed technical documents published by Service ARGOS.

- Argos System PTTs can transmit up to 256 bits of information encoded using a 32-bit word format. Measurement data may be analog or digital
- The following table gives approximate satellite visibility data, as a function of latitude, for a 24-hour period and for a two-satellite space segment.



latitude	cumulative visibility time over 24 hours	number of passes in 24 hours			mean pass duration
		min.	mean	max.	
± 0°	80 min.	6	7	8	10 min.
± 15°	88 min.	8	8	9	
± 30°	100 min.	8	9	12	
± 45°	128 min.	10	11	12	
± 55°	170 min.	16	16	18	
± 65°	246 min.	21	22	23	
± 75°	322 min.	28	28	28	
± 90°	384 min.	28	28	28	

<u>For further information</u> concerning tariffs and conditions, contact :

Mr. C. PERRIER DE LA BATHIE - Service ARGOS
C.N.E.S. - 18 av. Edouard Belin
31055 TOULOUSE CEDEX - FRANCE

228

I - DATA ACQUISITION AND PROCESSING

Base rates for PTTs transmitting every day

	Base rate applicability			refer to note(s) (opposite)
Operating time - in PTT - Years : - in PTT - days :	1 to 10 1 to 3650	11 to 20 3651 to 7300	More than 20 More than 7301	1
TARIFFS (in FF) Location only	90	80	70	2 and 7
Data collection only - Type A processing - Type B processing - Type C processing	0 10 Determined following examination of each particular case	0 9	0 8	3, 4 and 8 3, 5, 8 and 9 3, 6, 8 and 9
Location and data collection - Type A processing - Type B processing - Type C processing	90 100 90 + x x determined following examination of each particular case	80 89 80 + x	70 78 70 + x	2, 4 and 7 2, 5, 7 and 9 2, 6, 7 and 9

Special tariffs for intermittent use of the system.

- for intermittent use programmed by the user, tariffs are :
  . Days during which PTTs transmit : 100% of base rate
  . Days during which PTTs do not transmit : 10% of base rate.

Example : Location-only type PTT(s) transmitting once every three days for one PTT-year. Cost= base rate (FF 90) + 2x10% of base rate = FF 90 + 18 = FF 108 per day on which location calculations are performed

II - DISTRIBUTION OF RESULTS

Note : The tariffs indicated include postage at the appropriate rate. Consequently, any significant increase in postal rates will have a direct effect on the prices charged for the distribution of results.

	FRANCE	EUROPEAN POSTAL UNION	OTHER ZONES	NOTES
Automatic consultation and distribution of files over dedicated lines	1	1	1	Per PPT and per day (see also N.B.1. opposite)
Computer-controlled distribution of telex messages	1 + x	1 + x	1 + x	x can only be determined after users have identified the destination and transmission schedule
Computer print-out - first 50 pages : - every 50 pages thereafter	60 40	70 60	80 70	
Magnetic tapes, 1st experiment (1600 bpi, 9 tracks EBCDIC)	250	250	300	Unit price excluding customs duty. Mailings may be : fortnightly or monthly
Magnetic tapes, additional experiments(1600 bpi, 9 tracks, EBCDIC)	350	350	400	N.B.2
Microfiches				Under study

The tariffs indicated, in French Francs and exclusive of taxes, will be applicable until January 1, 1980.

CONDITIONS OF BASE RATE APPLICABILITY

1) A PTT year corresponds to 365 days of operation for a PTT linked to 32 bits of data. For more than 32 bits of data per PTT, see note 9 below.

2) The tariff indicated is only valid for up to 6 location determination calculations per 24 hour period. For more frequent calculations, see note 7.

3) The tariff indicated applies to the supply of data acquired during a maximum of 10 satellite passes. For more frequent data acquisition, see note 8 below.

4) The results supplied are not processed, in any way except for the decoding of data in decimal, hexadecimal, octal or BCD form (type A processing).

5) The results supplied are converted into engineering units using calibration curves supplied by the user for each sensor. Each curve is defined once and for all by a maximum of 20 points (type B processing).

6) Any processing other than that defined under note 4 or 5 (type C processing).

7) Supplement for the calculation of more than 6 locations per day :

7 to 10 inclusive : FF 1	21 to 25 inclusive : FF 20
11 to 15 inclusive : FF 3	26 or more : FF 25
16 to 20 inclusive : FF 10	

8) Supplement for data acquisition during more than 10 satellites passes per day :

11 to 15 inclusive : FF 0.50	21 to 25 inclusive : FF 4
16 to 20 inclusive : FF 2	26 or more : FF 6

9) For platforms equipped with sensors using more than 32 bits of data, an additionnal charge of FF 0,60 will be made per additionnal 32 bits of data (not applicable to note 4 above).

N.B.1 - Results are stored as and when they enter a memory that can be accessed directly by users. The user can interrogate the computer memory by telephone or telex or, the computer can interrogate the memory and send the results to the user over the Global Telecommunications System (GTS) or over a dedicated link.

N.B.2 - Any result or set of results for which an order is not received during the three months following the date of acquisition must be considered as lost.

III - MISCELLANEOUS

In the case of major programs (i.e. those totalling more than 20 platform-years or 7300 platform-days), Service ARGOS is prepared to study with the user the possibility of drawing-up an overall contract aimed at cost optimization.

Such solutions as the installation of dedicated lines or possibly the installation of terminals may be envisaged with payments to cover rental, leasing or outright purchase.

IV - CONDITIONS OF SALE

1) Unless other arrangements are agreed to by Service ARGOS, platform location and/or data collection shall be considered as :

   - billable so long as Service ARGOS continues to receive messages transmitted by one of the user's PTTs ;
   - terminated, for a given PTT, when no messages have been received for 30 consecutive days. In this event, the corresponding PTT file will be closed.

2) When placing an order, and before the user can be allowed to use the system, a deposit must be paia. The amount of the deposit will be :

   - FF 3000 if platform location is involved,
   - FF 1000 if only data collection is involved.

   This deposit will be refunded when the experiment has been declared terminated, except in the case of (a) experiments involving platform location lasting less than 1 month and (b) experiments involving only data collectin lasting less than 3 months.

3) Invoices will be made out quarterly by CNES and will cover all services rendered during the corresponding period. All invoices shall be payable two months from the the date of invoice. Payments should be in favor of the "Agent Comptable du CNES", a/c n°3.72.90.03.4., Société Générale de Toulouse, and addressed to :

   CNES
   18, avenue Edouard Belin
   31055 TOULOUSE CEDEX
   FRANCE

4) Whatever the conditions of sale, mode of distribution or delivery, items supplied by us are forwarded at the receiver's risk. In all cases of damage or losses noted upon reception, it is the receiver's responsability to make all necessary reservations and claims himself. (A draft letter can be provided at the request of the user).

ARGOS

APPENDIX B-5

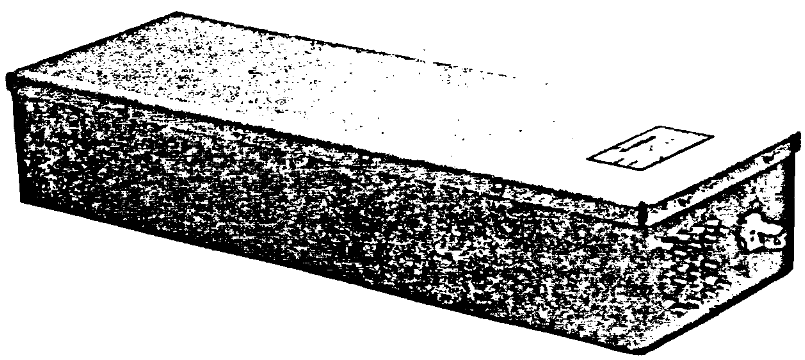
PTT MANUFACTURERS' INFORMATION

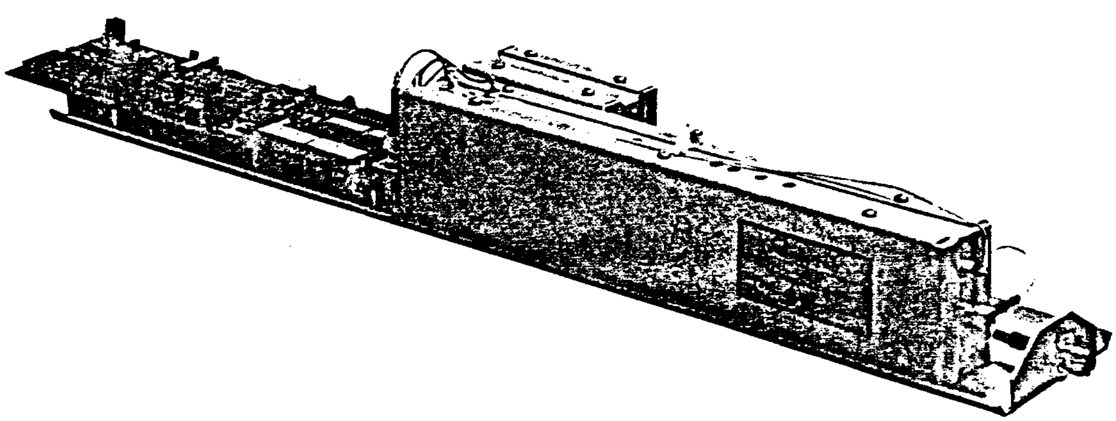
232

HANDAR

620A/621A TIROS/ARGOS LOW EARTH ORBITING DATA COLLECTION SYSTEM

- COST EFFECTIVE APPROACH FOR REMOTE DATA COLLECTION AND STATION POSITION INFORMATION
- POWERFUL MEASUREMENT SYSTEM EASILY CONFIGURED BY INDIVIDUAL USERS





THE TIROS/ARGOS LOW EARTH ORBITING DATA COLLECTION SYSTEM

The TIROS/ARGOS satellite presents the scientific user with the capability for low cost remote measurements. The ARGOS remote access measurement system aids meteorologists in mapping atmospheric pressure, temperature, wind directions and velocities; also, oceanographers in the data gathering of atmospheric pressure, wind speed, ocean currents, water temperatures and thermal profiles. Since an outstanding feature of the TIROS/ARGOS system is position location of platform transmitters, daily tracking of icebergs, glaciers and large animals can also be accomplished.

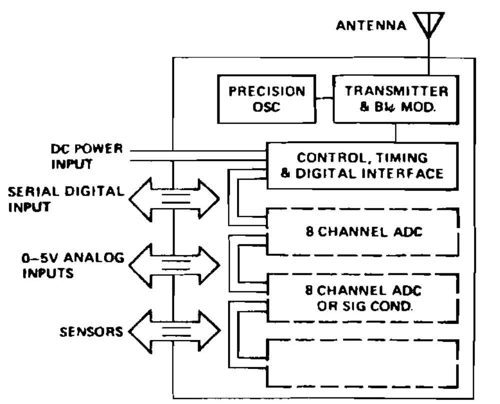
As the satellite passes a measurement platform, the transmitter carrier frequency is measured, time recorded, and sensor data demodulated. The information from each transmission is formatted and stored for readout at the end of each orbit. After satellite data readout, processing is performed at CNES in Toulouse, France, to compute platform position, velocity, and to recover sensor data. The processed data are then distributed to the various experimenters through the mail and other recorded media.

The ARGOS system can be used for any program concerned with environmental data collection. Applicants should request a copy of the document entitled "Access to the ARGOS System" from Service ARGOS in Toulouse, France. Handar furnishes a registration certificate with each 621A PTT. This certificate contains the information verifying the performance of the platform in conformance with ARGOS requirements. The user must complete the certificate and forward a copy to Service ARGOS as required for admission to the system.

Detailed information concerning the ARGOS System should be obtained from:

Service ARGOS
Centre National D'Etudes Spatiales
18, Avenue E. Belin, 31055 Toulouse, Cedex
France
Tel: (61) 53-1112
Telex: 531081F

THE HANDAR TIROS/ARGOS DATA COLLECTION SYSTEMS



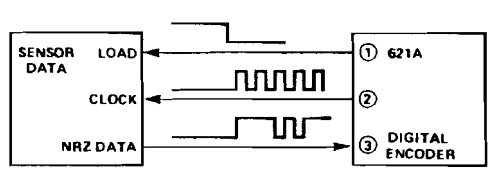
621A System Configuration

Fundamental to a successful measurement program is an economical transmitter and encoder capable of meeting the TIROS/ARGOS specifications. The Handar 620 series product line is a state-of-the-art solution providing a stable oscillator, transmitter, phase modulator, and several data encoder options. The stable oscillator employs a fundamental mode crystal at 10.04125 MHz. The multiplier output drives a high efficiency power amplifier with high immunity to antenna load mismatch. The different timing and encoder circuitry combinations allow the user a serial digital, analog, or combinations of both with up to 256 bits data capabity. All data encoding, timing, and analog to digital converter circuits use hermetic ceramic seal CMOS integrated circuits, minimizing power consumption while having good reliability.

THE 621A (DIGITAL INPUT ONLY)

The Handar 621A Data Collection Platform can accept from 32 to 256 bits of serial digital data. The digital interface is user programmable from 1 to 8 frames, with each frame containing 32 data bits. The digital data encoder accepts serial NRZ data after the ARGOS preamble has been transmitted through a simple 3 wire interface bus.

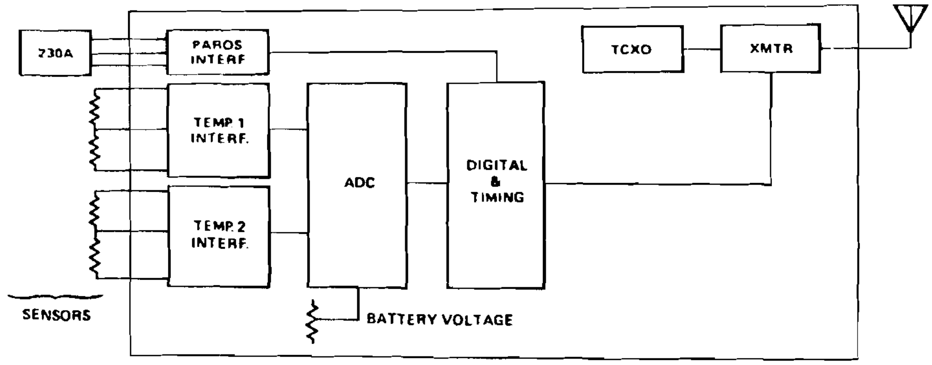
When data transfer is required by the 621A encoder, the "load data" line①(normally high) is pulled low and a gated 400 Hz clock②is supplied to the sensor electronics shifting the NRZ data③to the encoder interface. The interface contains own pull up terminations; thus, position only platforms are configured by simply leaving the digital interface①②③ unterminated.



621A Digital Interface

THE 620A (FGGE SYSTEM)

For customers requiring a system with sensor interfaces to pressure, 2 temperature channels and a battery voltage monitor, Handar can provide the model 620A. Originally intended for the first global G.A.R.P. experiment (FGGE), the 620A provides a programmable time interval counter interface to the paroscientific 230A pressure transducer. With a programmable pressure interface, the user may select any range and span within the capability of the basic paroscientific transducer (eg. 950–1050 MB or 825–1125 MB, etc.). The resolution of the pressure interface is 10 bits; thus, if a span of 100 MB is programmed, a 0.1 MB resolution may be obtained. The two temperature channels interface the YSI 44202 thermilinear network. A precision balanced bridge amplifier is used as the temperature interface. This provides common mode rejection of noise, reference aging and supply variations, reducing the temperature accuracy to the basic YSI network.

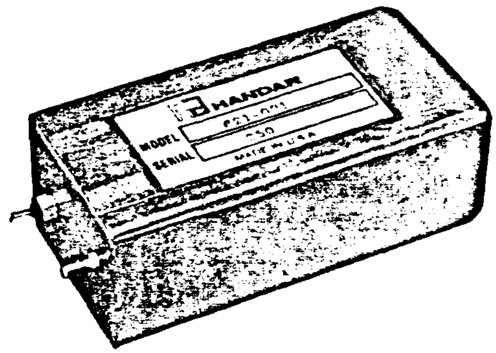


620A System Configuration

PERFORMANCE OPTIONS

Oscillators (Option 001)

The standard 621A oscillator is a TCXO intended for −5°C to +50°C environmental operation, with a maximum thermal change of 0.1°C/20 min. A high stability temperature stabilized oscillator (Option 001) is available for operation where the environment is below −5°C or the TCXO thermal stability measurements cannot be maintained. Option 001 will maintain the required TIROS/ARGOS stability from −50°C to +40°C and can tolerate a thermal change of 10°C/20 min. The oven set temperature can be specified by the user as a means of conserving power and should be >5°C above the maximum expected operating ambient.



Option 001 Temperature Stabilized Oscillator

Analog to Digital Converter (Option 002)

If analog inputs are required to the data collection system, an analog to digital converter option is available. The ADC assembly can be user programmed to accommodate from 1 to 8 analog inputs. When less than 8 analog channels are used the 621A system may be configured to accept serial digital inputs as well as analog data.

Signal Conditioning Board (Option 003)

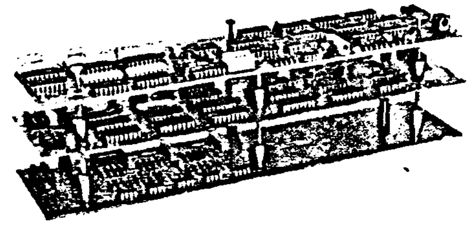
A signal conditioning board is available to supply an interface to 2 YSI 4402S thermilinear networks, battery voltage and a 2 pole drogue switch closure. Typical applications include drifting buoys measuring air temperature, water temperature, battery voltage and drogue attachment. The ADC option 002 must be ordered with Option 003.

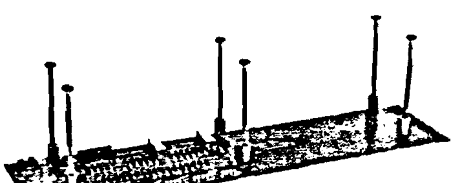
Packaging (Option 005)

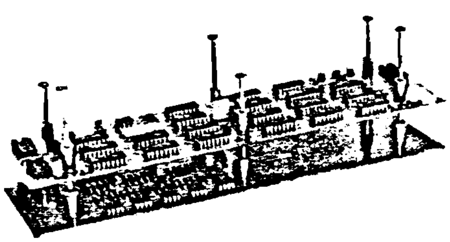
Two packaging options are available for the 621A. The standard package is an aluminum box RF enclosure, providing protection for the CMOS circuitry from handling and strong RF fields encountered in the immediate proximity to the antenna. All interface connections are made from one end of the enclosure providing a package easily configured into a user's system. Optional packaging consists of a spar buoy configuration intended to fit into a 4" PVC or fiberglass pipe.

SYSTEM CONFIGURATION

The 621A may be expanded to include multiple ADC and signal conditioning options. The options simply stack below the 621A timing and control board. If a complete system is specified at time of order, an integrated assembly with jumpers and interconnection cables will be supplied. When ordering ADC and signal conditioning options separately, the final configuration should be specified to ensure correct interconnection cables are included.



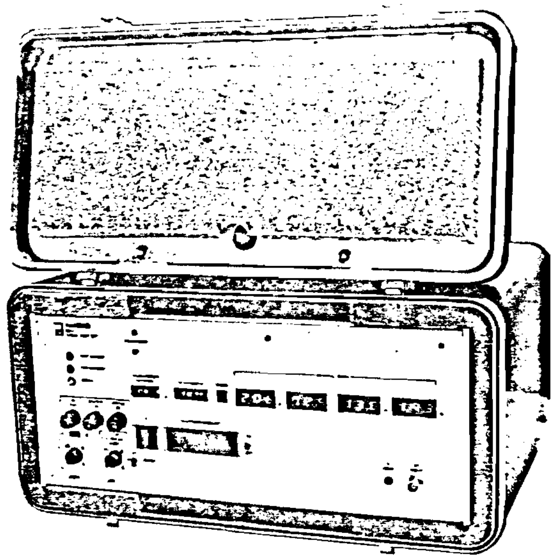




Options 002 & 003 Analog Interface and Signal Conditioning

COMPLETE TEST SET COMPATIBILITY

Both the 620A and the 621A are designed for easy performance verification with the Handar 602A field test set. A comprehensive check of the entire system—bit synch, ID Code, preamble, data encoding and storage, and modulation index can be accomplished with each transmission.



602A Field Test Set

621A TECHNICAL SPECIFICATIONS

FREQUENCY	401.65 MHz ±3 x 10^{-6}
FREQUENCY STABILITY	
Short Term	<1 x 10^{-9}/100 ms (Allen Variance)
Medium Term	<1 x 10^{-8}/20 min
Long Term	<2 x 10^{-6}/year
TEMPERATURE PERFORMANCE	
$\Delta f/f_o$	±1 x 10^{-6} (–5°C to +50°C)
$\Delta f/f_o$ Δt	1 x 10^{-7}/°C (Slope)
POWER OUTPUT (female TNC)	+33 dBm ±0.5 dB (2W nom) (for use with antenna option 008)
Output Impedance	50Ω (3:1 VSWR max)
MODULATION	
Type	BI ϕ L
Deviation	±63°
Stability	±6°
Symmetry $(\phi_1-\phi_2)/(\phi_1+\phi_2)$	<4%
SPURIOUS PRODUCTS	
<20 kHz from carrier	–50 dBc
>20 kHz from carrier	–45 dBc
HARMONIC PRODUCTS	–45 dBc

FORMAT	
Unmodulated Carrier	160 ms
Bit Synch	15 bits
Frame Synch	8 bits
Initialization	1 bit
No. Sensors	4 bits
Platform ID (DIP Switch Programmable)	20 bits (14 bits +6 bits error correcting)
Sensor Data	N x 4 x 8 bits ($1 \leq N \leq 8$ Data Frames)

DIGITAL DATA INPUT INTERFACE	3 wire
Input Level	0–12.5V CMOS
Logical 0	0V
Logical 1	+12.5V (Battery supply voltage)
Interface Connector	16 Pin DIP

Data Transfer Lines

1. Load data line goes low during data transfer.
2. 400 Hz gated clock is provided to shift data (N x 32 bits).
3. Serial Digital data is transferred to 621A and Manchester encoded. (Data should be shifted MSB first).
   –The 621A may be programmed to accept data in 32 bit increments from 32 bits to 256 bits. The load data line interval and gated clock duration are always coincident with the data density selected.

Transmit Interval	40 sec. to 200 sec. (DIP switch programmable in 5 sec. increments)
Accelerated Test Position	4.9 sec. (intended for laboratory testing only, should not be used while antenna is connected)

ADDITIONAL TIMING AND REFERENCE SIGNALS

–Begin Data Collection
–12.8 kHz clock
–400 Hz clock
– –10 VDC (100 μA max) Available with option 002
–1.22V ADC Reference

DC POWER INPUT	
Voltage	+11V to +14.5 VDC
Current	
Quiescent	<1.5 mA
Peak	<500 mA
Average	<4.5 mA (4 channels) Option 001 if used <5.2 mA (8 channels) (Transmission interval 60 sec. 32 data bits)

ENVIRONMENTAL	
Operating	–5°C to +50°C
Temperature Profile	0.1°C/20 min
Storage	–65°C to +70°C

HUMIDITY	0% to 90%

MECHANICAL	RF Enclosure Standard
Size	2.9" H x 5.5" W x 13.3" D (7.37 cm x 13.9 cm x 33.78 cm)
Weight	1.75 lbs. (0.8 kg)

SHIPPING	
Size	5" x 7" x 15" (12.70 cm x 17.78 cm x 38.1 cm)
Weight	3 lbs. (1.37 kg)
PRICE	$1,495.00 FOB Santa Clara, CA

PERFORMANCE OPTIONS

Temperature Stabilized High Stability Oscillator (Option 001)

FREQUENCY STABILITY	
Short Term	$<1 \times 10^{-9}$/100 ms (Allen Variance)
Medium Term	$<1 \times 10^{-9}$/20 min
Long Term	$<2 \times 10^{-6}$/year
TEMPERATURE PERFORMANCE	
$\Delta f_o/\Delta t$	1×10^{-9}/°C (−55°C to 5° of oven set point)
THERMAL RESISTANCE	>250°C/Watt

Additional power consumption can be computed by:
$P_{oven} = \Delta t/(250°C/Watt)$
Where ΔT = oven temp °C − ambient temp·°C
Example: Environment changes −55°C to +5°C
1. Oven set temp = 15°C
2. P_{oven} = 15°C − (−55°C)/250°C/Watt = 0.28 Watt
3. I_{oven} (−55°C) = P/E_{in} = 0.28/12.5V = 22.4 mA

The oven set temperature should be selected 5°C to 10°C above maximum ambient, and defined at time of order.

PRICE (Option 001)	$300.00
ANALOG INTERFACE (Option 002)	
No. Channels (User selected)	4 or 8
Input Connection (16)	16 Pin DIP With separate analog ground
Input Level	0–5 VDC
Input Impedance	100KΩ
ADC	Successive Approximation
Resolution	8 bits
Accuracy	0.4%
Temperature Coefficient	0.02%/°C
TRANSMIT INTERVAL	40 to 200 sec. (DIP switch programmable in 5 sec. increments)
Accelerated Test Position	4.9 sec.*
PRICE (Option 002)	$250.00

SIGNAL CONDITIONING BOARD (Option 003)

Temperature Measurement	(2 channels supplied)
Range	–20°C to +50°C
Sensor Type	YSI Thermilinear network (2 each supplied)
Accuracy	±0.5°C
Resolution	0.4% F.S. (8 bits)
Battery Voltage	0–15V
Resolution	60 mV
Drogue Sensor	2 switch closures (2 bits)

PRICE (Option 003) $225.00

LONG CHASSIS (SPAR BUOY CONFIGURSTION) (Option 005)

Length	<24.0 in (60.96 cm)
Diameter (Equivalent)	Fits inside 4" dia. pipe

PRICE (Option 005) N/C

GUARANTEED COLD TEMPERATURE PERFORMANCE TO –55°C (Option 007)

Additional testing and cold soak test at –55°C are performed on each unit to ensure operation at cold temperatures.

Note: Option 002 must be ordered with 001.

PRICE (Option 007) $300.00

ANTENNA (Option 008)

Type	1/4λ Quadrafiler Helix
Polarization	Right Hand Circular
Gain	+3 dB @ Zenith
VSWR	<1.5:1

SIZE

Diameter	3.0" (7.62 cm)
Length	15.0" (38.10 cm)
Flange	4.25" dia. 6 holes on 3.625 center 0.25" mating hole diameter
RF Connector	TNC

PRICE (Option 008) $350.00

COAX CABLE (Option 009)

Length	3' (1 m)
Connectors	TNC/TNC
Cable	RG-142

PRICE (Option 009) $30.00 + $1 each additional 30 cm

INTERFACE CABLE (Option 010)

Length	1' (30 cm)
Connectors	16 Pin DIP (2)
Cable	16 Cond. 28 guage

PRICE (Option 010) $10.00

620A TECHNICAL SPECIFICATIONS

FORMAT

Sensor Data	4 channels (32 bits)	
Channel 1	Pressure	10 bits
Channel 2	Battery Voltage	6 bits
Channel 3	Temperature 1	8 bits
Channel 4	Temperature 2	8 bits

SENSOR SIGNAL CONDITIONING

Inputs	RF Feedthrus (11)
Pressure	Programmable period averaging counter
Sensor Type	Paroscientific 230A-002 Barometer *not* included
Averaging Time	80 sec. nominal
Resolution	10 bits
Range	Pressure range programmable
Pressure transmitted two consecutive times	
Temperature (Digitized during Transmission)	
Sensor Type	YSI Thermilinear Network (2 each supplied with 620A)
Accuracy	±0.5°C
Resolution	8 bits
Battery Voltage (Digitized during transmission)	
Resolution	6 bits
DC Power Input	
Voltage	11V to +14.5V
Current	
Quiescent (620)	<1.5 mA
Sign. Cond. Avg.	<4.0 mA
Peak	<500 mA
Average	<8.5 mA (60 second transmission interval)
Mechanical	RF Enclosure Only
Size	2.9" H x 5.3" W x 14.8" D (7.37 cm x 13.97 cm x 37.59 cm)
Weight	1.9 lbs. (0.86 kg)

PRICE 620A $2,100.00

FOR PRICE AND AVAILABILITY INFORMATION

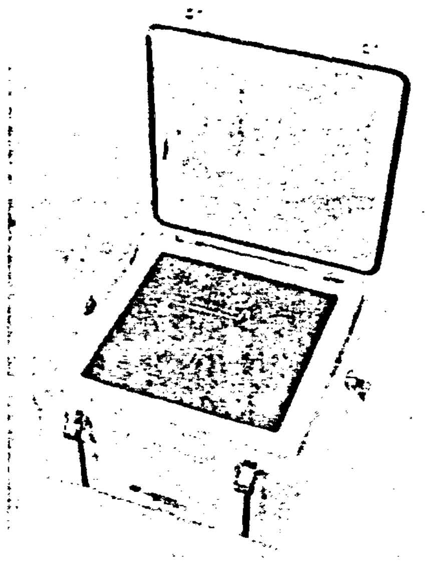
Handar
Marketing Department
3327 Kifer Road
Santa Clara, CA 95051

WARRANTY

All Handar Products are warranted against defects in materials and workmanship for one year. Handar will repair or, at its option, replace products which prove to be defective during the warranty period, provided they are returned to Handar. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED. HANDAR IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.

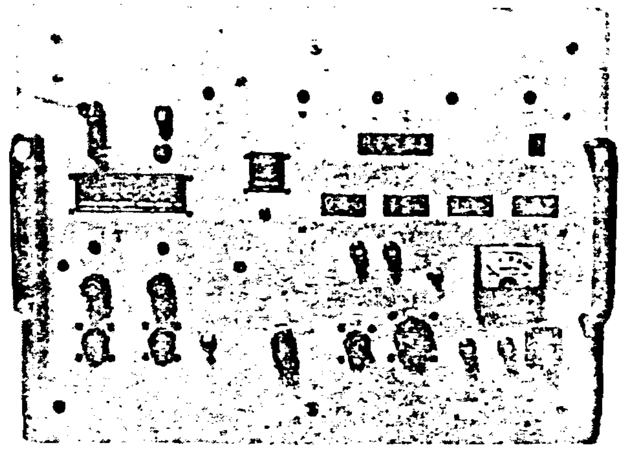
Prices and specifications are subject to change without notice.

ADAP (ARGOS DATA ACQUISITION PLATFORM)



A PORTABLE SELF-CONTAINED LAND-BASED
ARGOS DATA ACQUISITION SYSTEM
WHICH OPERATES ON AC, BATTERY, OR SOLAR POWER

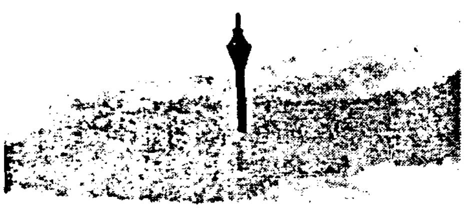
ARGOS PLATFORM TEST SET



PROVIDES COMPUTER DATA READOUT AND FUNCTIONAL TEST
OF ALL ARGOS DATA TELEMETRY SYSTEMS

PRL

POLAR RESEARCH LAB
123 SANTA BARBARA ST
SANTA BARBARA, CA 93101
U. S. A.
TEL: 805-963-1929

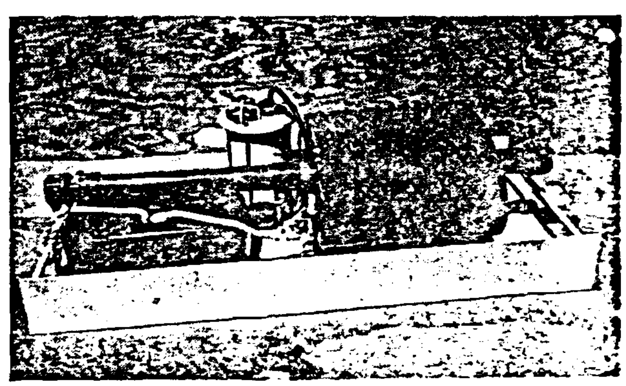


AIR DEPLOYMENT OF DRIFTING DATA BUOY

PRL MANUFACTURES A VARIETY OF DATA ACQUISITION PLATFORMS COMPATIBLE WITH THE NIMBUS 6 / RAMS AND TIROS / ARGOS SATELLITE TELEMETRY SYSTEMS. THE PLATFORMS PROVIDE REMOTE DATA COLLECTION CAPABILITIES ON LAND, THE OPEN OCEAN, LAKES, AND ICE COVERED BODIES OF WATER. PLATFORMS CAN BE PROVIDED WITH A VARIETY OF SENSORS SUCH AS BAROMETERS, AIR AND WATER TEMPERATURE SENSORS, WIND SENSORS, CURRENT METERS, CURRENT DROGUES, THERMISTOR STRINGS, WATER LEVEL SENSORS, RAIN GAUGES, AND SNOW LEVEL SENSORS

DATA BUOY FOR UNDER-WATER MEASUREMENTS
IN ICE-COVERED BODIES OF WATER
--SHOWN IN AIR DROP CONFIGURATION

OPEN WATER DRIFTING OR TETHERED DATA BUOY
FOR CURRENT MONITORING OR THERMAL PROFILING



CUBA (CALL-UP BUOY --ACOUSTIC)
A BOTTOM-RESTING UNIT WHICH SERVES AS AN UNDER-WATER MARKER.
A SURFACE BUOY IS RELEASED ACOUSTICALLY
AND PROVIDES AN RF SIGNAL FOR LOCATION.

ADAP

ARGOS Data Acquisition Platform

The ADAP is a portable self contained data acquisition system which transmits data to the TIROS/NOAA series satellites. These satellites contain the ARGOS system which is a randon access measurement system capable of handling up to 16,000 remote platforms.

In operation ADAP samples its sensors (up to 32), stores the data and transmits the data every one to three minutes depending on the transmit rate assigned. When the satellites orbit places it in view of the platform the transmissions are received by the satellite and the data is stored. Eventually the satellites orbit takes it over one of the three ground receiving stations at which time the data collected from the remote platform is dumped and disseminated to the users.

The number of satellite passes over a single platform ranges from an average of seven a day at the equator to 28 per day at the poles. The coverage pass duration is 10 minutes. Assuming a platform transmits 256 bits each two minutes, then up to 1280 bits of data per pass can be received. ADAP measures 41x41x41 centimeters and weighs 19.2 kilograms including the antenna and A.C. power supply. It is packaged in a rugged waterproof polyethelene case which doubles as the shipping container since the antenna and mount can be stored inside.

Sensor interfaces are available for serial digital, 16 or 32 channel analog (0 to 5 volt level) as well as custom interface for specialized needs.

Power supply options include AC operation with battery back-up (5 days), total battery operation (primary cells) or rechargeable batteries with solar charger.

Some of the many applications include rain and snowfall levels, water levels and thermal profiles in lakes and rivers, pollution monitoring, and monitoring of earth fault movements.

For more information and quotes on price and delivery, contact:

Walter P. Brown, Vice President
Polar Research Laboratory, Inc.
123 Santa Barbara Street
Santa Barbara, CA 93101 U.S.A.
Telephone - (805) 963-1929

TIROS Drifting Buoys

1. Introduction

The TIROS open ocean drifting buoys built by Polar Research Laboratory are designed to collect meteorological and oceanographic data. These buoys work with the ARGOS systems carried aboard the TIROS-N and NOAA-A satellites. A version of the buoy designed to gather barometric pressure and sea surface temperature is called the TIROS Meteorological Drifting (TMD) buoy (Figure 1.1). A second version used to track ocean surface currents called the TIROS Oceanographic Drifting (TOD) buoy carries a window shade drogue suspended below the buoy by a tether line which is usually attached to a drogue sensor. This sensor serves to alert the user if the drogue is lost.

In addition to the above specific configurations, buoys have been built with many types of sensors depending on the applications. Combinations of sensors used on the TMD and TOD buoys can be used. Buoys have also been configured with other sensors including anemometers, 1000 foot long thermistor strings and air temperature sensors.

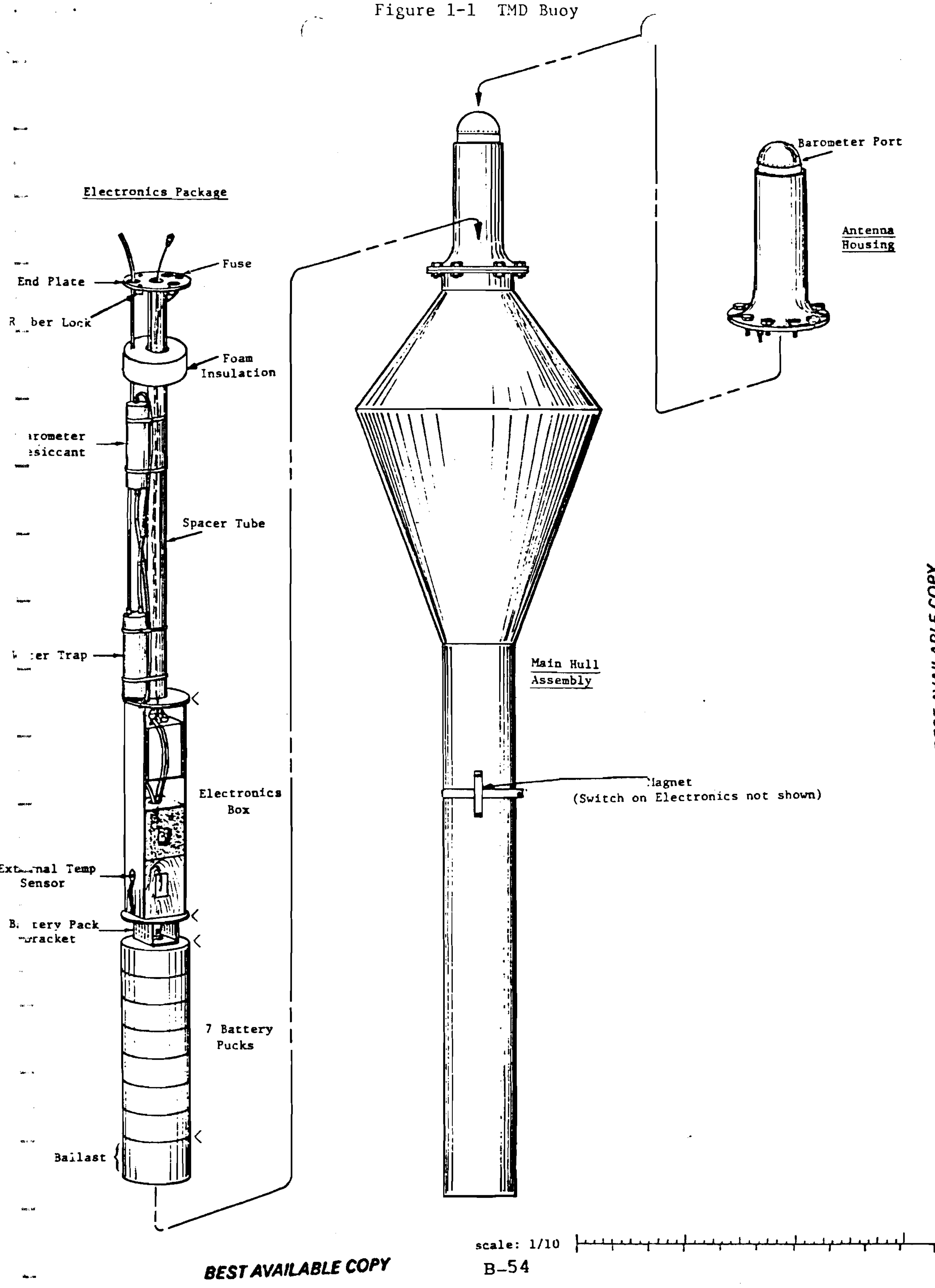
Buoys both with and without drogue can be air dropped and have been certified by the U.S. Air Force and U.S. Coast Guard for deployment from C130 and C141 aircraft. Drop altitudes covered ranges from 300 to 20,000 feet.

Both TMD and TOD buoys are being used operationally and have been both ship and air deployed. Fifty eight of the TMD buoys have been deployed in the southern ocean as part of the U.S. contribution to FGGE. Forty of these were ship deployed and 18 were air deployed. The latter was a reseeding effort in which failed buoys from various countries were replaced by air drops out of Australia, New Zealand and Argentina. Several programs using air deployed TOD buoys have been carried out in the Atlantic.

PRL has been manufacturing COSRAMS buoys for over three years for use with the NIMBUS-6 satellite RAMS system.

The TMD is almost identical to the COSRAMS buoy except for the electronics which have been redesigned for the TIROS/ARGOS system.

Figure 1-1 TMD Buoy



BEST AVAILABLE COPY

BEST AVAILABLE COPY

244

Over 180 of the COSRAMS buoys have been deployed in oceans all over the world. The reliability of the hull design has been demonstrated by buoys which wash ashore after up to three years in the water. The buoys were still in good condition and had been drifting in ice infested waters of the Davis Strait and the north Atlantic before being picked up on the beaches at the Faroe Islands and on the east coast of Scotland.

2. Specifications

2.1 Environmental

Parameter	Operation	Survival
Buoy in Situ		
Water Temperature -°C	-5 to +40	-5 to +50
Air Temperature -°C	-40 to +50	-55 to +70
Atmospheric Pressure -MBAR	900 to 1050	800 to 1100
Wind Speed - Knots	60	150
Max Wave Height - Ft	40	100
Surface Current	1	6
Buoy on deck or in lab		
Sensors & Signal Conditioning		
Air Temperature -°C	-5 to +35*	-55 to +70
Transmitter, Oscillator, Digital Encoder & Regulator and Power Supply		
Air Temperature -°C	-20 to +40	-55 to +70

* Depends on range of temperature sensor

2.2 Electrical

2.2.1 Antenna

Right hand circularly polarized 1/2 wave omnidirectional volute antenna

GAIN - +5 dBIC overhead

Impedance - 50 ohms nominal

V WR - 1.5:1 max

Bandwidth - 4 MHz min

Axial Ratio - 4 dB max

2.2.2 Electronics

Power Out - 1.5 watts minimum into 50 ohms

Transmit envelope rise time - <1 millisecond

Transmit Frequency - 401.65 MHz ± 1.2 KHz

Short Term

Frequency Stability - ≤1 x 10^{-9} in 100 msec

Medium Term

Frequency Stability - ≤4 Hz in 20 minutes with .5°C temperature change

Phase Modulation - Nominally ±1.1 radians

Unmodulated Carrier - 160 msec ± 2.5 msec

Duration

Transmission Duration - 360 msec ± 5 msec

Transmit Repetition Rate - 40 msec ± 4 msec
50 msec ± 5 msec
60 msec ± 6 msec

Modulation Bit Rate - 400 Hz ± 5 Hz

Harmonics and Spurious

Radiation

With ±20 KHz of unmodulated - ≤40 dB

Carrier

Outside ± 20 KHz of unmodulated - ≤-45 dB

Carrier

Protection Circuit - Monitors transmitter supply voltage and if it stays on greater than 1 second during normal transmit cycle or .6 sec outside normal transmit cycle the transmission will be terminated and not resumed for 15 to 16 transmit cycles

Power Requirements - +12 to +20 volts D.C. at 8 ma max continuous and 500 ma at duty cycle of .006

+3 volts D.C. at 20 ma max at duty cycle of .006

Note duty cycle based on 60 second rep rate at 40 sec rep rate duty cycle increases to .0088

2.2.3 Sensors

Barometer

Range - 900 to 1050 millibars

Resolution - .15 millibars

Accuracy - ± 1 millibar min*

.6 millibar RSS

Battery Voltage

Range - 8.4 to 18 volts

Resolution - .15 volts

Accuracy - ±.5 volts

Sea Surface and Internal Temperature

Range - +35 to -5°C**

Resolution - .156°C

Accuracy - ± 1°C min

.3°C RSS

* These accuracy figures could be exceeded at wind speeds above 60 knots

** TMD range, other ranges available

2.2.4 Mechanical

Overall Length	- 10 feet
Maximum Diameter	- 27 inches
Spar Dia	- 8 inches
Deployed Weight	- 210 pounds (with side and bottom tether)
	204 pounds (without tether points)
Total Buoyancy	- 503 pounds
Drogue Size	-
Drogue Weight	- 150 pounds in air
	100 pounds in water
Drogue Tether	- 1/2 inch diameter 8 ply plaited nylon line
Tether Length	- 100 meters-standard
	length specified by customer - optional

3. System Description

The TMD is a small open ocean free drifting buoy designed to acquire barometric pressure data, sea surface temperature and measure internal temperature and battery voltage. The data is acquired on a periodic basis and transmitted on a UHF RF link to the ARGOS system aboard the TIROS-N or NOAA-A polar orbiting satellites.

A block diagram of the electronic system is shown in Figure 3-1. In operation all of the sensors are sampled once every two transmit cycles or nominally every two minutes. The barometric pressure sample duration is nominally 60 seconds and the other sensors are sampled for 160 msecs. The signal conditioning unit converts the frequency output of the PAROS barometer to a 10-bit binary word using overflow counting techniques. The temperature sensors are conditioned to 8-bit binary words and the battery voltage to a 6-bit binary word using voltage to frequency converters and preset counters.

The binary data is stored between samples in the preset counters whose outputs are tied to a 32-bit data shift register. The Data and Preamble Formatter sets up the bit sync, frame sync, platform I.D., error code and sensor group number. These bits are integrated with the 32 data bits and shifted out as a bi-phase modulated data stream at the appropriate point in the transmitted message. The format of the message is shown in Figure 3-2. The platform I.D. and error code can be easily changed by a plug accessible on the outside of the electronics package.

The controller and timer provides the basic sequencing of the data samples and transmit cycles. The basic timing for all sequences is derived from a crystal oscillator with a stability of 30 ppm over the required temperature range. Although this stability is not required for the transmit cycle or the data bit rate it is necessary to maintain barometric pressure accuracy over the sample period of 60 seconds.

The Data and Preamble Formatter provides the 3 state phase modulation signals to the UHF transmitter. At the beginning of the

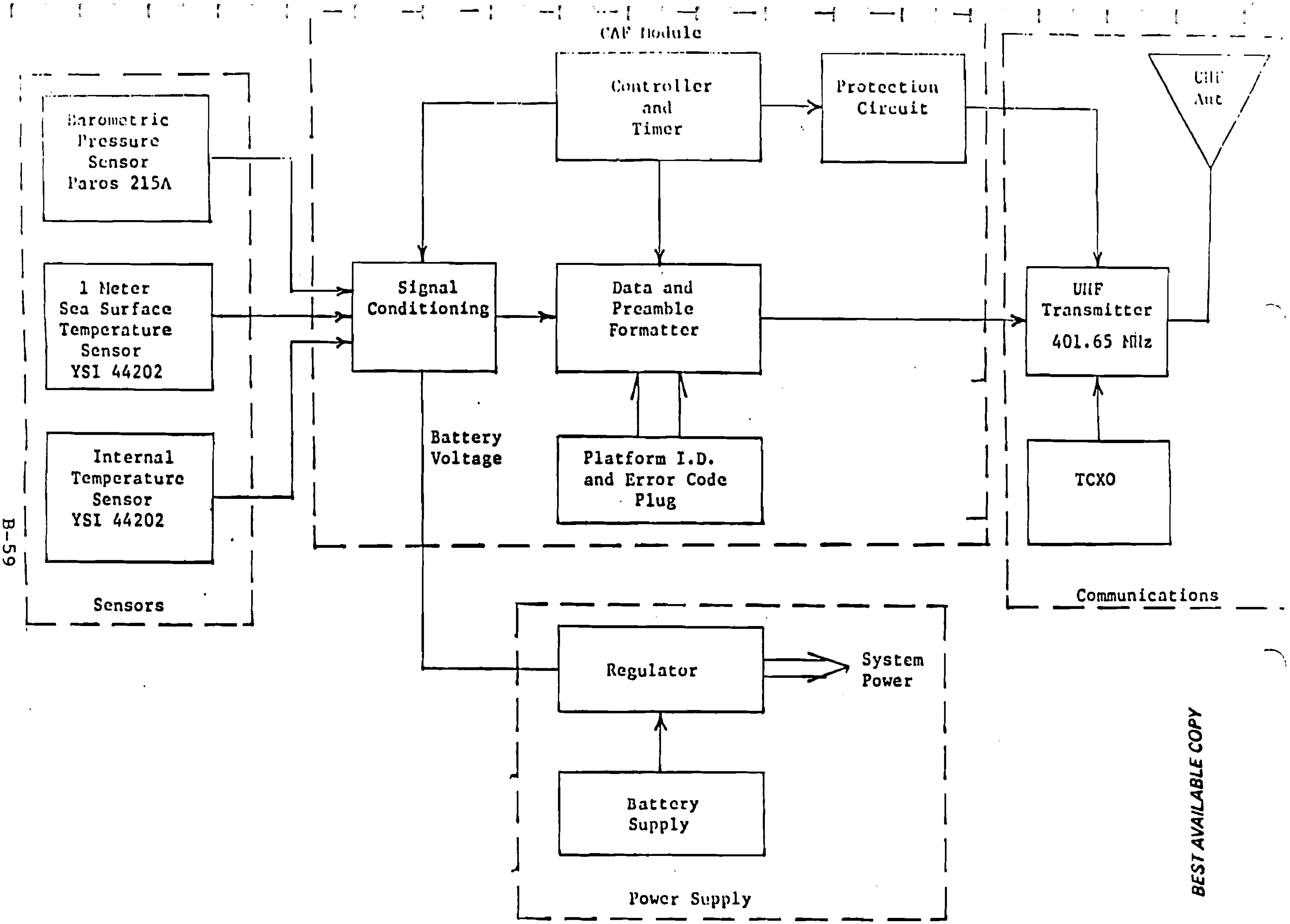


Figure 3-1 Functional Block Diagram of TMD

B-59

BEST AVAILABLE COPY

249

Unmodulated Carrier 160 milliseconds	Modulated Carrier 80 Bits - 200 Milliseconds								
	Bit Sync	Frame Sync	Init	No of Sensor Groups	Platform I.D.	Sensors			
						Barometer	Battery Voltage	Sea Surface Temp	Int. Temp
	15	8	1	4	20	10	6	8	8

Note: Numbers in Blocks Indicate Number of Bits for Parameter Indicated

Figure 3-2 TMD Message Format

250

transmit cycle the 0^{o} phase state is maintained for 160 msec followed by a $+60^{o}$ shift at the beginning of modulation and then shifting back and forth between plus and minus 60^{o} in response to the bi-phase data.

The UHF transmitter generates a stable 401.65 megahertz signal at a nominal power level of 33 dBM. The transmitter is driven by a temperature compensated crystal oscillator (TCXO) which will maintain the transmit frequency within ± 1.2 KHz over the required temperature range. The TCXO Box is thermally isolated within the buoy to maintain the rate of change of frequency with temperature to less than the 4.02 Hz per 20 minutes with a $.5^{o}C$ temperature change. A stable $\pm 60^{o}$ modulation is obtained with a hybrid coupled strip line phase modulation at the output frequency.

The transmitter drives a 1/2 wave quadrifilar helix type antenna with a hemispherical omni directional circularly polarized pattern. The EIRP of the antenna is a maximum of +36 dBM and fits the envelope required for the ARGOS system.

The CAF module also includes a protection circuit to prevent a system malfunction which would cause the RF output to remain "on" for longer than the one second as indicated in the ARGOS specification. The protection circuit senses the voltage applied to the final RF stage and if this remains applied for over one second the voltage is switched off by activating a normally closed reed relay. The relay is latched open for 16 normal transmit periods but closes again for the next normal transmit period. If the RF remains on again for one second the cycles repeat. This technique prevents extended transmission from locking up the satellite since transmissions are limited to the normal length of a platform with 32 sensors. If the problem corrects itself this technique allows the buoy to operate normally.

The power supply consists of a battery bank of 168 alkaline cells arranged in 14 parallel groups of 12 series cells. The 14 parallel groups are divided into 7 battery modules called pucks and each puck is isolated from the power buss by diodes. Another puck containing six cells is used to pr vide bias to the regulator switch.

The batteries feed a regulator which maintains a constant voltage on the UHF transmitter during the transmit cycle. The power supply is adequate to power the TMD buoy for a period of 12 months with additional capacity of provide four months shelf life at 25^{o}C.

PRL

POLAR RESEARCH LABORATORY, INCORPORATED

1/1/79

TMD Buoy Prices

Auxiliary Equipment:

Qty.	Drogue	1/2" Tether 1-30m	1/2" Tether 31 + m	Drogue Sensor & Interface	Battery Puck
1-10	$ 525	$120	$120+$1.50 per each add. meter above 30 meters	$325	$ 45
11-49	$ 475	$115	$115+$1.45 per each add. meter above 30 meters	$300	$ 40

Qty.	FGGE Interface	Paroscientific Barometer	Temperature Sensor, Interface, Battery Monitor	Air Deployment Package: For Buoy Without Drogue	Air Deployment Package: For Buoy With Drogue
1-10	$ 500	$ 2,600	$ 400	$ 480	$ 850
11-49	$ 475	$ 2,430	$ 375	$ 450	$ 800

Note: All prices are FOB Santa Barbara, California and are subject to change without notice. The air deployment package, which has been certified by the Air Force and Coast Guard, enables buoy launch from a C130 or other rear door aircraft at altitudes of 300 to 20,000 feet (the above price is in addition to all other options). A FGGE interface is required for installation of the barometer.

123 Santa Barbara Street - Santa Barbara, California 93101 - 805 963-1929

PRL

POLAR RESEARCH LABORATORY, INCORPORATED

1/1/79

TMD Buoy Prices

Buoy Combinations:	Quantity		
	1 - 10	11 - 24	25 - 49
Basic Buoy (Batteries for a 12 month life are included. Provides location only. No sensors or battery monitor are included).	4,500	4,350	4,200
FGGE Configuration Includes: A. Basic Buoy B. FGGE Interface C. Paroscientific Barometer D. (2) Temperature sensors E. Battery Monitor	7,600	7,255	7,105
TOD Configuration Includes: A. Basic Buoy B. Drogue C. 30 meter ½" tether D. Drogue sensor E. (1) Temperature sensor and interface F. Battery Monitor	5,870	5,615	5,465
TOD Option 1 Includes: A. TOD Configuration B. Paroscientific Barometer	8,470	8,045	7,895
TOD Option 2 (TOD Configuration Less temperature sensor and battery monitor)	5,470	5,240	5,090

Note: All prices are FOB Santa Barbara, California and are subject to change without notice.

123 Santa Barbara Street - Santa Barbara, California 93101 - 805 963-1929

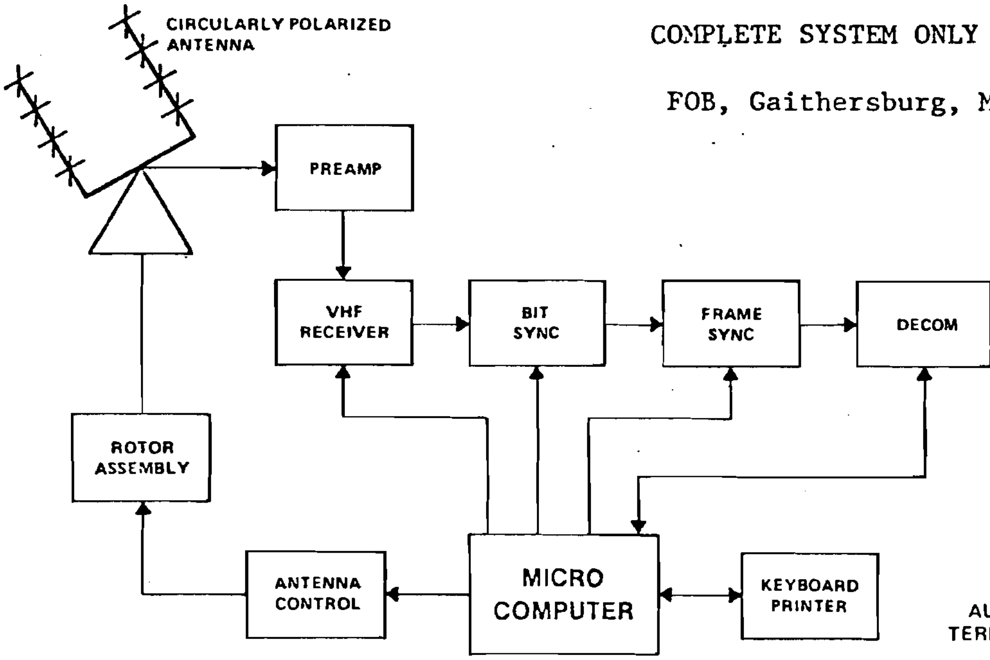
APPENDIX B-6

RECEIVING STATION MANUFACTURER'S INFORMATION

Automatic Direct Readout Terminal Tiros/Nimbus

COMPLETE SYSTEM ONLY $49,000

FOB, Gaithersburg, Maryland



AUTOMATIC DIRECT READOUT TERMINAL FUNCTIONAL DIAGRAM

A Completely Automatic Direct Readout Terminal

featuring modular construction with the following basic system elements.

- VHF Antenna System—Twin cross dipole circularly polarized yagi antenna on a rugged Az/El mount with built-in preamplifier and program track under computer control.
- Receiver—Detects VHF signal transmitted at any one of 4 frequencies (TIROS & NIMBUS) with automatic spacecraft selection under computer control.
- Bit Sync—Conditions demodulated telemetry signal to provide serial 'data' and 'clock'. Automatic adjustment to TIROS or NIMBUS telemetry bit rates under computer control. Built-in lock indicator LED.
- Frame Sync—Microprocessor controlled, converts serial data into parallel 'words' and provides 'frame' and 'word' strobes. Automatically selects TIROS or NIMBUS word/frame formats under computer control.
- Decommutator—Microprocessor controlled, extracts and stores into computer memory TIROS DCS data or NIMBUS RAMS data for user selected platforms during a real time satellite pass.
- Microcomputer—Non volatible program in 32k of Read Only Memory (ROM) controls all system functions. Computes latitude and longitude of all user selected remote platforms. Provides antenna pointing signal in real time in accordance with satellite ephemeris. Orbit information is continually being updated by means of one or more 'reference' platforms. Data storage in 16k (expandable) random access memory.
- Printer — ASCII printing terminal with standard RS 232 interface operating at 300 baud. User enters system initialization commands via keyboard. Optional video terminal available.

Additional options include: an analog tape drive for recording and later playback of raw demodulated telemetry data; digital tape cassette for recording, archival, and playback of raw or processed digital data.

OLD DOMINION SYSTEMS INCORPORATED

4 Professional Drive • Suite 119 • Gaithersburg, Md. 20760 • Telephone (301) 948-5200

APPENDIX C

TECHNICAL DESCRIPTION
NAVY NAVIGATION SATELLITE SYSTEM
(TRANSIT)

General Introduction

At present, there is only one world-wide satellite navigation system in operation. This is the Navy Navigation Satellite System (NNSS), better known as TRANSIT. TRANSIT was initially developed by the USN as a highly accurate, passive, all-weather world-wide navigation aid for Polaris submarines. The system has been continuously operational since January 1964 and has been available to the general public for non-military use since July 19, 1969. At that time, the system's details were released to commercial industry so that public user equipment could be developed and marketed. This equipment is now available from manufacturers in several countries, including France, Great Britain, Canada, Japan, and the United States, and is in world-wide use.

The TRANSIT system is composed of a constellation of six satellites that have been placed into 108-minute duration polar orbits at a nominal 1100 kilometers above the earth. Approximately a dozen or more satellites are in reserve to replace operational ones that malfunction. The predicted useful lifetime of each satellite is four years, however, the ones in the present group have been in orbit from four to ten years. Although present plans call for an eventual replacement of the TRANSIT system with the future Navstar Global Positioning System (GPS), present policy has guaranteed that TRANSIT will remain operational for ten years after the operational start of GPS, now scheduled for 1985. Thus, TRANSIT will be available until 1995.

The doppler shift, or apparent change in frequency of a stable source caused by relative motion between the observer and source, is used in the TRANSIT satellite system to determine both the satellite orbit parameters and user locations. Each of the satellites, which have been placed into prescribed earth orbits, contains a precision frequency source, a receiver, a transmitter, and a memory. At prescribed intervals, the satellite receiver receives a message from a ground station. This message, which contains a prediction of the satellite's orbit until the next update time, is stored in memory. The precision frequency source is used to develop the precise satellite transmitting frequency(ies) which is/are transmitted as a continuous wave transmission. At precise intervals (two minutes, for example), the information in memory, which includes the navigation message and other satellite identification and sync information, is modulated on the continuously transmitted carrier.

User equipment is comprised of three basic components, a receiving system, a data processor/display and a software package. Since the signal power of the satellite is very low, the receiver is ultra-sensitive and employs a phase-locked loop which enhances signal reception. It also employs a demodulator and an oscillator of good short-term stability. Long-term stability is not important, since the system is "clocked" by the highly stable satellite oscillator. The data processor can be a microprocessor or minicomputer depending upon the level of sophistication and desired accuracy. Software can be hardwired or externally entered, depending upon the facility, and can also vary in sophistication, depending upon the user's requirements.

In order to determine a fix, the user equipment must decode and extract the satellite message, measure and collect satellite velocities through integration of doppler counts and combine the doppler data with the satellite coordinates in order to obtain a computed antenna position at the time of the observation. A curve of the apparent shift in frequency due to the doppler effect, taken at several points in time, describes the user's unique location.

Users of TRANSIT must deal with several limitations and error sources. Some of the more important ones are listed below:

a. Infrequent satellite passes
b. Overlapping passes and co-interference
c. Geometrical effects on errors
d. Propagation anomolies
e. Coordinate transformations

f. Geoidal height variations

g. Velocity considerations

h. User equipment capability

Since the TRANSIT system is polar-orbiting, the frequency of overhead passes varies with latitude. One of the six satellites is visible (and thus available to compute a locational fix) every one-half hour at the poles, but only every two hours at the equator. Between these passes, no real time fix may be obtained from the satellite. Estimated positions may be obtained with the use of a dead-reckoning computer interfaced with the TRANSIT computer or with the use of a combination of TRANSIT with other radio navigation systems, such as OMEGA. In these cases, the secondary system monitors location between satellite passes and is updated to prime accuracy at the time of each pass.

TRANSIT accuracy has improved as a result of improved techniques. As an example, the accuracy of orbital determination has been increased to about 5-10 meters by using the WGS-72 geopotential model. The system's initial model, APL 1.0, provided only 100-150 meters accuracy. The system's total error budget is now 15-30 meters. Typical single-pass solution errors for navigation sets range from about 100 to 300 meters and up to about 50 meters for survey sets. Multiple-pass solutions and translocation methods can reduce the total fix error to 1-5 meters (translocation referenced to a known location; multiple-pass point positioning relative to WGS-72).

Table C-1 summarizes the characteristics of the TRANSIT system. Compared with other radio position-fixing systems, TRANSIT has numerous advantages. They include:

1. The system can be used all over the world.
2. The accuracy is greater than that of any other position-fixing system with world coverage.
3. The user does not need to contribute to the enormous cost of the system.
4. Special charts are not required.

Coverage:	World-Wide
Availability:	24 hours per day
Number of possible users:	Unlimited
<u>Satellites</u>	
Quantity:	Six (one presently inoperative)
Type of orbit:	Circular, polar
Period of orbit:	108 minutes
Altitude of orbit:	1100 kilometers (nominal)
<u>Satellite Transmissions</u>	
Frequency:	150 and 400 MHz
Type of emission:	CW, phase modulated
Data interval:	2 minutes
Data transmitted:	Fixed orbital parameters, variable orbital parameters, time and sync marks
Update interval for variable data:	12-16 hours
Fix availability:	Hourly at middle latitudes
Method of fixing:	Measure doppler data and combine with satellite coordinates to compute location at time of observation
Datum:	WGS-72
Operating Agency:	U.S. Navy (Astronautics Group)
Number of tracking stations:	Four
Number of injection stations:	Two
System Accuracy:	15-30 meters, RSS
<u>Application Accuracy</u>	
Translocation:	1-5 meters, RMS (relative to known point)
Point positioning:	5 meters, RMS (relative to WGS-72)
Navigation:	100-300 meters, RMS (relative to WGS-72)

Table C-1: CHARACTERISTICS OF THE NAVY NAVIGATION SATELLITE SYSTEM (TRANSIT)

5. The position is automatically stated as longitude and latitude, and requires no corrections to be made by the navigator.
6. Lane slip cannot occur.
7. The system does not involve reflection of radio waves, so no alterations in propagation time or phase can arise. The refraction in the ionosphere to which the waves are subjected is measured and corrected for by receiving two frequencies simultaneously.
8. The system's computer can also perform other tasks to increase safety or advance efficiency.

Disadvantages include:

1. The initial cost is high, though this may be reduced in the future.
2. The interval (maximum about 4 hours) between two position fixes is long.
3. Errors in the ship's course and speed data supplied to the computer detract from the accuracy of position fixing.
4. It is probable that in the future another, still better, satellite system for position-fixing will become available.
5. The present NNSS system is unsuitable for aircraft because, among other things, the average time between satellite passes is too long relative to the average duration of a flight.
6. Unless the satellite receiver is programmed to select only useable passes, the receiver may perform doppler counts on passes that are too high or too low, or may switch over from one satellite to another. In such cases the fixes are inaccurate or useless.

<u>TRANSIT User Equipment</u>

TRANSIT user equipment manufacturers market either navigation or survey sets or both. Navigation sets are typically capable of single-frequency operation and less accuracy than the survey sets. They are often times designed to be used as one sensor in a larger navigation system. Survey sets are stand-alone and can provide excellent accuracy. Characteristics of a cross-section of navigation equipment are contained in Table C-2. Selection of the equipments for presentation was based solely on availability of information. Individual costs are not listed in the tables, because extensive options are available for most systems. Acquisition costs range from about $15,000 for a simple navigation set to around $150,000 for a complete translocation survey system.

Following Table C-2 are company brochures describing two popular Magnavox Satellite Navigator Systems, the MX 1142 and the MX 1242.

CHARACTERISTIC	MAGNAVOX MX1102	NAVCOM 4800	NAVIDYNE ESZ-3000	TRACOR SATELLITE NAVIGATOR
Power:	100/115/208/230 ± 15% VAC, 45-66 Hz, 1ø, 150 W max.	100/110/230 VAC, -20 to +15% VAC, 44-67 Hz, 1ø, 95 W max.	105-230 VAC, 44-67 Hz, 1ø, 100 W max.	100-125 or 210-250 VAC, 50-60 Hz, 1ø, 130 W max
Battery Backup:	10 minutes	30 minutes	10 minutes	None
Receiver Frequencies:	400 MHz	150 & 400 MHz	400 MHz	400 MHz
Receiver Sensitivity:	-145 dbm	-150 dbm	-150 dbm	-146 dbm
Tuning Method:	Automatic or Programmed	Automatic or Programmed	Automatic	Automatic
Self Test:	Yes	No	No	No
Displays:	Approximately 20 Navigation and Satellite information functions & self-diagnostic readout on LED display screen	Status lights for power, AGC lock, valid data, valid message, plus or minute refraction & hard copy nav. data	Status lights for power, AGC lock, valid data, valid message & hard copy nav. data	Latitude, longitude and GMT on LED's & status lights for message sync, RF lock and power
Receiver Size				
Height:	432 mm	304 mm	153 mm	343 mm
Width:	419 mm	483 mm	489 mm	317 mm
Depth:	356 mm	483 mm	483 mm	508 mm
Weight:	34 Kg	40 Kg	20 Kg	18 Kg
Antenna Size				
Height:	445 mm	152 mm	185 mm	610 mm
Diameter:	625 mm	432 mm	222 mm	76 mm
Weight:	4.1 Kg	3.6 Kg	1.8 Kg	3.6 Kg
Features:	Extensive display, simple operation, single-unit construction, programmed tracking, self-indicating malfunction testing, auto dead reckoning*	Hard-copy data, simple operation, 2 equipments in a single package, automatic dead reckoning*, self-check meter, dual frequency	Hard-copy data, simple operation, single-unit construction, auto dead reckoning*, encapsulated ant./pre-amp	LED displays, 2 units in a single package, automatic dead reckoning*
Options:	Automatic speed & heading input, remote monitor, printer, alarms	Remote display & recorder, alarms, integration with other nav. systems	Automatic speed & heading input, integration with other nav. systems	Automatic speed & heading input, remote display, alarm signals
Fix Accuracy: (WGS-72 datum)	100 meters + 400 meters per knot of user's speed error	Same as MX1102	Same as MX1102	200 meters + 400 meters per knot of user's speed error

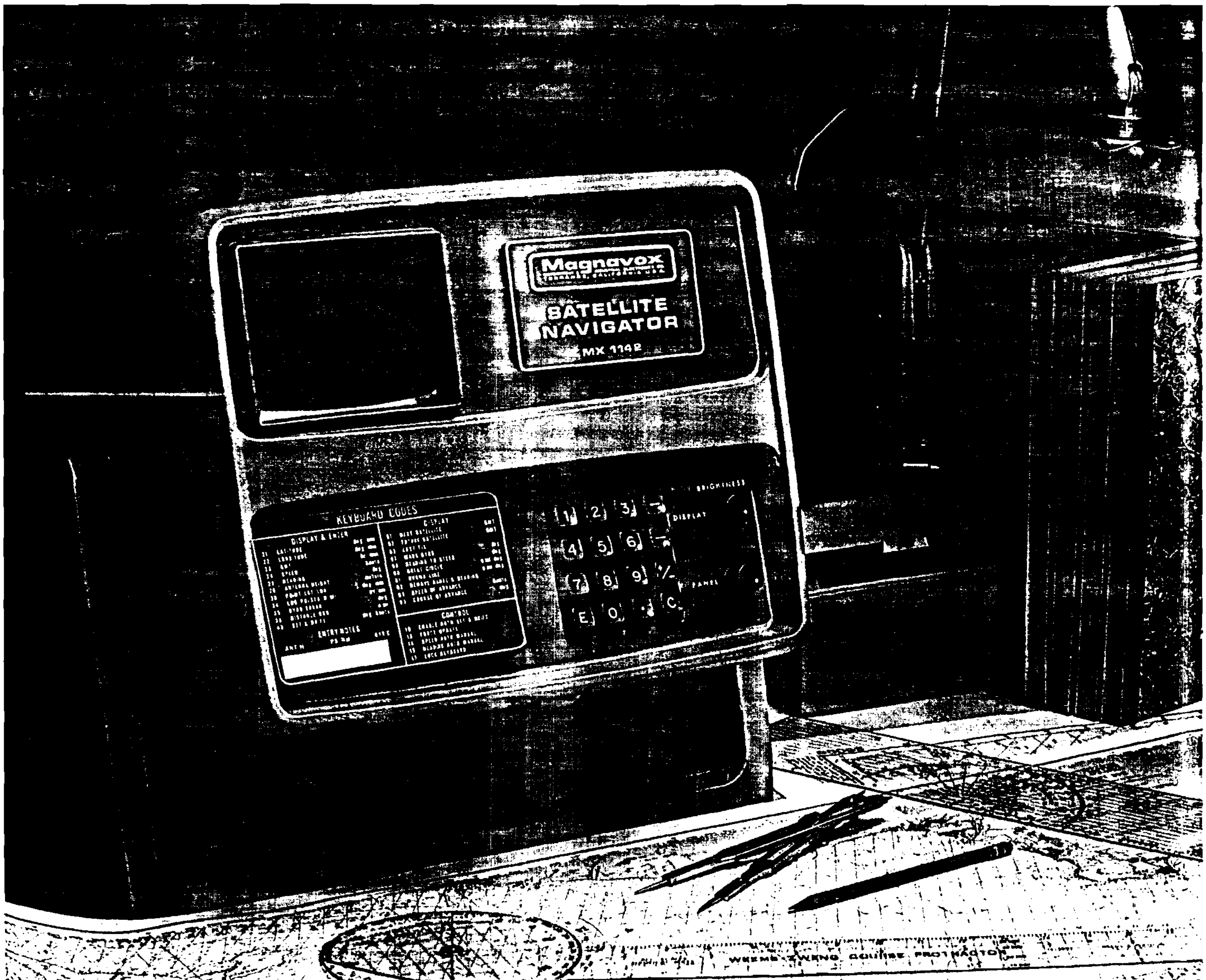
*Manually entered user's speed and heading.

Table C-2: CHARACTERISTICS OF SELECTED TRANSIT NAVIGATION USER EQUIPMENT

Magnavox MX 1142 Single Channel Satellite Navigator

Collins Marine Corporation
PIER 32 – SAN FRANCISCO CALIFORNIA 94105
TELEPHONE (415) 957 1300

Complete, Accurate Navigation Information Anywhere, In Any Weather, At Any Hour



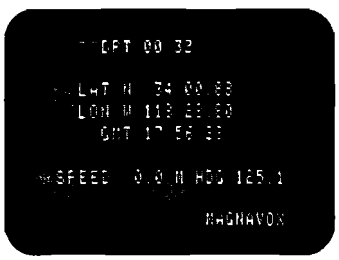
The MX 1142 Satellite Navigator is a member of the recently introduced Magnavox family of microprocessor-based navigation systems. This single channel satellite navigator provides continuous real-time shipboard navigation. It automatically and continuously computes and displays the ship's position, frequently updated by Transit satellites orbiting the earth.

Increased Reliability and Compactness

A primary objective in designing the MX 1100 series of satellite navigators was to establish a new standard of reliability for marine electronic navigation equipment. This objective has been realized through use of the latest LSI circuit technology and a microprocessor based designed that has enabled Magnavox engineers to improve equipment performance and reliability.

Except for its weather-sealed above-deck antenna, the entire system—satellite receiver, microprocessor, keyboard, and display—is securely mounted in a single, rugged, cast housing. This housing is similar in size to a small portable television set.

Complete Navigation Information at a Glance



The MX 1142 Satellite Navigator does its work automatically, unattended. It displays navigation data in brilliant red characters on a black background for maximum legibility. Once initialized it goes on acquiring data, updating and displaying all the information you need in its most usable form.

A typical readout tells you:

- ☐ Continous display of current dead-reckoned position in latitude and longitude updated by each satellite position fix.
- ☐ Greenwich Mean Time—accurate to within one second.
- ☐ Speed—manual or automatic input.
- ☐ Heading—manual or automatic input.
- ☐ Dead reckoning time—elapsed time since last satellite position update.

In addition, the MX 1142 can display on command a wide range of navigation and operational information, including:

- ☐ Set and drift.
- ☐ Heading to steer.
- ☐ Total distance run.
- ☐ Course of advance.
- ☐ Speed of advance.
- ☐ Course and distance to or between present location and/or multiple waypoints—Great Circle or Rhumb Line course.
- ☐ GMT of next and future usable satellite passes.
- ☐ Maintenance and troubleshooting data.
- ☐ Comprehensive last fix data display.

MX 1142 key features are:

Accuracy:

- ☐ Static fix with 0.05 NMI (RMS).
- ☐ Perfect fix update reliability.
- ☐ GMT accurate to one second.

Simple operation:

- ☐ Fully automatic.
- ☐ Fully programmed—no program to load.
- ☐ Automatic speed/gyrocompass interface.
- ☐ Pushbutton operation.
- ☐ Simple mnemonic codes.
- ☐ High legibility red character CRT display.
- ☐ Illuminated keyboard.
- ☐ Keyboard lock.

Reliability:

- ☐ All solid-state components.
- ☐ 0-50°C. temperature specification.
- ☐ Automatic self-test.
- ☐ Manual self-test.
- ☐ Board-level fault isolation.
- ☐ Speed and gyro input failure warning.

Options:

- ☐ D.C. power supply. Full operation battery backup and charger.
- ☐ Printer.
- ☐ Remote displays.

Simple to Operate

Any navigator can learn to operate the MX 1142 with an hour or two of practice. There are no complicated procedures or control panels to master. All inputs are entered through the keyboard, using simple two-digit codes listed on the front panel. All system outputs are displayed in a concise, easily understood format. The navigator need never touch the MX 1142 after initial startup when the automatic speed and heading interface is used. The system will go on automatically computing and displaying accurate, up-to-the-second navigation information as long as power is supplied.

All data is displayed in its most immediately usable form without hand calculations or conversions—location in latitude and longitude, direction in degrees, time in hours, minutes, and seconds, distance in nautical miles.

Automatic Memory Protection

In the event of power failure, the computer program and stored information are automatically protected for up to 15 minutes by the memory battery. The battery is automatically recharged when power is restored.

(The memory battery is not the same as the optional full operation back up battery.)

© Copyright 1978 Magnavox Government and Industrial Electronics Co. R5916 9/78. Printed in U.S.A.

Once initialized, the system functions virtually without operator attention. With each valid Transit satellite pass, it automatically computes the vessel's position within 0.1 nautical mile (nominal) and then dead-reckons until the next satellite update.

Since the Transit satellite network blankets the earth, and is unaffected by local weather conditions, the MX 1142 functions flawlessly at any hour, anywhere, in any weather.

Great Circle or Rhumb Line Course

Upon command, the MX 1142 continuously calculates and displays the Great Circle and Rhumb Line course and distance from the ship to from one to nine selectable destinations, turn points, way stations or obstacle locations – anywhere on the earth's surface. It also displays the gyrocompass heading (corrected for gyro error and set and drift) required to maintain the desired course.

In addition, the system can display the course and distance between any two of the nine waypoint positions, permitting the navigator to plan future course changes.

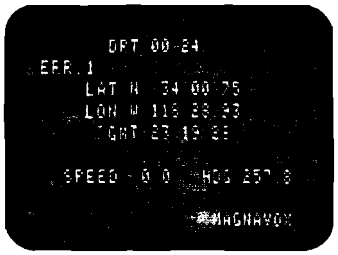
Programmed Tracking

The MX 1142 sets a new standard for fully automatic satellite navigation signal processing. As the MX 1142 tracks each satellite, it stores the orbit data and predicts the time of the next usable pass. Having acquired data from all satellites, the system preferentially tunes to the passes having acceptable elevation angles. In this way, satellite blocking is eliminated. The result is that the MX 1142 produces about ten percent more usable position fixes than other satellite navigation systems and can reduce the maximum time between satellite fixes substantially.

Alerts

The system also provides alert signals to call the operator's attention to anomalous navigation information, deviation from selected heading to steer, near approach to designated waypoints, etc.

Automatic Self-Test

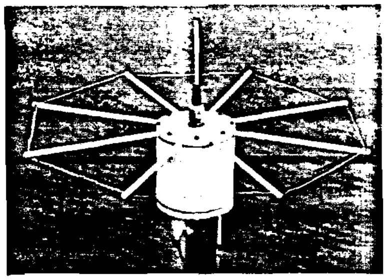


Approximately every two hours, without interrupting normal operation, the MX 1142 conducts an automatic self-test of all major functions. At such times, the notation "TEST" appears on the display indicating test in progress, and disappears at the end of the test if no error is detected. If an error is found, the notation "ERR" appears on the display, with digits or letters identifying the most probable defective part. Self-test also may be initiated manually.

Maintenance in the Field

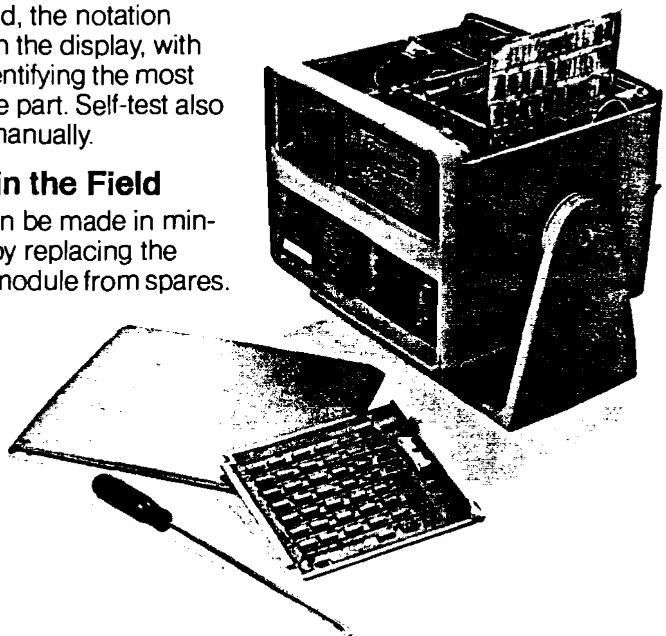
Most repairs can be made in minutes on the spot by replacing the defective plug-in module from spares.

Antenna/Preamplifier Unit



Like other components of the system, the MX 1142 antenna/preamplifier is designed for the rigors of the environment in which it operates. It is ruggedly constructed to withstand vibration and temperature extremes, and is sealed against the effects of water, sun, wind and salt.

The antenna is easily mounted in any relatively unobstructed above-deck location within 200 feet (60 meters) of the MX 1142 Satellite Navigator unit. One hundred feet of cable is normally supplied with the system.



Automatic Speed and Heading Input

The MX 1142 is available with either of two standard speed and heading interface modules which plug inside the chassis and accept signals from most standard marine gyrocompasses and speed logs. With one of these interfaces, the MX 1142 continuously monitors the speed and/or heading and performs fully automatic dead reckoning between satellite fix updates. The system allows manual entry of corrections for speed log scale factor and gyrocompass error. The gyrocompass input can be synchro, stepper or two speed synchro. Speed can be provided by contact closures, pulse train, or two speed synchro signals.

Options

Emergency Internal Battery and Recharger

An optional internal battery backup system is available to provide continuous MX 1142 operation when there is a temporary loss of external power. With this option installed, when there is a loss of external power, the MX 1142 automatically switches to battery power, indicates main power failure on the display, and continues to operate without interruption or loss of data.

The batteries automatically recharge upon resumption of external power.

Remote Display Monitor

One or more remote displays may be added to the MX 1142 system for duplication of the information on the main unit at any desired location.

Printer

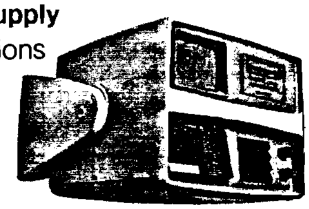
A printer output signal is provided, permitting a printer to be connected to the system to provide a hard-copy record of the navigation information. Magnavox can also supply a variety of different optional printing devices depending on the particular needs of the customer.

Alarm Signal

For vessels with a centralized alarm system, an alarm relay contact output is provided to activate the alarm in case the MX 1142 fails self-test, loses power, or detects anomalous information from the gyrocompass or speed log.

D.C. Power Supply

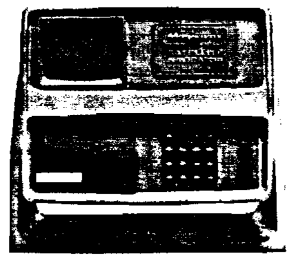
For applications requiring a 24 VDC input, an optional power supply is available.

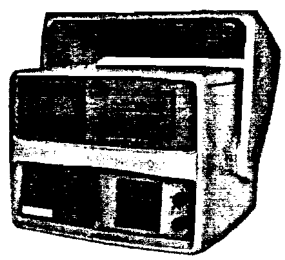


(Memory protection is not required or provided with this option.)

Mounting

The MX 1142 is designed for easy installation. The mounting yoke can be rotated to provide tabletop, bulkhead, or overhead mounting. No external junction boxes or components other than the antenna/preamp are required. The small antenna/preamp unit mounts in any abovedeck location affording a relatively unobstructed view of the horizon. Installation can be accomplished easily during a normal port turnaround interval within a few hours.



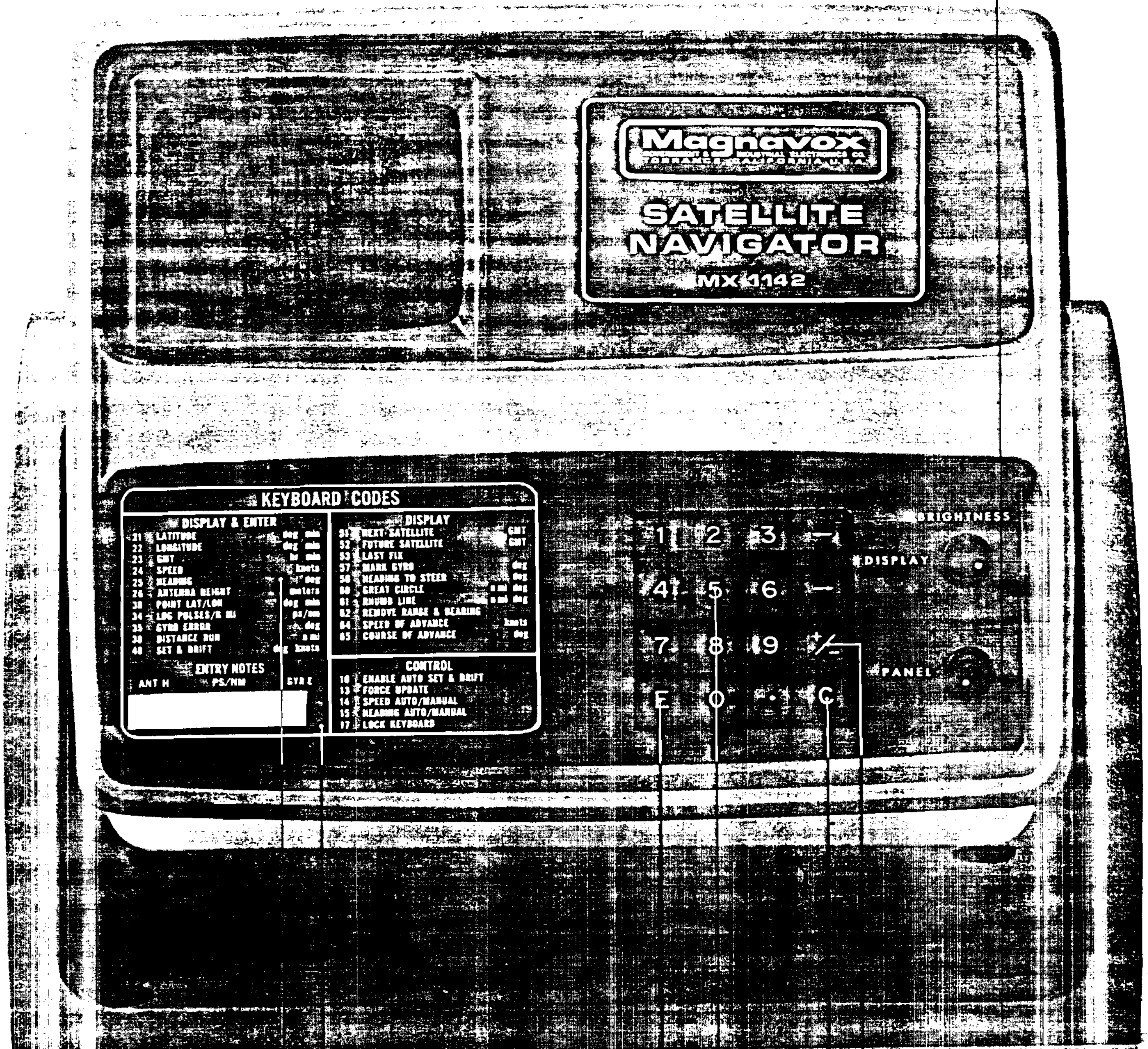


MX 1142 Specifications

SATELLITE FIX ACCURACY	0.05 Nautical Mile plus 0.2 Nautical Mile per Knot of Speed Error (RMS)
ENVIRONMENTAL	Operating Temperature – Main equipment 0° to 50°C – Antenna/Preamp −25° to +70°C Relative Humidity to 95% at 40°C Ventilation – Intake and exhaust through front panel
RECEIVER FREQUENCY	400 MHz Transit Satellite Channel
SENSITIVITY	−145 dbm
TUNING	Automatic and Programmed
SELF TEST	Automatic with Diagnostics to Module Level
DIMENSIONS	Overall height 432mm (17 in); Overall depth 356mm (14 in) Overall width 419mm (16.5 in); Weight 34 Kg (75 pounds)
ANTENNA GROUP	Diameter 625mm (24 in); height 445mm (17.5 in); Weight 4.1 Kg (9 pounds) Cable 30 meters (100 ft) normally supplied; maximum length which can be used is 60 meters (200 feet).
POWER	100/115/208/230 ± 15% VAC. 45 to 66 Hz. Single Phase 120 watts maximum, with 15-minute memory protection in case of power failure.
OPTIONAL INTERNAL BACKUP BATTERY	10 minutes operation with full charge
OPTIONAL D.C.	24 VDC,−10%+25%.

Magnavox reserves the right to make changes to its products and specifications without notice.

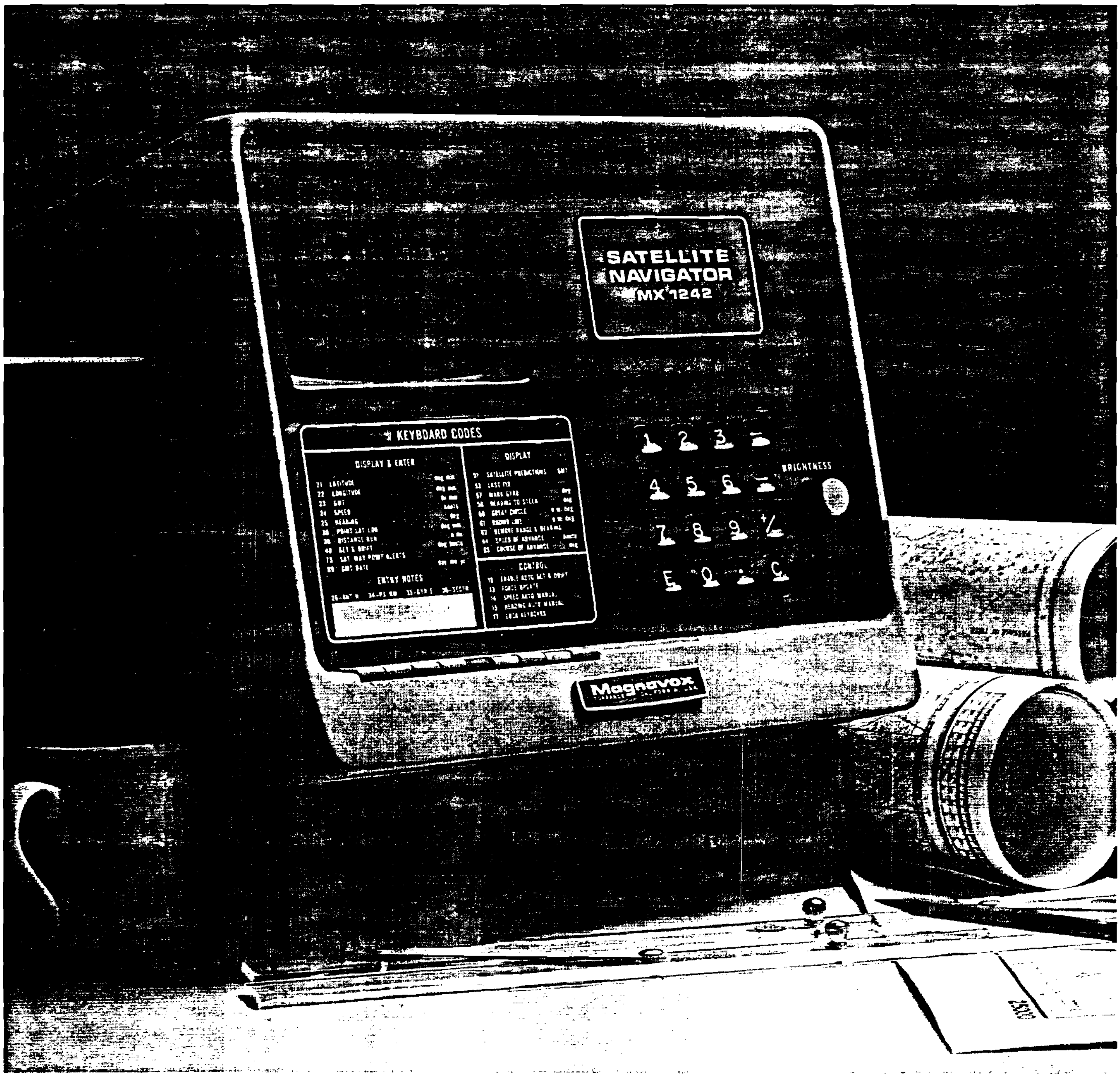
The MX 1142 Satellite Navigator



BEST AVAILABLE COPY

Magnavox
MX 1242
Single Channel
Satellite Navigator

Complete, Accurate Navigation Information Anywhere, In Any Weather, At Any Hour.



Worldwide Precise All-weather Navigation— Simple and Convenient

Operational simplicity... precise navigation data... rugged dependability... compact convenience... these are the key qualities of the Magnavox MX 1242 single channel satellite navigator.

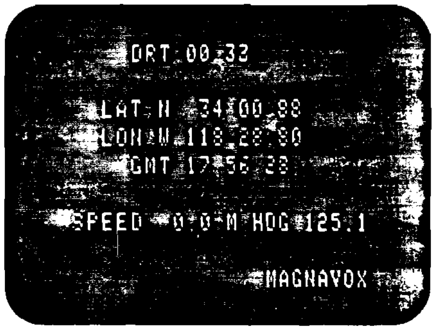
The MX 1242 Satellite Navigator is a member of the recently introduced family of Magnavox microprocessor-based navigation systems.

Increased Reliability and Compactness

A primary objective in designing the MX 1242 was to establish a new standard of reliability for marine electronic navigation equipment. This was accomplished by using the latest solid state circuit technology and through exhaustive component selection and evaluation. This design concept has resulted in thousands of extra hours of trouble-free performance in the marine environment.

Except for its weather-sealed above-deck antenna, the entire system – satellite receiver, microprocessor, keyboard, and display – is securely mounted in a single, rugged, housing. This housing is similar in size to a small portable television set.

Complete Navigation Information at a Glance



The MX 1242 Satellite Navigator does its work automatically, unattended. It displays navigation data in sharp red characters on a black background for maximum legibility. Once initialized, it goes on acquiring data, updating and displaying all the information you need in its most usable form.

A Typical Readout Tells You:

☐ Continuous display of current dead-reckoned position in latitude and longitude updated by each satellite position fix.
☐ Greenwich Mean Time – accurate to within one second.
☐ Speed – manual or automatic input.
☐ Heading – manual or automatic input.
☐ Dead reckoning time – elapsed time since last satellite position update.

In addition, the MX 1242 can display on command other navigation and operational information including:

☐ Great Circle or Rhumb Line distance and course up to nine way points.
☐ Sailing program alert.
☐ Course made good.
☐ Speed made good.
☐ Total distance run.
☐ Compass error compensation.
☐ Maintenance and trouble-shooting data.
☐ Set and Drift.
☐ Satellite tracking alert.
☐ Satellite fix alert.
☐ Comprehensive last fix data display.
☐ Time, elevation angle, and identification of next eight satellite passes.

MX 1242 Key Features are:

Accuracy:
☐ Static fix with 0.05 NMI (RMS).
☐ GMT accurate to one second.

Simple Operation:
☐ Fully automatic.
☐ Fully programmed – no program to load.
☐ Programmed Tracking.
☐ Pushbutton operation. Simple mnemonic codes.
☐ High legibility CRT display.

Reliability:
☐ All solid-state components.
☐ 0-50°C temperature specification.
☐ Factory burn-in of systems.
☐ Automatic self-test.
☐ Manual self-test.
☐ Board-level fault isolation.
☐ Speed and gyro input failure warning.
☐ Automatic memory protection and auto restart in event of main power failure.
☐ Automatic speed/ gyrocompass interface.

Options:
☐ Printer.
☐ Remote displays.

BEST AVAILABLE COPY

© Copyright 1979 Magnavox Government & Industrial Electronics Co R6000 2/79 Printed in U.S.A.

Simple to Operate

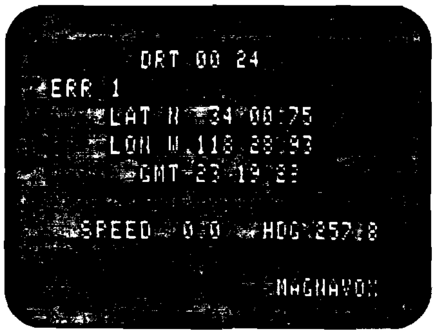
Any navigator can learn to operate the MX 1242 with an hour or two of practice. There are no complicated procedures or control panels to master. All inputs are entered through the keyboard, using simple two-digit codes listed on the front panel. All system outputs are displayed in a concise, easily understood format. The navigator need never touch the MX 1242 after initial startup when the optional automatic speed and heading interface is used. The system will go on automatically computing and displaying accurate, up-to-the-second navigation information as long as power is supplied.

All data is displayed in its most immediately usable form without hand calculations or conversions – location in latitude and longitude, direction in degrees, time in hours, minutes, and seconds, distance in nautical miles.

Once initialized, the system functions virtually without operator attention. With each valid TRANSIT satellite pass, it automatically computes the vessel's position within 0.1 nautical mile (nominal), and then dead-reckons until the next satellite update.

Since the TRANSIT satellite network blankets the earth, and is unaffected by local weather conditions, the MX 1242 functions flawlessly at any hour, anywhere, in any weather.

Automatic Self-Test



Approximately every two hours, without interrupting normal operation, the MX 1242 conducts an automatic self-test of all major functions. At such times, the notation "TEST" appears on the display indicating test in progress, and disappears at the end of the test if no error is detected. If an error is found, the notation "ERR" appears on the display, with digits or letters identifying the most probable defective part. Self-test also may be initiated manually.

Maintenance in the Field

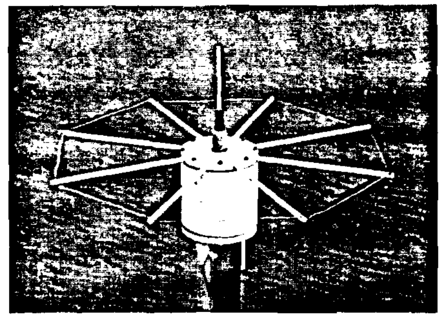
Most repairs can be made in minutes on the spot by replacing the defective plug-in module from spares.

Automatic Speed and Heading Input

The MX 1242 is available with either of two standard speed and heading interface modules which plug inside the chassis and accept signals from most standard marine gyrocompasses and speed logs. With one of these modules, the MX 1242 continuously monitors the speed and/or heading and performs fully automatic dead reckoning between satellite fix updates. The system allows manual entry of corrections for speed log scale factor error.

The gyrocompass input can be synchro, stepper or two speed synchro. Speed can be provided by contact closures, pulse train, or two speed synchro signals.

Antenna/Preamplifier Unit



Like other components of the system, the MX 1242 antenna/preamplifier is designed for the rigors of the environment in which it operates. It is ruggedly constructed to withstand vibration and temperature extremes, and is sealed against the effects of water, sun, wind and salt.

The antenna is easily mounted in any relatively unobstructed above-deck location within 200 feet (60 meters) of the MX 1242 Satellite Navigator unit. One hundred feet of cable is normally supplied with the system.

Emergency Internal Battery

An internal battery backup system is included to provide protection of memory contents and automatic restart without reinitialization for power blackouts up to two hours or more.

The battery automatically recharges upon resumption of external power.

BEST AVAILABLE COPY

Mounting

The MX 1242 is designed for easy installation. No external junction boxes or components other than the antenna/preamplifier are required. The small antenna/preamplifier unit mounts in any above-deck location affording a relatively unobstructed view of the horizon. Installation can be accomplished easily during a normal port turnaround interval within a few hours.

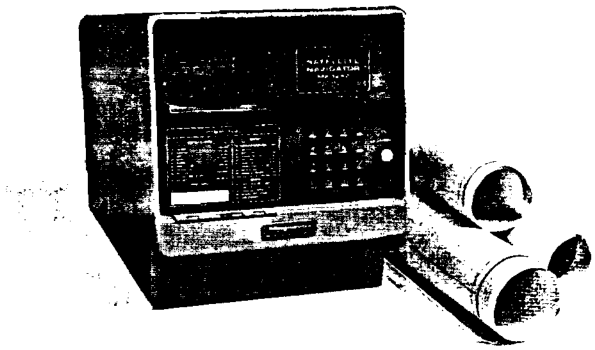
Options

Printer

An optional printer output signal can be provided permitting a printer to be connected to the system to provide a hard-copy record of the navigation information. Magnavox can also supply a variety of different optional printing devices depending on the particular needs of the customer.

Remote Display Monitor

One or more remote displays may be added to the MX 1242 system for duplication of the information on the main unit at any desired location on the ship.

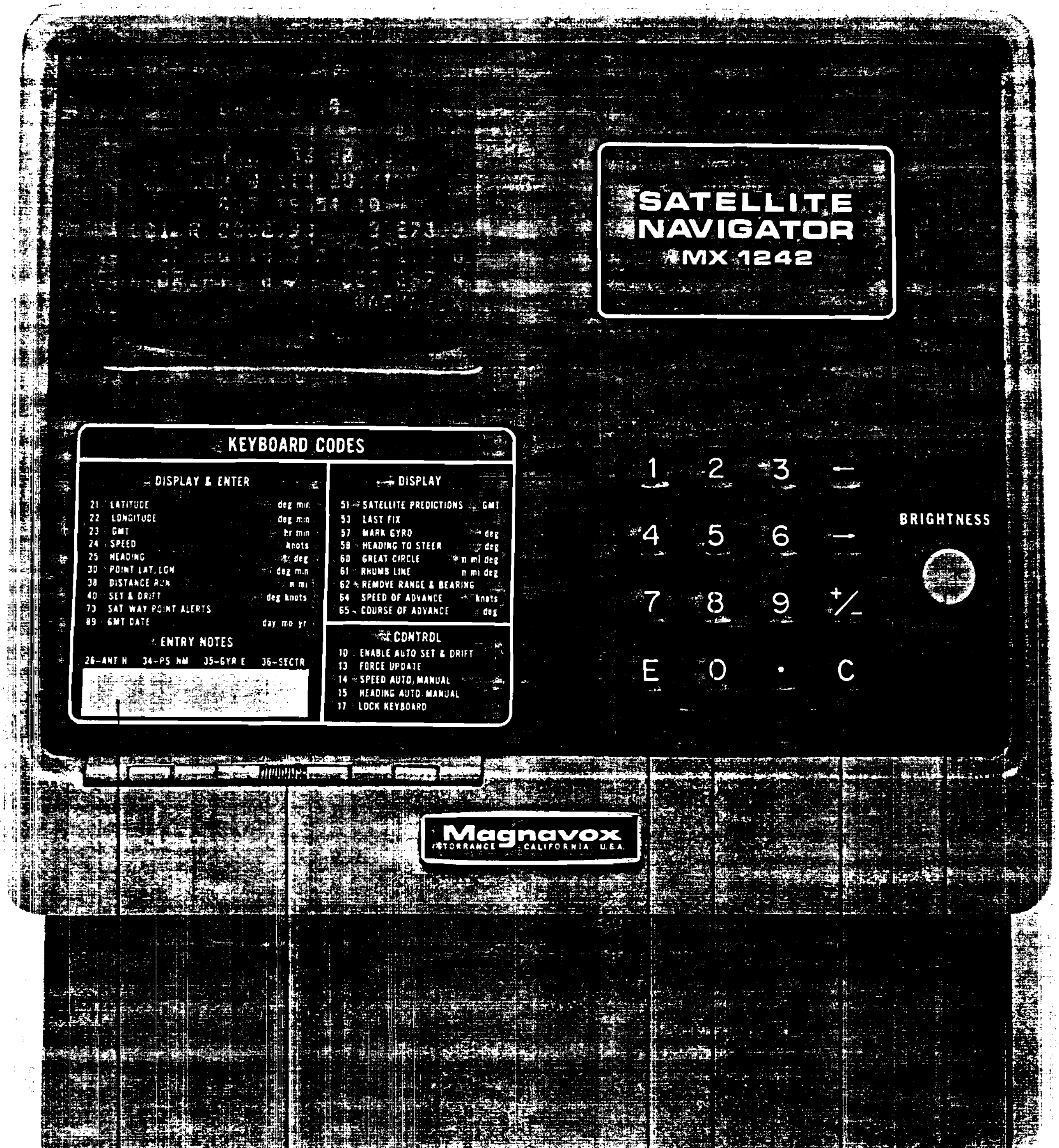


MX 1242 Specifications*

Power:	100/115/208/230 ± 15% VAC 45 to 66 Hz, single phase, 180 watts max.
Satellite Fix Accuracy:	0.05 Nautical Mile plus 0.2 Nautical Mile per knot of speed error (RMS)
Environmental:	Operating Temperature—Main equipment 0° to 50°C—Antenna/Preamplifier—25° to 70°C. Relative humidity to 95% at 40°C. Ventilation—Intake and exhaust through front panel.
Receiver Frequency:	400 MHz Transit Satellite Channel
Sensitivity:	−145 dbm
Tuning:	Automatic
Self-Test:	Automatic With Diagnostics to Module Level
Dimensions:	Overall height 26.11cm (10.28 in.) Overall depth 33.884cm (13.34 in.) Overall width 30.958cm (12.188 in.) Weight 34 Kg (75 pounds)
Antenna Group:	Diameter 625mm (24 in.) Height 445mm (17.5 in.) Weight 4.1 Kg (9 pounds) Cable 30 meters (100 ft) normally supplied, maximum length which can be used is 60 meters (200 feet).

*Magnavox reserves the right to make changes to its products and specifications without notice.

The MX 1242 Satellite Navigator



BEST AVAILABLE COPY

274

APPENDIX D

TECHNICAL DESCRIPTION
OMEGA RADIO NAVIGATION SYSTEM

System Concept

The OMEGA system was developed in 1957 by the U.S. Navy to provide a long-range electronic navigational aid with continuous worldwide coverage. It is a hyperbolic system based on measuring the phase difference between continuous-wave signals from pairs of transmitters. The phase difference between the alternating currents in the transmitting aerials of a pair of stations need not be zero but must be constant, otherwise the measurements made at the receiver will not accurately indicate the hyperbola on which the receiver is located.

Older radio position-fixing systems, such as Decca, synchronize the slave transmitter directly with the master. On receiving the signals transmitted by the master, the slave amplifies them and supplies them to its transmitting aerial; thus the frequency and phase of master and slave signals are synchronized.

For the OMEGA system, the aerial currents need not be synchronized in this way. Every station is provided with one or more cesium atomic oscillators. Such an oscillator generates oscillations whose frequency, compared with that of any other kind of oscillator, is extremely stable. The atomic-oscillator frequency is converted to 10.2 kHz and, after amplification, is supplied to the transmitting aerial.

Equipping each OMEGA transmitter with such an atomic oscillator ensures that the difference in phase between the aerial currents remains constant for a long time. The deviation of the oscillator frequency is only a few cycles in 10^{12}. Nevertheless the slightest deviation in the phase of a transmitting aerial current is corrected.

The OMEGA system consists of eight VLF transmitting stations each radiating 10 kilowatts of power, with an average separation between stations of about 5000 nautical miles. Each station transmits, in time sequence, three frequencies, approximately 10.2 kHz, 11.33 kHz, and 13.6 kHz, that are harmonically related to a precise frequency standard. The OMEGA transmission format entails a three frequency, sequential transmission from each of the eight stations, the total system period being 10 seconds. Measurement at the receiver of phase difference between transmissions from any two stations yields a hyperbolic line of position (isophase contour) focused on the positions of the two transmitting stations. Two lines of position (LOP's) (isophase contours) are generated by the phase differences between two transmitter pairs. The position of the receiver is established by the intersection of these constant phase difference contours.

System Accuracy

The waveguide (skywave) mode of propagation is employed due to the operating frequencies of the system. Since one boundary (the ionosphere) of the waveguide varies diurnally and seasonally, it is necessary to correct for the variation in propagation phase velocity caused by this shift, either manually by using tables, or with a pre-programmed computer. The diurnal effects are currently predicted and published by the Naval Oceanographic Office for the areas covered. Such predictions are based both on theoretical and monitored information and are the major source of the system's inaccuracy. In addition, there are unpredictable propagation anomalies which affect the accuracy of the measurements and for which there is no suitable warning system yet developed. System accuracy is estimated by the developer to be 1 to 2 NM 95% of the time.

There are some major ambiguities in the operation of the OMEGA system. Receiver motion causes the phase angle difference reading to change. Therefore, when the receiver moves a distance equal to one-half wavelength of an OMEGA frequency, the phase difference reading changes by one cycle (360 electrical degrees). The LOP's separated by one cycle define a lane; the difference measurements of which are repetitive from lane to lane leading to ambiguities in position determination that must be resolved. The basic navigation frequency is 10.2 kHz resulting in a cyclic ambiguity of 8 NM on the baseline between the two transmitting stations. Hence, the basic "lane" is 8 miles wide. Resolution of this ambiguity is accomplised either by continously counting the lane boundary crossings (lane integration) or by concurrent measurement of phase difference at the two "resolution" frequencies 13.6 kHz and 11.33 kHz. Differencing the "resolution" frequencies with the navigation frequency yields successive lane widths of 24 NM (3.4 kHz) and 72 NM (1.33 kHz). In the absence of an automatic lane count, a user therefore must know his position plus or minus 72 NM to resolve the remaining ambiguity.

Should the system ever go down, one must know his position relatively accurately in order to properly initiate the system. As already mentioned in Appendix C, combination systems do exist. One of the more popular combinations is OMEGA/TRANSIT. The performance of the integrated system is superior to that of either or both of its component systems operating separately. It combines the continuous-fix capability of OMEGA with the periodic-fix accuracy and all-weather dependability of the TRANSIT satellite system, and continuously maintains redundant navigation positions derived from two independent references, alerting the operator if there is a significant discrepancy between them.

The system employs the accurate satellite fix as a position reference to calibrate the calculated OMEGA skywave correction values. This procedure provides a substantial improvement in OMEGA navigation accuracy during long-term ionospheric distrubances and polar cap anomalies.

The navigator thus has the advantage of high-accuracy periodic satellite position fixes, providing corrections for the variable OMEGA system biases and checking the lane count, and also of OMEGA-improved position data during the intervals between satellite fixes.

OMEGA Charts

OMEGA charts are published by the U.S. Naval Oceanographic Office; a section of one of them covering part of the waters of Papua-New Guinea is shown in Figure D-1. The charts show only one in three of the OMEGA lines; each of those shown is marked with a lane number (the center line is always 900), and one in three of those shown is also marked with the letters of the station-pair. The lines applying to the various station-pairs are printed in different colors, and no chart shows the lines for more than four station-pairs.

Advantages and Disadvantages of OMEGA

Comparing OMEGA with other hyperbolic systems, the following points are to the advantage of OMEGA:

1. It can be used all over the world on land and sea, and below the sea, so changing during the voyage or flight from one system to another is not necessary. Of course one has to change from one pair of stations to another, but there is no break in the position fixing.
2. All the stations together make use of only three frequencies, in a frequency band that is used by only a small number of transmitting stations.
3. In the future, at every location in the world the number of receivable station-pairs will be sufficient to provide LOP's with a good intersection angle.
4. Accuracy will probably be improved in the future as a result of better predictions of skywave corrections.
5. The relative accuracy, important for some applications, is reasonably good.
6. The user does not contribute to the cost of the system.

On the other hand, there are the following disadvantages:

1. The absolute accuracy is, at present, not so good.
2. There is the possibility of lane slip.

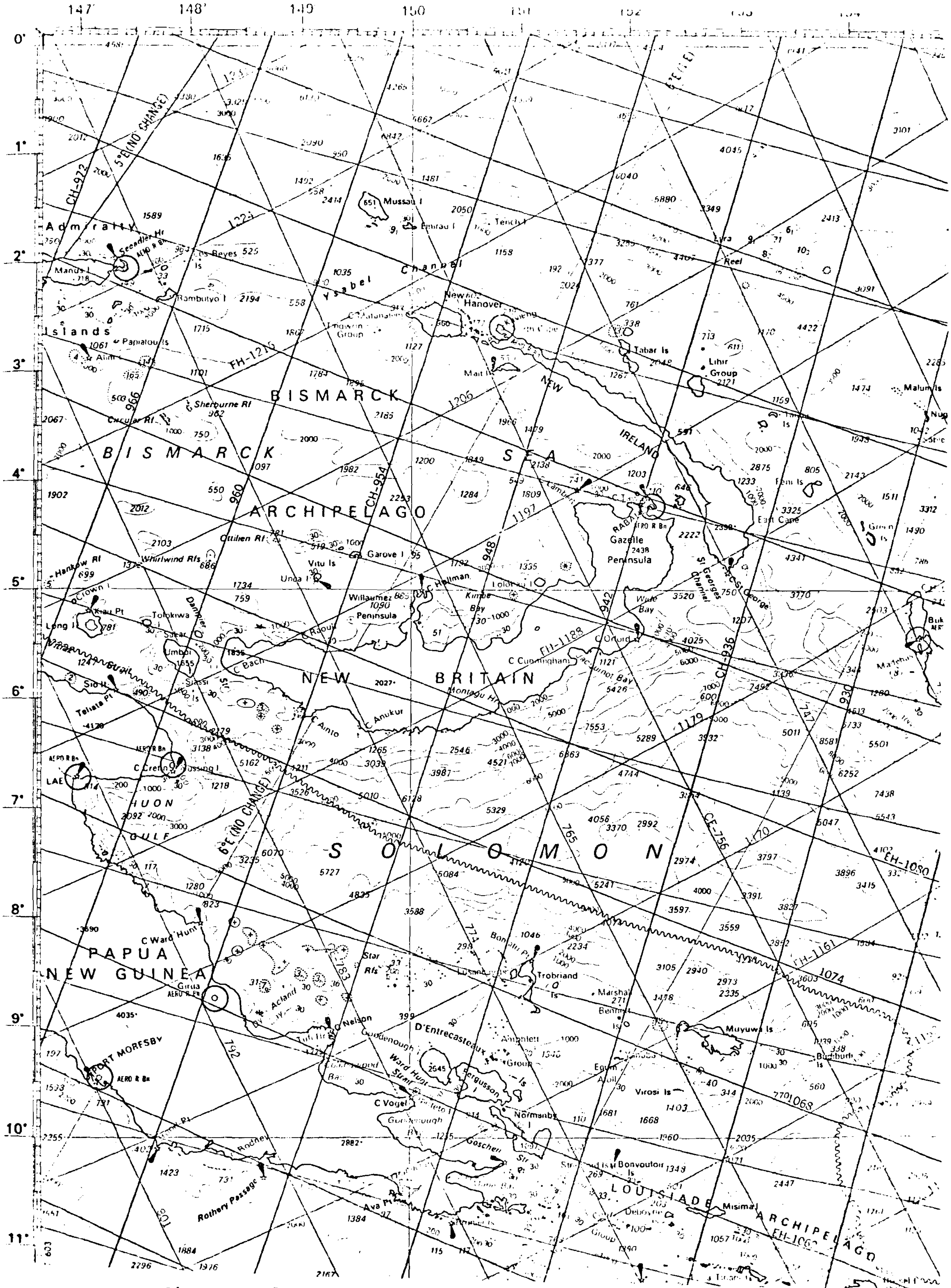


Figure D-1: OMEGA CHART OF NEW BRITAIN *BEST AVAILABLE COPY*

3. In general four stations are required for a position fix, so one has to look up four skywave corrections and apply them.

4. It is difficult to identify the stations, especially in certain areas.

5. At distances shorter than 650 miles from a transmitter the accuracy can be less than at longer distances.

OMEGA User Equipment

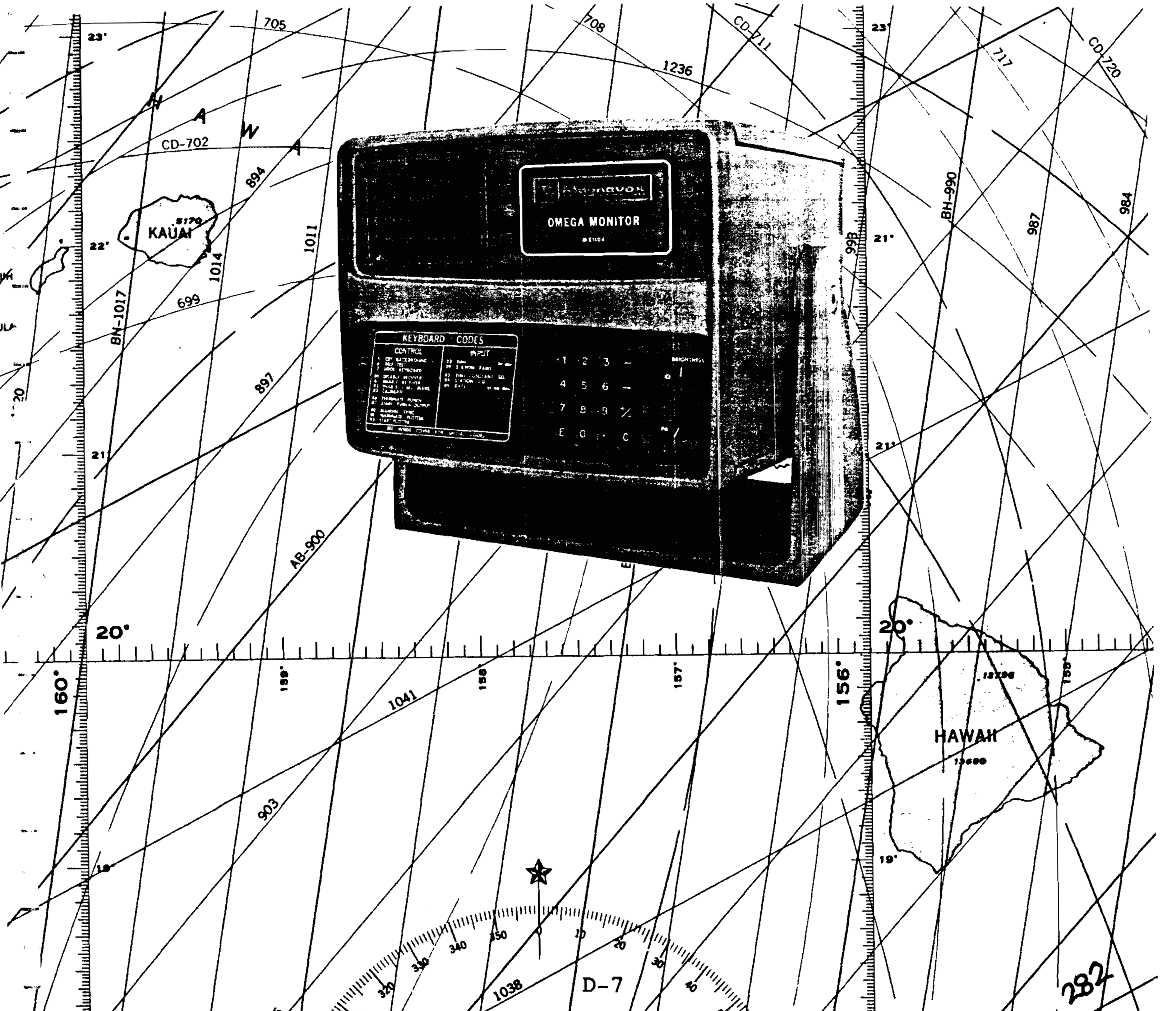
It is estimated that there are some 20 companies offering receivers for use with OMEGA. Unit prices of $4,000 - $10,000 are being asked for the shipboard receiver. Brochures for two such systems are included at the end of this Appendix. A representative combination system, the Magnavox MX1105 Satellite/OMEGA Navigator, costs approximately $20,000 - $25,000. Its brochure is also included.

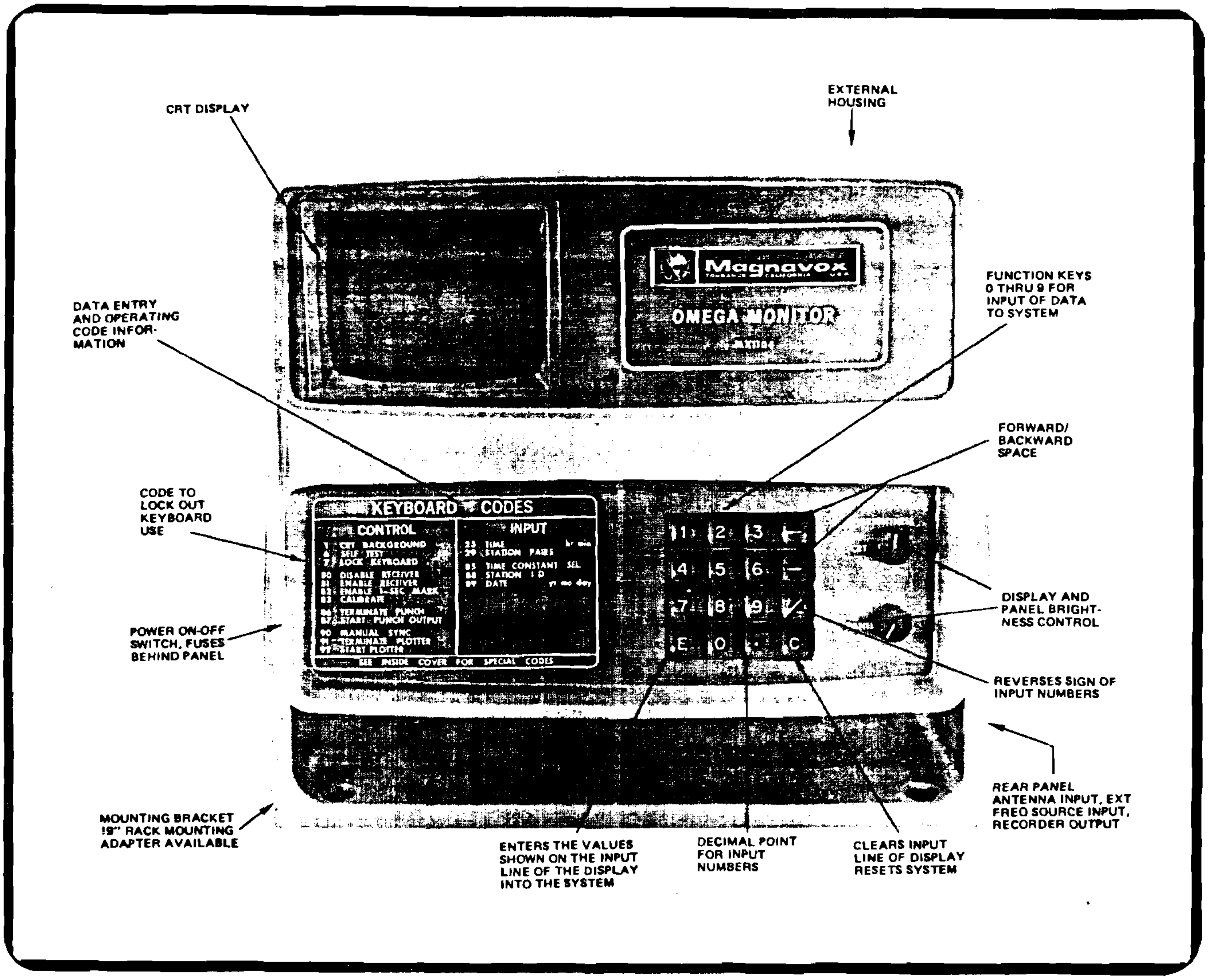
Collins Marine Corporation
PIER 32 – SAN FRANCISCO, CALIFORNIA 94105
TELEPHONE (415) 957 1300

Magnavox

MX-1104

OMEGA SIGNAL MONITOR SYSTEM





MAGNAVOX MX-1104 OMEGA MONITOR

UNIQUE FEATURES

- ALL SOLID STATE CONSTRUCTION — FEATURING MSI AND LSI.
- ALL OPERATOR CONTROLS CONTAINED ON SINGLE KEY BOARD.
- COMPREHENSIVE SELF TEST — PROVIDING CHECKS AND CALIBRATION OF VIRTUALLY ALL FUNCTIONS.
- OPERATOR SELECTABLE TIME CONSTANTS FOR INCREASED TRACKING CAPABILITY.
- RUGGED CAST CONSTRUCTION — ENSURING DEPENDABLE OPERATION IN A MARINE ENVIRONMENT.

These features combined with the convenient man/machine interface provided by the Keyboard and CRT, make the MX-1104 the most advanced, yet most reliable monitor system available.

PRINTED IN U.S.A. MAY 1976 R-5346

MX-1104

OPERATION

The MX-1104 is a microprocessor controlled, three frequency OMEGA receiver configured to provide comprehensive automatic OMEGA Signal monitoring and recording. This capability is obtained through the extensive use of LSI microprocessor techniques and Magnavox generated software. The MX-1104, receives the signals transmitted from the eight OMEGA transmitting stations at frequencies of 10.2 kHz, 11.33 kHz, and 13.6 kHz. The data obtained is then processed and the system:

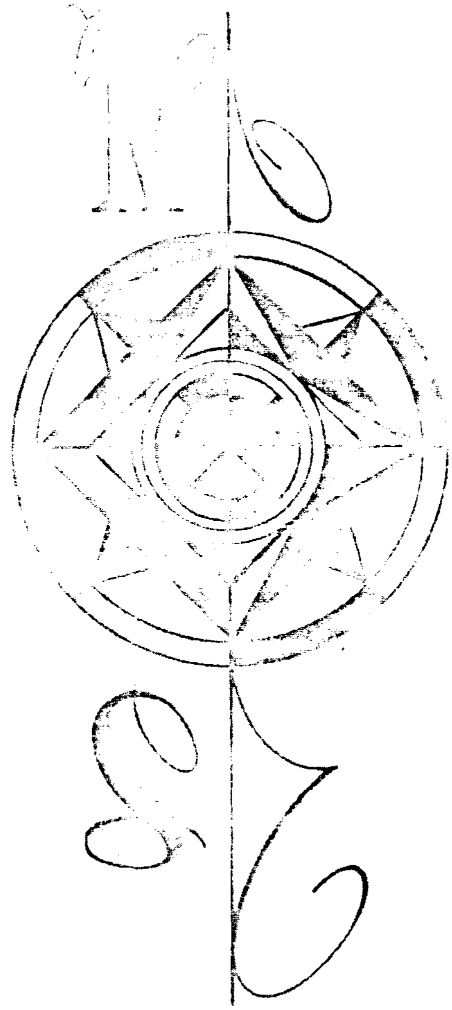
- PROVIDES AUTOMATIC PHASE SYNCHRONIZATION AND TRACKING OF ALL THREE FREQUENCIES AND ALL 8 STATIONS (A TOTAL OF 24 PHASE LOCKED LOOPS).
- MONITORS AND DISPLAYS PHASE AND SIGNAL/NOISE CHARACTERISTICS OF ALL STATIONS ON 10.2 kHz, 11.33 kHz and 13.6 kHz. COMPUTES AND DISPLAYS PHASE DEVIATION.
- MEASURES PHASE WITH RESPECT TO INTERNAL REFERENCE, EXTERNAL REFERENCE, OR ANOTHER OMEGA STATION AS SELECTED BY OPERATOR.
- PROVIDES FOR SYNCHRONIZATION TO AN HP 5061A (OR EQUIVALENT) FOR ONE WAY PHASE MONITORING WITH AN INSTRUMENTATION PRECISION OF 100 NANOSEC.
- PROVIDES DIGITAL OUTPUTS OF PHASE AND SIGNAL NOISE CHARACTERISTICS FOR RECORDING ON PAPER TAPE.
- INTERFACES WITH UP TO 8 ANALOG RECORDERS TO PROVIDE ACCURATE ANALOG PLOTTING OF PHASE AND SIGNAL/NOISE.
- PROVIDES AUTOMATIC SELF-TEST AND CALIBRATION INCLUDING CONTINUOUS MEASUREMENT OF RECEIVER PHASE DELAY TO ALLOW ACCURATE ONE WAY PHASE MONITORING.
- OPERATES FROM A VARIETY OF POWER SOURCES:

  AC — 105/115/125/210/230V ± 15% 47 — 420 HZ,
  DC — INTERNAL OR EXTERNAL BATTERY (12/24 VDC) WITH AUTOMATIC POWER TRANSFER.

THE SYSTEM IS ALSO CONFIGURED TO PROVIDE THE FOLLOWING OPTIONAL CAPABILITIES WITH "PLUG IN" ASSEMBLIES.

- ACCURATE POSITION FIXING AND RECORDING USING THE NAVY NAVIGATION STATELLITES. (ACCURACIES OF BETTER THAN 30 METERS OBTAINABLE.) [2 CARDS PLUS MEMORY CHANGE.]
- REMOTE CONTROL (BOTH INTERROGATION AND COMMAND). [1 CARD PLUS MEMORY CHANGE.]

MX-1104 SPECIFICATIONS



OPERATIONAL

Frequency:	Receives 10.2 kHz, 11.33 kHz and 13.6 kHz
Sensitivity:	Limited only by atmospheric noise
Receiver Noise:	Less than 0.1 uv/m/$\sqrt{\text{Hz}}$
Dynamic Range:	120 dB
Phase Resolution:	Better than 100 nanoseconds
Phase Measurement Time Constant:	Operator selectable, 1.0 min to 5.0 min ± 10%
Synchronization:	Automatic
Tracking:	Automatic for all OMEGA stations; frequencies of 10.2, 11.33, 13.6 kHz (24-phase locked tracking loops)
One Way Phase Measurement:	Instrumentation precision of 100 nanoseconds
Frequency Reference:	5 MHz internal reference with aging rate of less than 2 parts in 10^9 per day, provision for external 5 MHz standard.
Data Display:	CRT with monitor data displayed as requested by operator through keyboard.
Data Output Available:	GMT, date, station phase with respect to reference, station phase with respect to selected stations, signal/noise indication, phase deviation, system status (self-test). Selected time constant, selected recording interval.
Data Recording:	All output data is available in a digital format for recording on an external paper tape recorder. Signal phase and signal/noise parameters are also available for recording on up to eight analog recorders.
Power Requirements:	AC 105/115/125/210/230v ± 10% — selectable, 47—420 Hz DC internal or external battery (+12 vdc) with automatic power transfer.

PHYSICAL

Antenna:	Single section 8 foot whip with active coupler
Receiver:	Height 11.2" (28.4 cm), width 14.5" (36.8 cm), depth 12.7" (32.3 cm), weight 58 lbs (26 kg).

ENVIRONMENTAL

Operating Temperature:	Receiver 0—50°C, antenna/coupler −54 to +65°C.
Humidity:	95%.
Vibration:	Meets or exceeds requirements of MIL-STD-167 Type 1.

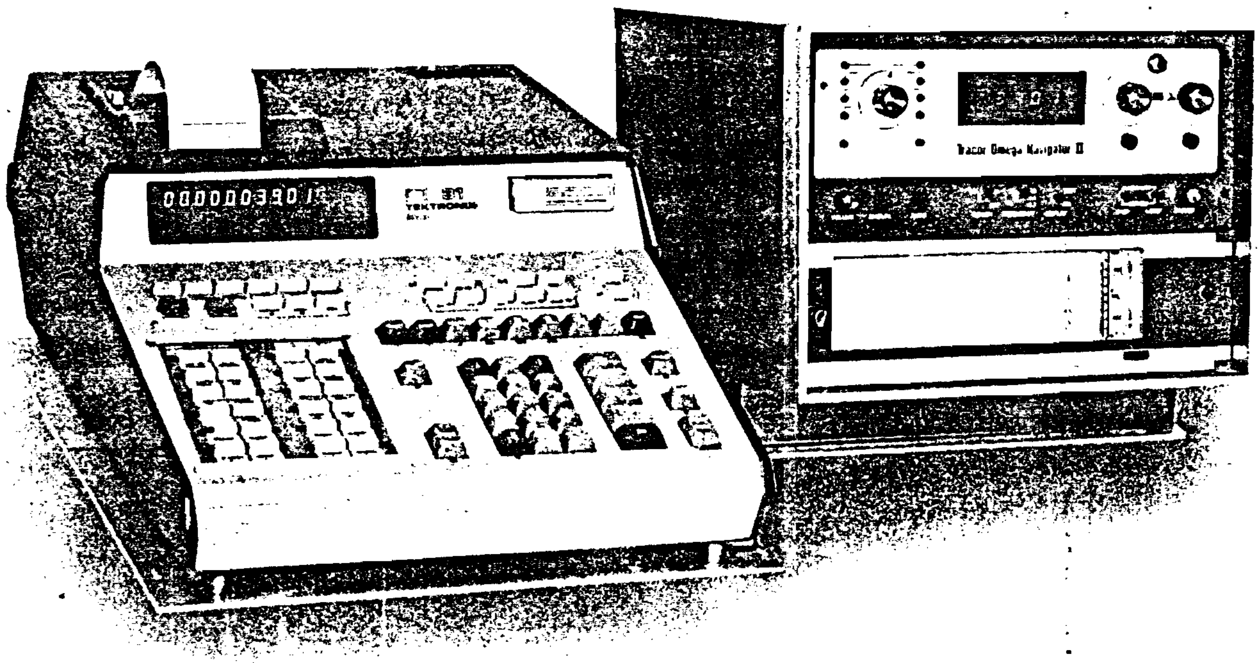
PLUG-IN OPTIONS

Position Fixing:	Accuracies of 30 meters, using Navy Navigation Satellites — 3 plug-in assemblies.
Remote Operation:	Interrogation and command remote control 2 plug-in assemblies.

Magnavox reserves the right to make changes in product specifications without notice.

Magnavox / advanced products division
MARINE SYSTEMS OPERATIONS
2829 MARICOPA STREET • TORRANCE, CALIFORNIA • U.S.A.

Model 231
Computerized Omega System



The Tracor Model 231 Computerized Omega System is a stand-alone, fully automatic system which provides complete latitude and longitude information without requiring operator intervention. The Model 231 consists of the Tracor Omega Navigator II and a Programmable Calculator.

Following a brief initialization procedure in port, or at another known location, the system continues to keep track of latitude and longitude, so long as signals are received. If an Omega transmitter should go down for a period of time, the Model 231 automatically reverts to dead reckoning. This can be based on recently calculated rates derived from Omega reception, operator keyboard input, or a digital course and speed interface which can be specially ordered as an additional option.

The Model 231 performs the propagation correction calculation which relieves the navigator of the tedious task of looking up and applying these skywave corrections. The latitude and longitude calculation gives a more accurate result than can be achieved by plotting on a standard Omega chart.

The system also operates using the 13.6 kHz Omega transmissions as well as those at 10.2 kHz. This can be important in areas of weak reception where the 13.6 kHz signal-to-noise ratio is often 6-10 dB better than the 10.2 kHz ratio. When the Omega Navigator II is switched for 3.4 kHz operation, the calculator automatically prints out lane verification numbers. Daily use of this procedure virtually insures against a lane skippage, even if a transmitter is down for several hours.

All information is provided on a hard copy printout, giving a permanent record for history purposes.

Tracor, Inc.

BEST AVAILABLE COPY

Features

Latitude-longitude readout is computed automatically. . .more accurate than that achieved by manual plotting on a standard Omega chart.

The Model 231 performs the propagation correction calculation. . .relieving the navigator from having to work with three or more skywave correction tables and applying the corrections found in each.

The system automatically reverts to dead reckoning if an Omega transmitter is down. . .thus continuing accurate navigation until the Omega system is again intact.

Unattended operation is standard with navigation data presented at whatever time interval is desired. . .freeing personnel for other bridge or shipboard duties.

The calculator is available for other shipboard computations. . .providing a powerful, useful capability for any desired calculations.

A printout of distance and bearing to any one of several way points is available on operator command. . .again, the kind of valuable information which can help optimize any voyage.

13.6 kHz and 3.4 kHz operation is optionally available. . .giving more reliable tracking in areas of weak reception.

New lines of position (LOP's) are easily substituted. . .making area and chart transitions trouble-free.

The following information is available from the Model 231 on command:

- Present time and position.
- The expected receiver reading for a third Omega line of position.
- Distance and bearing to selected way points.

Standby power supply for calculator is available as an option.

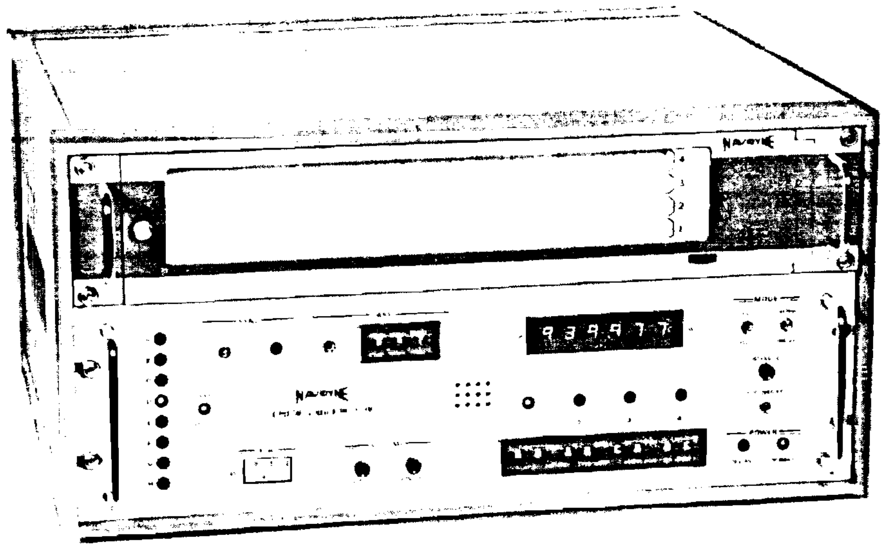
Technical data
Tektronix Model 31 Calculator

Physical
Weight: 32 lbs; 14.5 kg
Height: 7.9 ins; 20 cm
Width: 14.3 ins; 36 cm
Length: 20.5 ins; 52 cm

Power
110/220 VAC ±10%
48 to 66 Hz

Environmental
Operating Temperature: 0°C to 50°C
Non-Operating Temperature: -55°C to 75°C

Your authorized Tracor representative:



ESZ-1001/S

NAVIDYNE CORPORATION

ALPHA-OMEGA NAVIGATION [illegible]

MODEL ESZ-1001

The ESZ-1001 meets the highest standards for precision and ruggedness in marine electronic equipment. The system is intended for use as an all-weather global navigation aid, using signals from the international Omega network.

The system's 0.1 CEC resolution (about 15 meters) and exceptional tracking stability permit its effective use for other navigation functions such as: (a) accurate calculation of true ship's speed, (b) high-accuracy coastal navigation in areas where Alpha-Omega or automatic differential Omega coverage is available, and (c) optimum integration with other navigation sensors such as Nav-Sat or inertial. Operational simplicity and ease of maintenance are other key features of the system.

FEATURES

- **0.1 CEC Resolution** — Permits accurate measurement of true ship's speed and provides 50 foot position sensitivity for high-accuracy Alpha-Omega or automatic differential Omega operation, ten times more resolution than any other Omega receiver available.
- **4 LOPs/Parallel Processing** — 8 separate tracking loops provide 4 independent lines-of-position. With parallel processing, an electronic failure will almost always affect only one LOP.
- **Tracking Capability** — Proprietary tracking techniques are used to achieve stable tracking of extremely weak signals.
- **Automatic Synchronization** — With manual back-up mode.
- **Modularity** — Almost all repairs can be made by replacing a functional plug-in module. In most cases fault isolation to the module level can be done without external test equipment.
- **Signal-to-Noise Monitor** — Provides audible and visible warnings if a station goes off the air or becomes too weak for optimum tracking. Front panel speaker and phone jack are provided for direct assessment of Omega signal quality.
- **Reserve Power Supply** — Internal battery provides uninterrupted operation during external power outages. An alarm alerts the operator when reserve power is in use.
- **BCD and Incremental Outputs** — Available as options.
- **Warranty** — 3 years (For details, see Warranty Statement.)

SPECIFICATIONS

System Performance

Readout Resolution	0.001 lane (0.1 CEC) (approximately 15 meters)
Operating Frequency	10.2 kHz
Synchronization	Fully automatic with manual backup mode.
Warm-up Time	Zero
Number of Tracking Channels	8 (4 independent lines of position)

Receiver Characteristics

Sensitivity	0.03 microvolt
Input Signal Dynamic Range	
(A) Total	90 db
(B) Relative	60 db
Adjacent Channel Rejection	80 db

Size

ESZ-1001/S	19.75 x 9.75 x 18 inches - (502 x 248 x 457 mm)
ESZ-1001	19.75 x 6.25 x 18 inches - (502 x 159 x 457 mm)
Either unit can be removed from case for mounting in a standard 19-inch rack.	

Weight

30 lb (13.6 kg)

Power

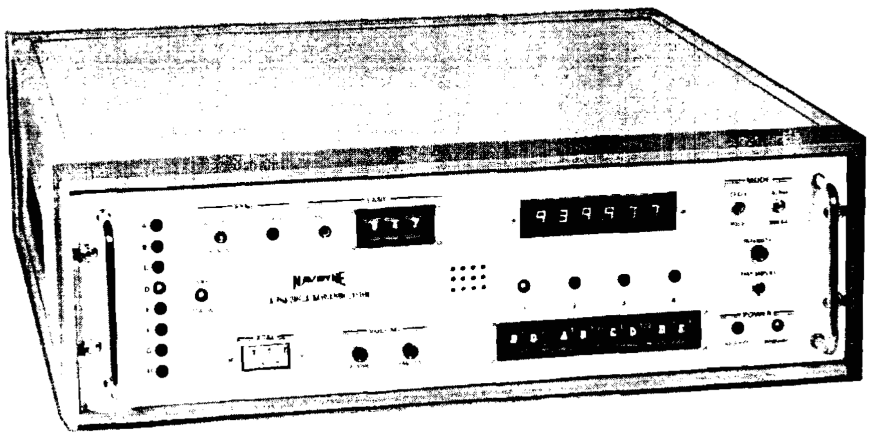
Primary	105-125 volts AC/47-440 Hz or 210-240 volts AC/47-440 Hz, 60 watts
Reserve	Battery pack, with automatic power transfer

Ambient Temperature Range

0°C to + 50°C
(Antenna Coupler: -30°C to 70°C)

Antenna and Coupler

Whip antenna, environmentally sealed coupler, cable, connectors and mounting hardware are provided with each system.



ESZ-1001

OPTIONS

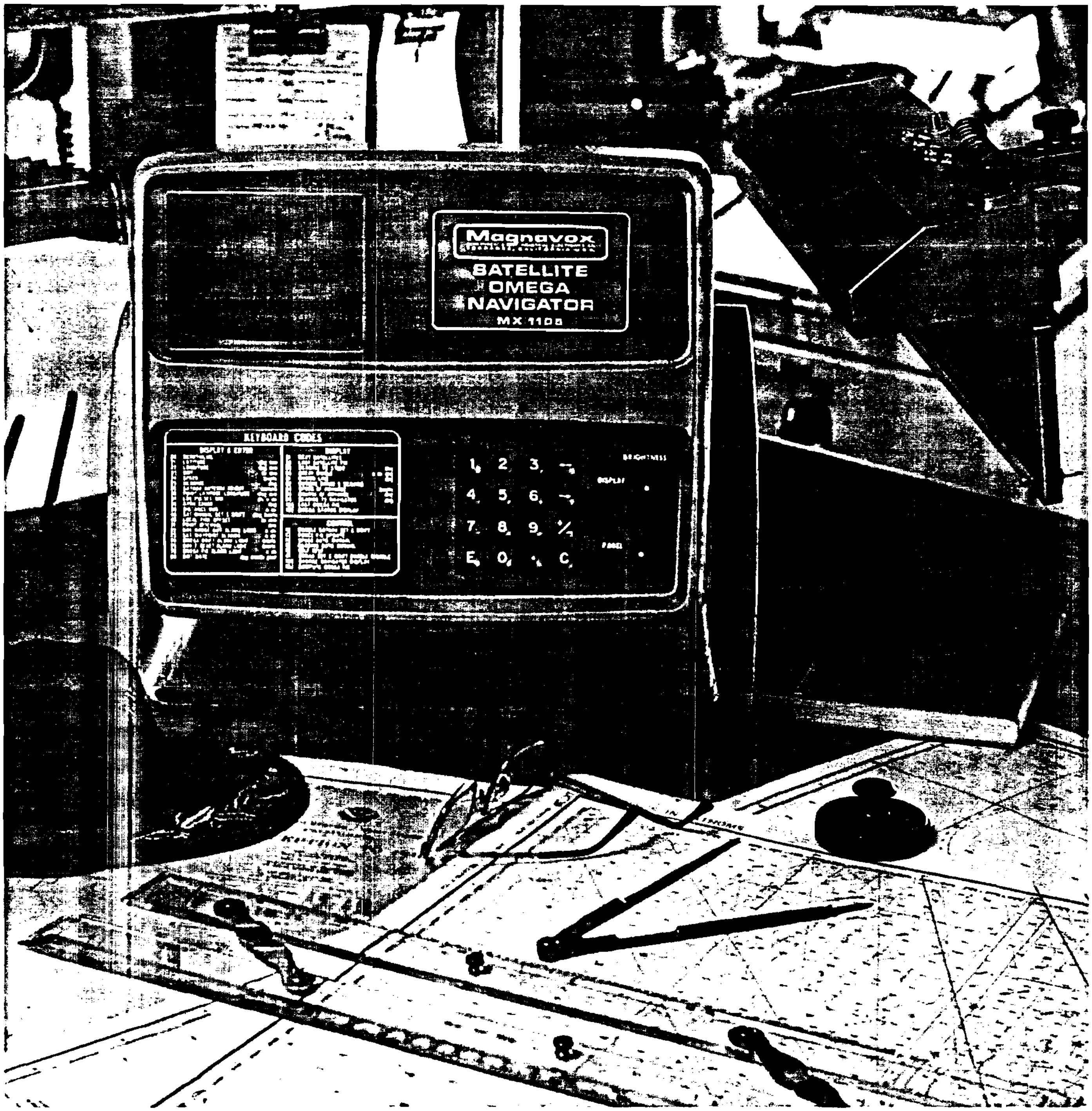
Omnitrack Display
Time Standard for Circular (Rho-Rho) Operation
Data Printer
Magnetic Tape or Paper-Punch Recorder
4-Channel Strip Chart Recorder (Included with ESZ-1001/S)

Further information on the ESZ-1001 is contained in the paper, "Automated Navigation for the Coastal and Harbor Entrance Zones — An Omega-Compatible Approach", presented at the 1974 RTCM Assembly Meeting. A copy will be sent on your request.

NAVIDYNE CORPORATION
408 Industry Drive Hampton, VA, 23661, U.S.A.
Phone: (804) 838-4115 Telex: 82-3653 (NAVIDYNE HAMP)

Magnavox MX 1105 Satellite/Omega Navigator

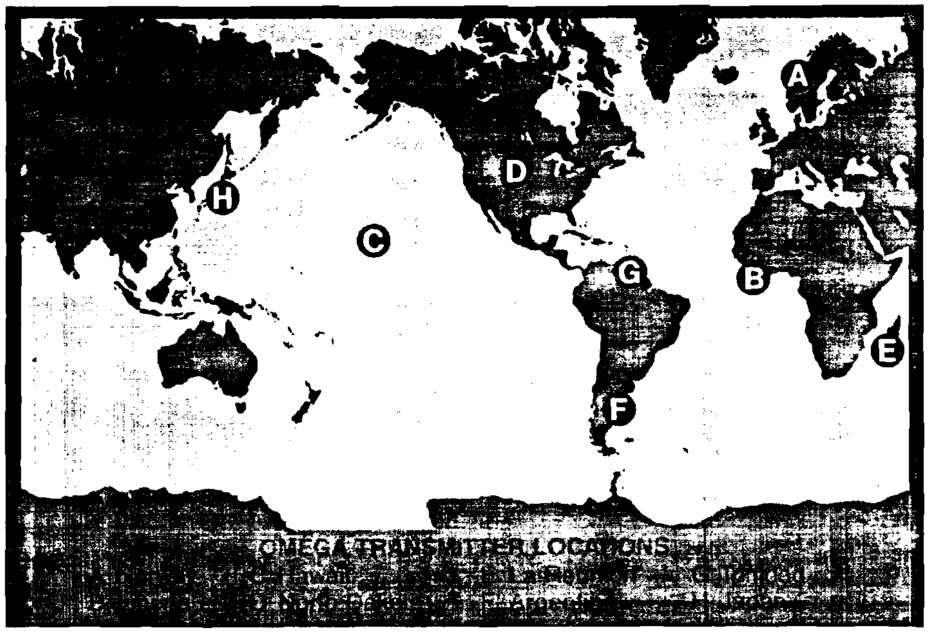
Complete, Accurate, Integrated Navigation Information Anywhere, In Any Weather, At Any Hour



BEST AVAILABLE COPY

Satellite-Omega Integration Gives You The Best of Two Navigation Worlds

The Magnavox MX 1105 Satellite/Omega Navigator integrates the complementary capabilities of the worldwide Transit and Omega positioning systems in one compact, easily-operated instrument.



The performance of the integrated system is superior to that of either or both of its component systems operating separately, because the MX 1105:

- ☐ combines the continuous-fix capability of Omega with the periodic-fix accuracy and all weather dependability of the Transit satellite system, and
- ☐ continuously maintains redundant navigation positions derived from two independent references, alerting the operator if there is a significant discrepancy between them.

The navigator thus has the advantage of high-accuracy periodic satellite position fixes, providing corrections for the variable Omega system biases and checking the lane count, and also of Omega-improved position data during the intervals between satellite fixes.

Two Superior Systems In One Compact Unit

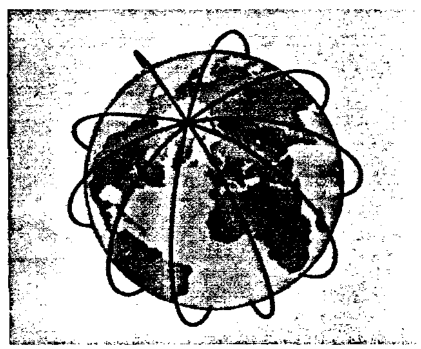
The MX 1105 combines the technologies of the instrument that has become the world's standard satellite navigator — the MX 1102 — and the official U.S. Coast Guard Omega Monitor — the MX 1104. Large numbers of both of these Magnavox systems have been in the field since 1976, with performance and reliability exceeding the most optimistic predictions.

In one of its two operating modes, the MX 1105 functions as a satellite navigation instrument, utilizing capabilities inherited directly from the MX 1102 Satellite Navigator. Simultaneously, its second mode of operation is as an integrated satellite/Omega system, capable of deriving both Transit and Omega position fixes, and navigating with speed, heading and Omega inputs between satellite updates.

The MX 1105 can also be operated as a stand-alone Omega navigator.

The Satellite Navigator

The MX 1105 automatically receives and processes precise time and position data transmitted on the Transit satellite 400 MHz channel. This information is integrated with speed and heading inputs from shipboard sensors to determine the vessel's position within 0.1 nmi (nominal). The system employs speed and heading inputs for dead reckoning between satellite passes, which occur every 30 to 110 minutes, on the average, depending on latitude.



Improved Automatic Omega

MX 1105 Omega operation is also entirely automatic, eliminating the need for special charts, plotting or correction tables.

The system's powerful microcomputer provides for automatic synchronization and tracking of all available Omega stations on the 10.2 kHz, 11.33 kHz, and 13.6 kHz frequencies. It converts phase data from the three frequencies — received from all available Omega stations — to compute set, drift and position.

© Copyright 1978 Magnavox Government & Industrial Electronics Co.

BEST AVAILABLE COPY
R5890 9/78 Printed in U.S.A.

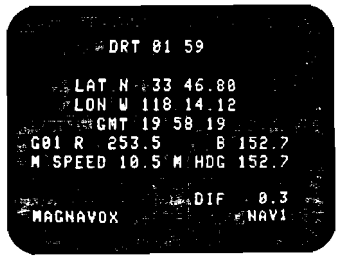
Integrated Operation

The integration of Satnav and Omega makes possible the unique "pseudo-differential Omega" technique, in which the microprocessor employs the accurate satellite fix as a position reference to calibrate the calculated Omega skywave correction values. This procedure provides a substantial improvement in Omega navigation accuracy during long-term ionospheric disturbances and polar cap anomalies.

Both satellite and Omega navigation positions are continuously maintained in the MX 1105, and either may be called up for display at any time. In addition, the range difference between the two positions is displayed constantly, and the operator is alerted by both audio and visual signals if the discrepancy between the two positions exceeds an operator-selectable limit. Since the factors that can produce a significant error in the Omega position do not normally affect the accuracy of the satellite position, and vice versa, possession of the two independent solutions provides the navigator with valuable data redundancy.

Position Fixes

After each usable satellite pass, the MX 1105 automatically updates the position to within 0.10 nmi (nominal) of the true position. The navigator may also command an automatic three-frequency Omega position fix.



SATNAV DISPLAY

Operating Simplicity

Navigators can learn to use the MX 1105 with an hour or so of practice. There are no complicated procedures or control panels to master. All inputs are entered through the keyboard, using simple codes listed on the front panel. All system outputs are displayed in a concise, easily-understood format.

There is no need to load a program with the MX 1105. The program is permanently built into the system hardware.

The navigator need never touch the MX 1105 after initial startup so long as normal operation continues.

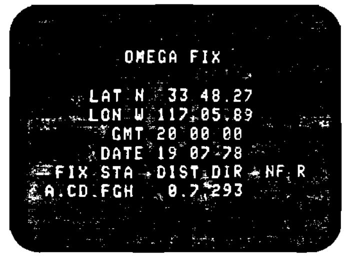
Navigation data is continuously displayed, ready for instant plotting on any standard marine chart with no manual correction. Even geoidal height and Omega skywave corrections are automatically calculated and applied.

The keyboard enables the navigator to select and change the mode of operation at will, to enter manual inputs, and to call up desired data for display.

If operation in only one of the two navigation modes is desired, the other mode may be ignored.

Information Display

The MX 1105 does its work automatically, unattended. Once initialized, it goes on automatically acquiring data, updating, and displaying all the information you need in its most immediately usable form.



OMEGA FIX DISPLAY

The two available navigation displays provide:

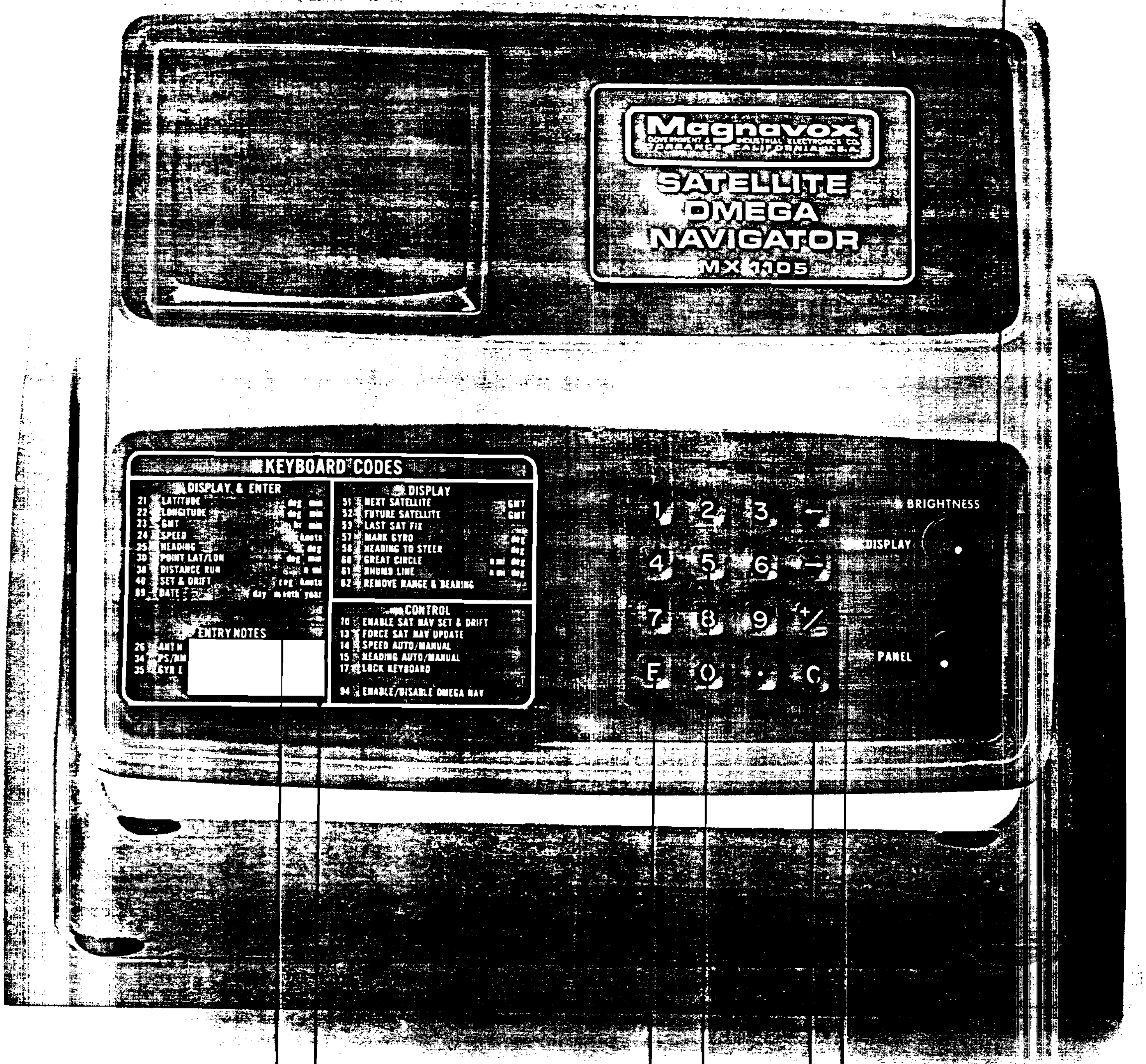
- ☐ Current latitude and longitude updated with every usable satellite pass.
- ☐ Greenwich Mean Time — accurate to within 1 second.
- ☐ Input speed — manual or automatic.
- ☐ Input heading — manual or automatic.
- ☐ Elapsed time since last satellite position update.
- ☐ Course and distance to or between present location and/or multiple waypoints — Great Circle or Rhumb Line.
- ☐ Range difference between Satnav and Omega navigation positions.

In addition, the MX 1105 can display a wide range of navigation and operational information, including:

- ☐ Set and Drift (Satellite, manual, or Omega).
- ☐ Heading to steer.
- ☐ Total distance run.
- ☐ Course made good.
- ☐ Speed made good.
- ☐ GMT, satellite I.D., and satisfactory fix indication of next eight satellite passes.
- ☐ Omega Status display.
- ☐ Maintenance displays.

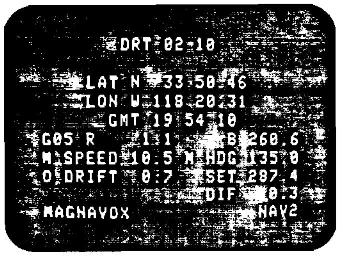
BEST AVAILABLE COPY

Magnavox MX 1105 Satellite/Omega Navigator



BEST AVAILABLE COPY

Set and Drift Compensation



To improve dead-reckoning accuracy between satellite fixes, two separate set and drift values are continuously calculated by the system. In the satellite operating mode, set and drift is automatically calculated at each satellite update. Simultaneously, in the satellite/Omega mode, set and drift is automatically and continuously calculated, using Omega signals.

Set and drift can also be entered manually.

Great Circle or Rhumb Line Course

Upon command, the MX 1105 continuously calculates and displays the course and distance from the ship to any one of nine selectable destinations, turn points, way stations or obstacle locations — anywhere on the earth's surface — via either Great Circle or Rhumb Line. It also displays the gyrocompass heading (corrected for gyro error, and set and drift) required to maintain the desired course.

In addition, the system can display the course and distance between any two of the nine waypoint positions, permitting the navigator to plan future course changes.

Programmed Tracking

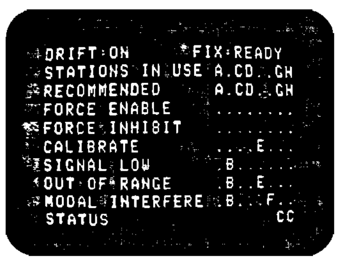
The MX 1105 sets a new standard for fully automatic satellite navigation signal processing. As the system tracks each satellite for the first time after an initialization, it stores the orbit data and predicts the time of the next usable pass. Having acquired data from all the satellites, it preferentially tunes to the passes presenting acceptable elevation angles, eliminating satellite blocking.

The result is that the MX 1105 produces about 10% more usable position fixes than other satellite navigation systems. This feature can reduce the maximum time between fixes substantially.

Multiple Satellite Prediction

If desired, the MX 1105 can provide a display showing the rise time, maximum elevation angle, satellite number, and predicted usability of each of the next eight satellite passes.

Omega Status Display



At the navigator's option, an Omega status display can be selected that provides such information as which stations are being used for navigation and which are not, as well as the reason for deselection of those not used.

This is important to keep the navigator advised of the overall Omega system status at a particular location. Reasons for station deselection can include:

- ☐ station off the air
- ☐ model interference
- ☐ low signal-to-noise ratio.

Automatic Speed and Heading Input

Either of two standard speed and heading interface modules which plug inside the chassis and accept signals from most standard marine gyrocompasses and speed logs may be used with the MX 1105. The appropriate module enables the system to monitor the speed and/or heading continuously and to perform fully automatic dead reckoning between satellite fix updates, or to integrate speed and heading data with Omega inputs for continuous navigation information.

Corrections for speed log scale factor and gyrocompass error may be entered manually. The gyrocompass input can be synchro, stepper or two-speed synchro. Speed can be provided by contact closure, pulse train, or two-speed synchro signals.

Automatic Self-Test

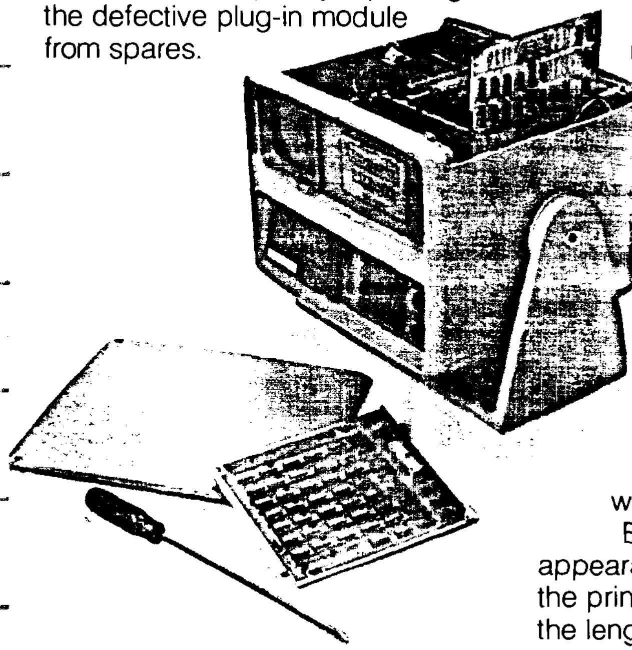
Approximately every two hours, without interrupting normal operations, the MX 1105 conducts an automatic self-test of all major functions. At such times, the notation "TEST" appears on the display, indicating test in progress, and disappears at the end of the test.

If an error is detected, the notation "ERR" appears on the display, with digits or letters identifying the most probable defective part. In addition, a continuous check is made of the gyrocompass and speed log input.

Self-test also may be initiated manually.

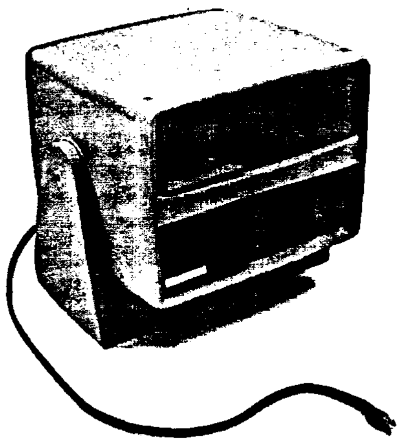
Most repairs can be made in

minutes on the spot by replacing the defective plug-in module from spares.



Emergency Internal Power

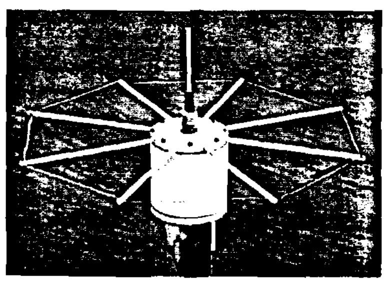
In case of temporary loss of external power, the MX 1105 automatically switches to internal batteries, indicates main power failure on the display, and continues to operate without interruption. The batteries automatically recharge upon resumption of external power.



Antenna/Preamplifier Units

Like other components of the system, the MX 1105 antenna/preamplifier units are designed for the rigors of the environment in which they operate. The Transit and Omega antenna units are ruggedly constructed to withstand vibration and temperature extremes, and are sealed against the effects of water, sun, wind, and salt.

Both units are of similar appearance and construction, the principal difference being the length of the vertical rod. Both mount easily to any above-deck location affording a relatively unobstructed view of the horizon.



Options

Remote Display Monitor

One or more remote displays may be added to the MX 1105 system for duplication of the main unit display at any desired location on the ship.

Printer

An optional printer output signal can be provided, permitting a printer to be connected to the system in order to provide a hard-copy record of the navigation information. Magnavox can also supply a variety of different optional printing devices depending on the particular needs of the customer.

Alarm Signal

For vessels with a centralized alarm system, an optional alarm relay contact output can be provided to activate the alarm in case the MX 1105 fails a self-test, overheats, or loses power.

Alerts

The system also provides alert signals to call the operator's attention to anomalous navigation information, deviation from selected heading to steer, near approach to designated waypoints, etc.

Mounting

The MX 1105 is designed for easy installation near the navigator's chart table. The mounting yoke can be rotated to provide tabletop, bulkhead, or overhead mounting. No junction boxes or additional components other than the antenna/preamp units are required. Installation can be accomplished easily during a normal port turnaround interval.

Retrofit Capability

The MX 1102 and MX 1112 Satellite Navigators can be upgraded into an MX 1105 Satellite/Omega Navigator. The upgrade requires the installation of an Omega Antenna/Preamplifier, Omega receiver and interface printed circuit boards, and an exchange of the central processor and memory boards. This retrofit can be accomplished in less than one day at any location in the world.

MX 1105 Specifications

OPERATIONAL — SATNAV	
FREQUENCY	400 MHz Transit satellite channel
SENSITIVITY	−145 dBm
TUNING	Automatic and programmed
SATELLITE FIX ACCURACY	0.05 nmi, +0.2 nmi per knot of speed error (RMS)
OPERATIONAL — OMEGA*	
FREQUENCY	10.2 kHz, 11.33 kHz, 13.6 kHz Omega frequencies
SENSITIVITY	Limited only by atmospheric noise
RECEIVER NOISE	Less than $0.1\mu v/m\sqrt{Hz}$
DYNAMIC RANGE	120 dB
SYNCHRONIZATION	Automatic
TRACKING	Automatic for all stations, frequencies of 10.2, 11.33, 13.6 kHz (24 phase locked loops)
DATA DISPLAY	CRT with 10 lines of up to 24 alphanumeric characters (red color for night visibility)
POWER	100/115/230 VAC ±15%, 45 to 440 Hz, single phase, 24 VDC ±15%, less than 100 watts, internal battery with automatic power transfer and re-charge.
ENVIRONMENTAL	
OPERATING TEMPERATURE	0° to 55°C (Main equipment) −25° to 70°C (Antenna/preamplifiers)
RELATIVE HUMIDITY	to 95% at 40°C (Main equipment)
VENTILATION	Intake and exhaust through front panel
PHYSICAL	
ANTENNA	Satellite: 178mm (7 in.) whip with ground plane and preamplifier Omega: 2.44m (8 ft.) whip with active coupler
RECEIVER (with mounting yoke)	Height: 432mm (17 in.) Width: 419mm (16.5 in.) Depth: 356mm (14 in.) Weight: 34 kg (75 lbs.)
CABLES	Two required (SatNav and Omega) 30 meters supplied (Maximum length—60 meters)

*The U.S. Coast Guard has issued the following caution regarding the Omega System:

Mariners are warned that the OMEGA Navigation System is considered to be in the experimental stage. Changes in station "off air" periods and in station locations will continue to occur. Such occurrences will be promulgated by Notice to Mariners and radio navigational warning messages. As the Omega transmitter stations are upgraded and monitoring of Omega signals accomplished, the navigational accuracy of this system will be better established. While accurate position fixes may be obtainable in some areas, prudent navigation dictates that positioning information derived at present from the Omega system should not be relied upon without reference to other navigational positioning methods.

The integration of Omega with satellite navigation satisfies proposed U.S. Coast Guard regulations for coastal confluence navigation.

Magnavox reserves the right to make changes to its products and specifications without notice

BEST AVAILABLE COPY

APPENDIX E

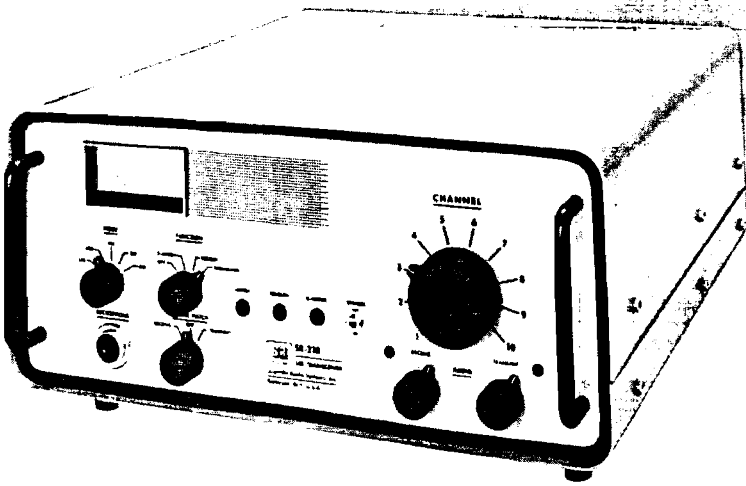
HIGH FREQUENCY SINGLE SIDE BAND RADIO DATA LINK
(REPRESENTATIVE MANUFACTURER'S INFORMATION)

SYSTEMS

Scientific Radio Systems, Inc.

Collins Marine Corporation
PIER 32 – SAN FRANCISCO, CALIFORNIA 94105
TELEPHONE (415) 957-1300

SR-210
SSB TRANSCEIVER



SR-206 and SR-210

HF SSB TRANSCEIVER

for Base Station, Mobile or Marine Use

The SR-200 Series of Transceivers represent the ultimate in commercial radio communication equipment. Solid state devices including integrated circuits are used in all low level stages and throughout except for the power amplifier and the receiver front end. For a completely solid state receiver section, a modular FET amplifier directly replaces the tube as an option.

Modular plug-in printed wiring board construction is used throughout to permit easy service or change of channel frequency in the field.

Circuit design of the SR-200 Series Transceivers is such that burn-out due to high receiver input voltages or short or open circuits at the transmitter output is virtually impossible.

Modes of operation are A3H, A3J, A3A, CW and FSK. In addition A1 and A2 Modes of operation are possible as well as F1 and F2. Models are available as either simplex or two-frequency simplex (half duplex). Basically the half duplex equipment is identical to the simplex except that a receive frequency generator module and switching module is included and duplex types of channel cards are used. Note the designation MS and MD are for Type Accepted models for simplex and two-frequency simplex.

FEATURES

- Frequency Range 1.6 to 30 MHz
- Up to 10 channels
- 20 Frequencies with optional Frequency Generator
- Power output 150 watts PEP 100 watts average
- Half Duplex capability available
- Modular construction
- Built-in FSK Keyer Converter Option
- Built-in Phone Patch (except for Remote)
- Receiver Front End burn-out proof
- Transmitter immune to damage from short or open circuit
- Solid State except for P.A. Section
- Modular power supplies
- AC or DC supplies
- Full line of accessories
- FCC Type Accepted
  Parts 81, 83, 87, 89 and 91
  Models SR-206MS SR-206MD
  SR-210MS SR-210MD

Twenty Frequency operation can be provided by including an additional frequency generator module and "A/B" switch option.

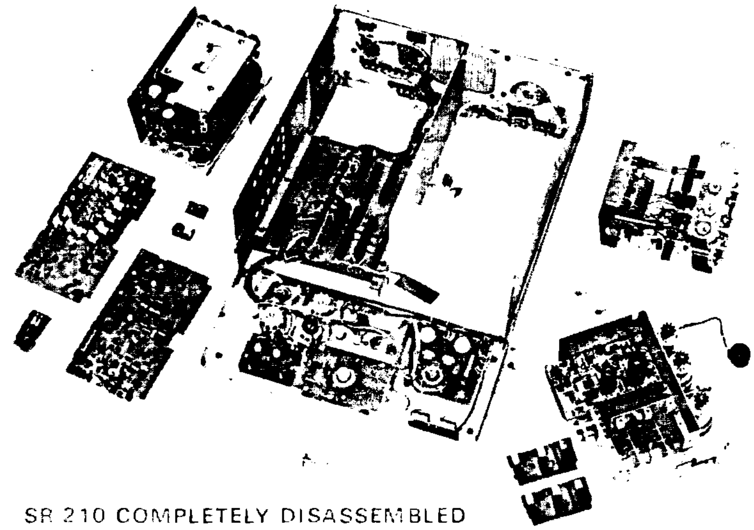
The SR-200 Series Transceivers are designed for continuous duty applications at high average power output including Radio Teletypewriter service and facsimile.

Power output is 150 watts P.E.P. and 100 watts average. Power input is 115/230 volts 47 to 63 Hz single phase or DC (12, 24 or 32 volts).

DISASSEMBLES FAST AND EASY

It is possible to completely disassemble the SR-200 Transceiver in less than one-half hour using only one tool — a Phillips screw-driver.

The SR-200 Series Transceivers break down into six basic functional modules. These are: RF Amplifier, P.A. Matching Network, Frequency Generator, IF-Audio, Power Supply and Main Frame.



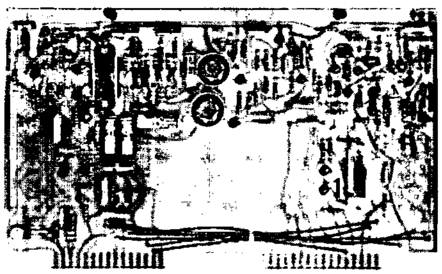
SR 210 COMPLETELY DISASSEMBLED

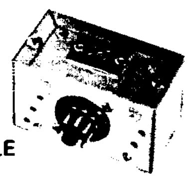
UNIQUE MODULAR FEATURES

Among the unique features of the SR-206 and SR-210 Transceivers are plug-in printed wiring board options. Among these options are a plug-in printed circuit board FSK Keyer/Converter Module which can be added at any time. The FSK Keyer/Converter Module is available with 2000 Hz Center Frequency and ±425 Hz Shift. Other Shifts and Center Frequencies are available.

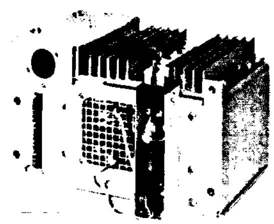
A plug-in board accepts VOX, CW and Squelch Modules while the Clarifier Module and Noise Limiter Modules plug into the Frequency Generator Board and IF-Audio Board respectively.

Power Supplies are plug-in and easily removeable.

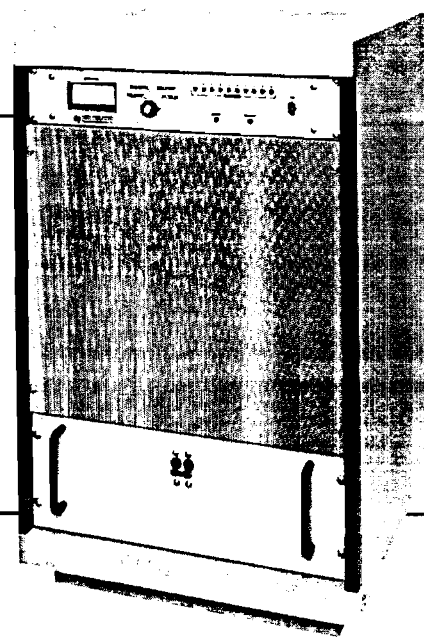




AR-236 TELETYPEWRITER KEYER AND CONVERTER MODULE



AR-260 DC POWER SUPPLY MODULE



SR-110 1KW LINEAR AMPLIFIER

LINEAR AMPLIFIER

The SR-110 1KW Linear Amplifier is designed to operate automatically with the SR-200 Series Transceivers. Power Output is 1000 watts PEP and 1000 watts average. Power Input 115/230 Volts 47 - 63 Hz.

BEST AVAILABLE COPY

REMOTE CONTROL

SR-1601 REMOTE CONTROL

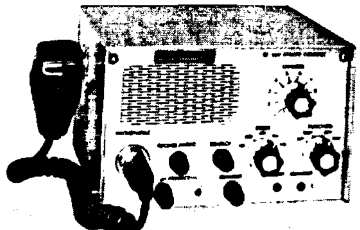
SR-1601 Remote Control is a multi-conductor remote control system for selection of channel, mode, on-off, etc., for an AC operated SR-206 or SR-210. The SR-1601 consists of the Motor Box and the Control Unit.

SR-1602 REMOTE CONTROL

The SR-1602 Remote Control is a multi-conductor remote control which performs the same functions as the SR-1601, but it is used in DC mobile or marine applications.

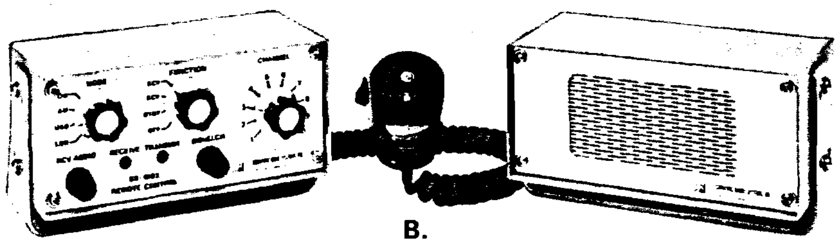
SR-1650 TELEPHONE LINE REMOTE CONTROL

The SR-1650 can control an SR-200 Series Transceiver over virtually any distance on two telephone pair (one pair optional). Control of Channel, Mode, and Function is provided with Supervisory.

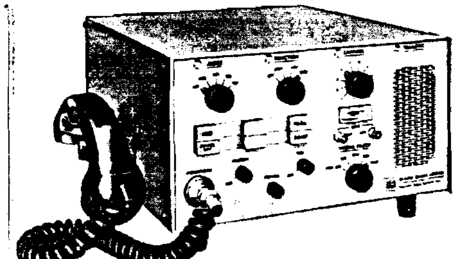


A.

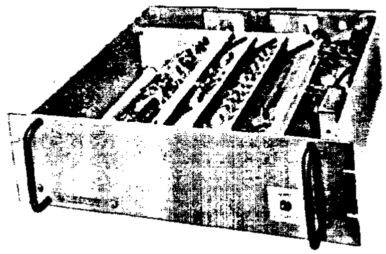
A. SR-1601 REMOTE CONTROL
B. SR-1602 REMOTE CONTROL
C. SR-1650L REMOTE CONTROL
D. SR-1650R REMOTE CONTROL



B.

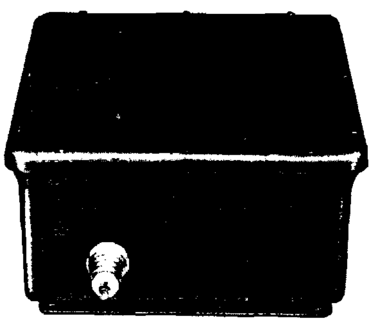


D.



C.

ANTENNA COUPLER AND ANTENNAS



SR-610M ANTENNA COUPLER

SR-610M AUTOMATIC ANTENNA COUPLER

The SR-610M is a compact antenna coupler in a watertight fibreglass case. It is designed for very stringent environmental conditions such as those encountered on ships or vehicles. Maximum number of channels is 10 and switching is automatically programmed by an SR-200 Series HF SSB Transceiver. The network design ensures excellent efficiency even at the low frequency range with short antennas. Frequency range is 1.6 to 30 MHz and antennas from 9 ft. whips to 150 ft. long wires can be accommodated.

ANTENNA OUTPUT

The SR-200 Series of Transceivers can be ordered with separate output connectors for each channel so that doublet antennas can be used. The standard Transceivers have a single output connector and should be used with a broad band antenna or the SR-610M antenna coupler.

ANTENNAS

AR-247	Doublet Antenna Kit
AR-248	75 Foot Long Wire Kit
AR-249	150 Foot Long Wire Kit
AR-264	Vertical 25 Foot Fibreglass Marine Antenna
AR-265	Vertical 16 Foot Aluminum Telescoping Whip
AR-266	Vertical 35 Foot Aluminum Telescoping Whip
AR-267	9 Foot Stainless Steel Whip
AR-268	Vertical 16 Foot Fibreglass Whip
AR-269	Vertical 35 Foot Fibreglass Whip

BEST AVAILABLE COPY

SPECIFICATIONS

	[illegible]
FREQUENCY RANGE	1.6 to 30.0 MHz
SR-206	Up to 6 channels
SR-210	Up to 10 channels
POWER INPUT	350 watts maximum 115/230 volts, 47-63 Hz single phase 12, 24, or 32 volts DC
OPERATING MODES	LSB (A3J), USB (A3J), Compatible AM (A3H), Reduced Carrier (A3A)
OPTIONS	Selectable Sideband, Squelch, Noise Limiter, FSK Keyer/Converter, Voice Clarifier, RF Gain, [illegible]
TEMPERATURE RANGE	-30°C to +[illegible]°C
SIZE	7¼" x 16¼" W x 17" D including power supply 18.4 cm x 41.3 cm x 43.2 cm
WEIGHT	48 pounds, 21.8 Kg

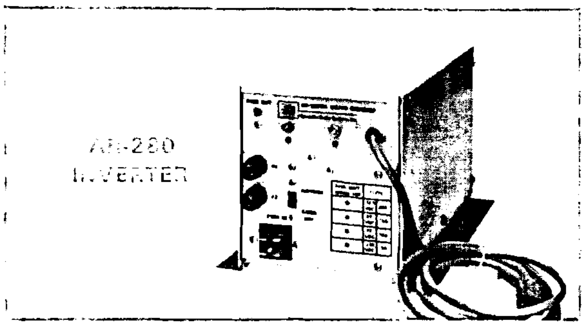
TRANSMITTER

POWER OUTPUT	150 [illegible], 100 watts Average
2nd Harmonic	-40 db [illegible] than -60 db with optional harmonic [illegible]
UNDESIRED SIDEBAND	-50 db
CARRIER SUPPRESSION	-50 db
INTERMODULATION DISTORTION	[illegible] db
FREQUENCY STABILITY	1 part in [illegible]
OUTPUT IMPEDANCE	50 Ohms
PPC AND ALC	Provide [illegible] and prevent damage from improper [illegible] including short and open [illegible]

RECEIVER

SENSITIVITY	SSB 0.5 microvolt for 10 db S+N/N AM 1.5 microvolt for 10 db S+N/N
FREQUENCY STABILITY	1 part in [illegible]
BANDWIDTH	2.1 KHz - with 6 to 60 db shape factor of 2.5:1
ANTENNA IMPEDANCE	50 Ohms
AGC	Threshold 2.5 microvolts, fast attack
CIRCUIT	Double conversion superheterodyne
AUDIO OUTPUT	4 watts (speaker) 0 dbm (600 Ohms)

ACCESSORIES



POWER SUPPLIES

AR-250	AC Power Supply 115/230 volts 50/60 Hz
AR-250M	AC Power Supply 115 volt sine wave or square wave
AR-260	DC Power Supply 12 or 24 volts DC
AR-280	DC to AC Inverter 12, 24 or 32 volts DC - use with AR-250M

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

OPTIONS - ACCESSORIES

AR-230	Selectable Sideband Module
AR-231	VOX Module
AR-232	CW Module
AR-233	Squelch Module
AR-234	Noise Limiter
AR-236	Teletype Keyer and Converter Module
AR-237	Blower Kit
AR-238	Telegraph Key
AR-239	Clarifier
AR-256	RF Gain
AR-257	Duplex Switching Module
AR-258	Duplex Frequency Generator Board
AR-259A	Bracket Kit
AR-259B	Shock Mount Kit
AR-821	Teletype Loop Power Supply

SR SYSTEMS
Scientific Radio Systems Inc.
367 ORCHARD ST. ■ ROCHESTER, N.Y. 14606
CABLE: SIRAD PHONE: (716) 458-3733
TELEX: 978368

SR-206, 210 (5-77) PRINTED IN U.S.A.

BEST AVAILABLE COPY

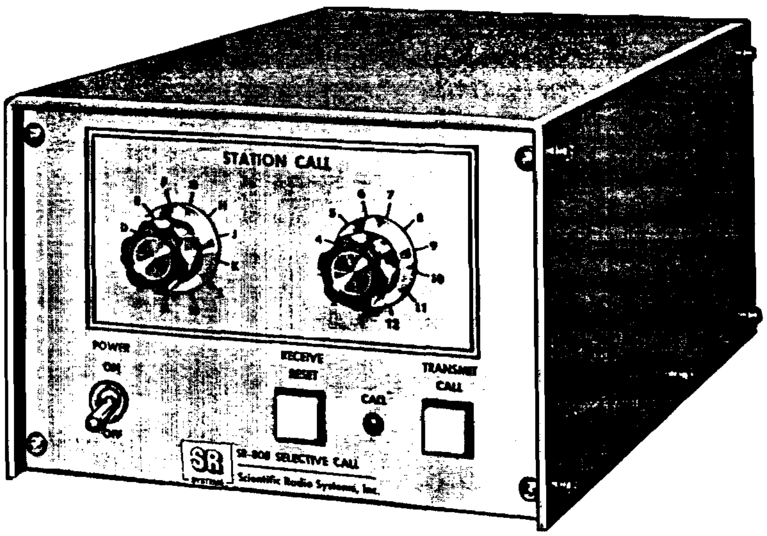
BEST AVAILABLE COPY

301

-SYSTEMS

Scientific Radio Systems, Inc.

Collins Marine Corporation
PIER 32 – SAN FRANCISCO CALIFORNIA 941C5
TELEPHONE (415) 957 1300



SR-808

SELECTIVE CALL

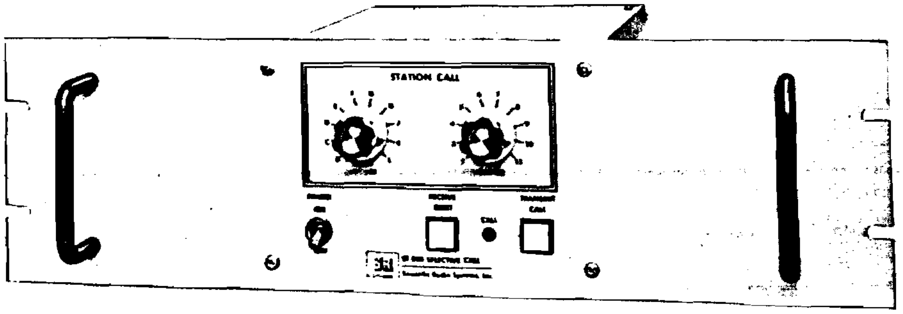
The SR-808 Selective Call unit is a digital encoder/decoder that generates call codes for paging individual stations or an entire communications net, and decodes and analyzes received data to determine if a valid code has been received. The system uses wide band FSK techniques for signal data transmission. Because of the digital/FSK signal processing, the SR-808 is especially suited to HF communications, and is not as vulnerable to problems of radio equipment frequency instability, atmospheric signal fading, man made or natural interferences, etc., as tone type selective call units.

FEATURES

- 143 Individual station calls
- 1 Net call or collective call
- Plug-in module boards
- All solid state
- Buzzer, lamp, and dry contacts for received call
- SIZE: 5"H x 7-1/2"W x 12"D (Also available for 19" rack mounting)
- WEIGHT: 6 pounds

BEST AVAILABLE COPY

302



RACK MOUNT VERSION OF SR-808

SPECIFICATIONS

INPUT FROM RECEIVER	-30 dbm to +10 dbm, 600Ω nominal
OUTPUT TO TRANSMITTER	0 dbm (adjustable), 600Ω nominal
INPUT POWER	115/230 VAC or 12VDC, 3 watts
TEMPERATURE RANGE	-30°C to +50°C
INTERCONNECTIONS TO TRANSCEIVER	Audio Input, Audio Output, Keyline
FSK TONE FREQUENCIES	1800 Hz center frequency, ±425 Hz FSK. (Other center frequencies available as required)
CALL CODE CONFIGURATION	Two 4 bit BCD digits
CALL MESSAGE FORMAT	16 bit sync pattern followed by call code, repeated six times
ERROR COMPENSATION	At least two of the six call codes must be verified before station call alarm will sound
FRONT CONTROLS	Power ON/OFF, Transmit Call, Receive (call) Reset, Call Indicator, Station Call Select Switches
BOTTOM CONTROLS	Station Code
CONNECTORS	Audio Input/Output, Keyline (15 pin)

BEST AVAILABLE COPY

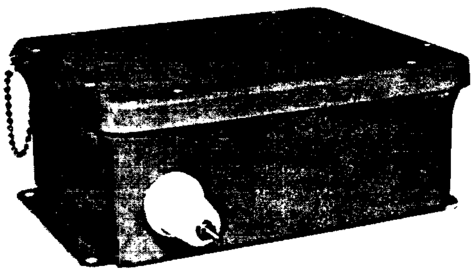
Collins Marine Corporation
PIER 32 - SAN FRANCISCO CALIFORNIA 94105
TELEPHONE (415) 957 1300

Scientific Radio Systems Inc.
367 ORCHARD ST. • ROCHESTER, N.Y. 14606
CABLE: SIRAD PHONE: (716) 458-3733
TELEX: 978368

SR-808 (11-74)
PRINTED IN U.S.A.

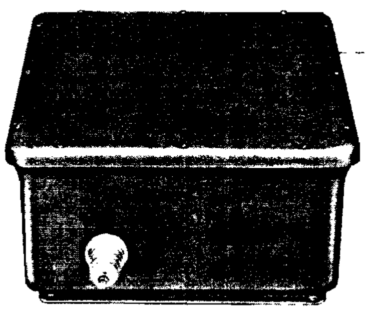
BEST AVAILABLE COPY

ANTENNA COUPLERS



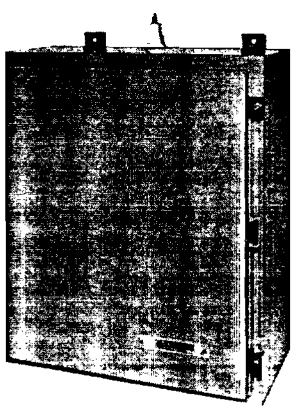
SR-604 BASE STATION AND VEHICULAR AUTOMATIC ANTENNA COUPLER

The SR-604 is a compact antenna tuner housed in a spray-tight fiberglass case. The SR-604 is meant for use with the SR-204 six channel transceiver for voice or CW communications. Maximum number of channels is six and switching is automatically programmed by an SR-204 HF SSB Transceiver. Frequency range is 1.6 to 30.0 MHz and antennas from 9 ft. whips to 150 ft. long wires can be accommodated.



SR-606M/SR-610M MARINE AND VEHICULAR ANTENNA COUPLER

The SR-606M and SR-610M are compact antenna couplers in water-tight fiberglass cases. They are designed for very stringent environmental conditions such as those encountered on ships or vehicles. Maximum number of channels is 10 for the SR-610M and 6 for the SR-606M. Switching is automatically programmed by an SR-200 Series HF SSB Transceiver. The network design ensures excellent efficiency even at the low frequency range with short antennas. Frequency range is 1.6 to 30 MHz and antennas from 9 ft. whips to 150 ft. long wires can be accommodated.



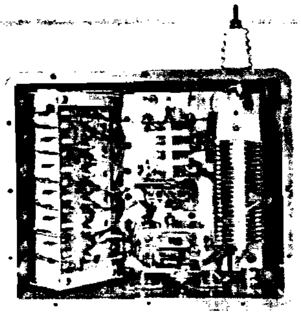
SR-650A 1 KW ANTENNA COUPLER

The SR-650A Antenna Coupler is designed to operate with the SR-100 Series 1 Kilowatt Linear Amplifier. As with the lower power antenna couplers, operation is automatic after the initial tune-up. The SR-650A has maximum channel capability of 10 channels in the 1.6 to 30 MHz frequency range. It will operate with 16 ft., 25 ft., and 35 ft. whips or 75 ft., and 150 ft. long wire antennas. An SR-650B version of the antenna tuner is available as a 50 ohm to 50 ohm harmonic filter.

BEST AVAILABLE COPY

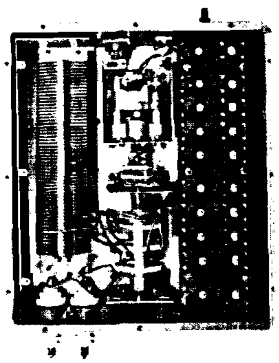
SPECIFICATIONS

SR-604 BASE STATION AND VEHICULAR ANTENNA COUPLER



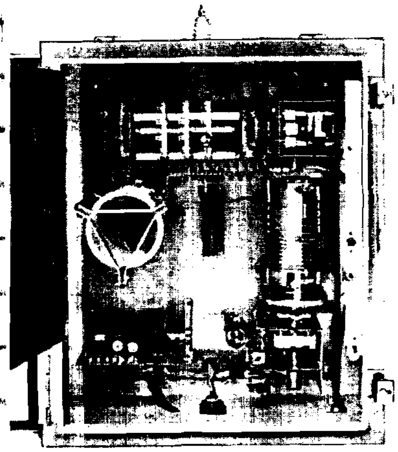
INPUT IMPEDANCE	50 ohms
FREQUENCY RANGE	1.6 to 30 MHz
MAXIMUM NUMBER OF CHANNELS	Six channels
POWER HANDLING	125 watts PEP
CHANNEL SWITCHING TIME	3 seconds or less
SWITCHING METHOD	Open seeking motor drive
CONSTRUCTION	Tapped coil and variable coil
TYPE OF ANTENNAS	9, 16, 25, and 35 foot whips 75 and 150 foot long wires
ENCLOSURE	Water-tight fiberglass
SIZE	9¼"H x 11¼"W x 4½"D (23.5H x 28.6W x 14.5D cm)
WEIGHT	8 lbs. (3.6 kg)
TEMPERATURE RANGE	−30°C to +60°C

SR-606M/SR-610M MARINE BASE STATION AND VEHICULAR ANTENNA COUPLER



INPUT IMPEDANCE	50 ohms
FREQUENCY RANGE	1.6 to 30 MHz
MAXIMUM NUMBER OF CHANNELS	Ten for SR-610M, Six for SR-606M
POWER HANDLING	150 watts PEP 100 watts Average
CHANNEL SWITCHING TIME	3 seconds or less
SWITCHING METHOD	Open seeking motor drive
CONSTRUCTION	Tapped coil and variable coil
TYPE OF ANTENNAS	9, 16, 25, and 35 foot whips 75 and 150 foot long wires
ENCLOSURE	Water-tight fiberglass
SIZE	13½"H x 15½"W x 6"D (34.3 cm x 39.3 cm x 15.2 cm)
WEIGHT	18 pounds (8.2 kg)
TEMPERATURE RANGE	−30°C to +55°C
DUAL OUTPUT	Optional Dual Output for use with two different antennas

SR-650A 1 KILOWATT ANTENNA COUPLER



INPUT IMPEDANCE	50 ohms
FREQUENCY RANGE	1.6 to 30 MHz
MAXIMUM NUMBER OF CHANNELS	Ten
POWER HANDLING	1000 watts PEP, 1000 watts Average
CHANNEL SWITCHING TIME	10 seconds maximum
SWITCHING METHOD	24 VAC motor-resistor bridge
CONSTRUCTION	Motor driven variable coil
TYPE OF ANTENNAS	16, 25, and 35 foot whips 75 and 150 foot long wires
ENCLOSURE	Weather-tight metal case
SIZE	27"H x 20"W x 12"D (68.6 cm x 50.8 cm x 30.5 cm)
WEIGHT	75 pounds (34 kg)
TEMPERATURE RANGE	−30°C to +55°C
SAFETY INTERLOCK	When cover is removed over high voltage circuits, the Transmitter is automatically unkeyed.

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

R SYSTEMS

Scientific Radio Systems Inc.
367 ORCHARD ST. • ROCHESTER, N.Y. 14606
CABLE: SIRAD PHONE: (716) 458-3733
TELEX 978368

BEST AVAILABLE COPY

BEST AVAILABLE COPY

CHAPTER I

INTRODUCTION

1.1 FUNCTIONAL DESCRIPTION.

The SR-224 is a completely solid-state mobile Transceiver for high-frequency single-sideband operation on four channels. The Transceiver is mounted in a storage compartment in the vehicle, and normally it is operated from a cab-mounted remote control unit.

The SR-224 has four simultaneous receive channels and one programmable transmit channel, which may be used to transmit on any of the receive channel frequencies.

A companion SR-624 Antenna Coupler Unit is mounted at the antenna and controlled by the Transceiver. The SR-624 provides impedance matching of the transmitter signal to a whip antenna, and a multicoupler in the unit matches the antenna to the four receive channels in the Transceiver.

1.2 SPECIFICATIONS.

Following are nominal physical and electrical specifications for the radio set.

GENERAL.

Frequency Range	3-18 MHz
Frequency Stability	1 part in 10^6
Channel Oscillators	Individual TCXO for each channel.
Modes	• FSK, 4 channel simultaneous receive, 1 selected transmit channel, external FSK keyer/converter. • Voice on one selected channel, receive and transmit.
Primary Power	11-15 Vdc
Current Drain	Receive 0.37 Amp, Transmit (full out) 17 Amp.
Size (inches) and Weights	Transceiver - 4.25H x 13.375W x 14.5D, 18 lb. Antenna Coupler - 6.44H x 15.38W x 13.25D, 8 lb.
Operating Temperature Range	-10°C to +55°C
Storage Temperature Range	-40°C to +70°C
Relative Humidity	95% at 40°C
Mounting	Hard mounting with brackets for Transceiver Unit and flanges for Antenna Coupler Unit. May be shock mounted for operation under severe shock/vibration and where increased reliability is required.

RECEIVER SECTION.

Mode	USB (A3J)
Sensitivity	0.5µV at receiver input for 10 dB (S + N)/N.
Dynamic Range	100 dB
Audio Output	600Ω unbalanced 0 dBm nominal output. (Will drive 600Ω load at 3.5V p-p max.)
Audio Response	300 Hz to 2.1 kHz
Selectivity	3 dB min. at 1.9 kHz; 60 dB at 5.4 kHz max.
Spurious	-60 dB
AGC	2.5µV threshold, fast-attack, slow-release. A buffered AGC output from each channel is available for external use. Output impedance 600Ω, +5 Vdc max. into open circuit.
Circuit	Double-conversion superheterodyne.

TRANSMITTER SECTION.

Output Power	100W (at 12.5 Vdc input)
Channel Selection	4 wires plus common
Duty Cycle	20%; 6 seconds on and 24 seconds off at full rated power.
Harmonics	-40 dB
Undesired Sideband	-50 dB at 1 kHz
Carrier	-50 dB
Spurious	Consistent with FCC Rules & Regulations part 81 (where applicable and consistent with other specifications herein).
T/R Keying	External control from a remote control unit; transmitter reaches full power and on-frequency within 50 milliseconds after keying.
Input Modulating Signal	600Ω unbalanced input, 0 dBm to -12 dBm.

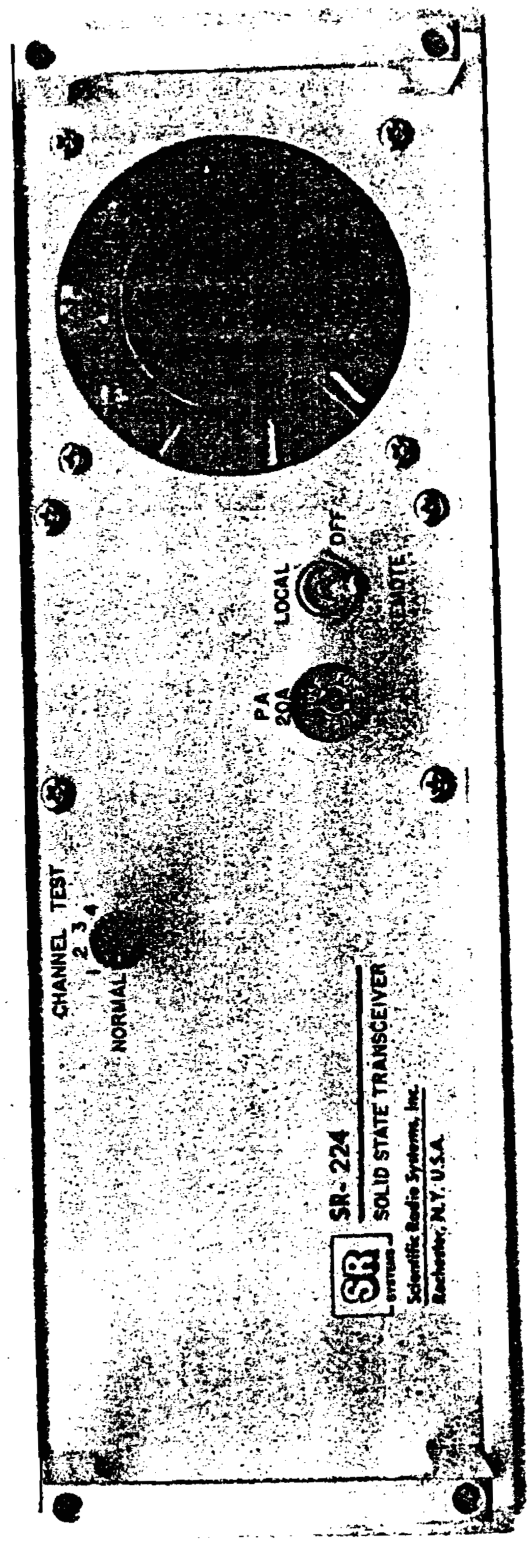
ANTENNA COUPLER SECTION.

Receive Signal	Multicoupler circuit to feed four separate receive channels in Transceiver Unit.
Transmit Signal	Tuned circuit selected to match each channel.

1.3 LIST OF ASSEMBLIES.

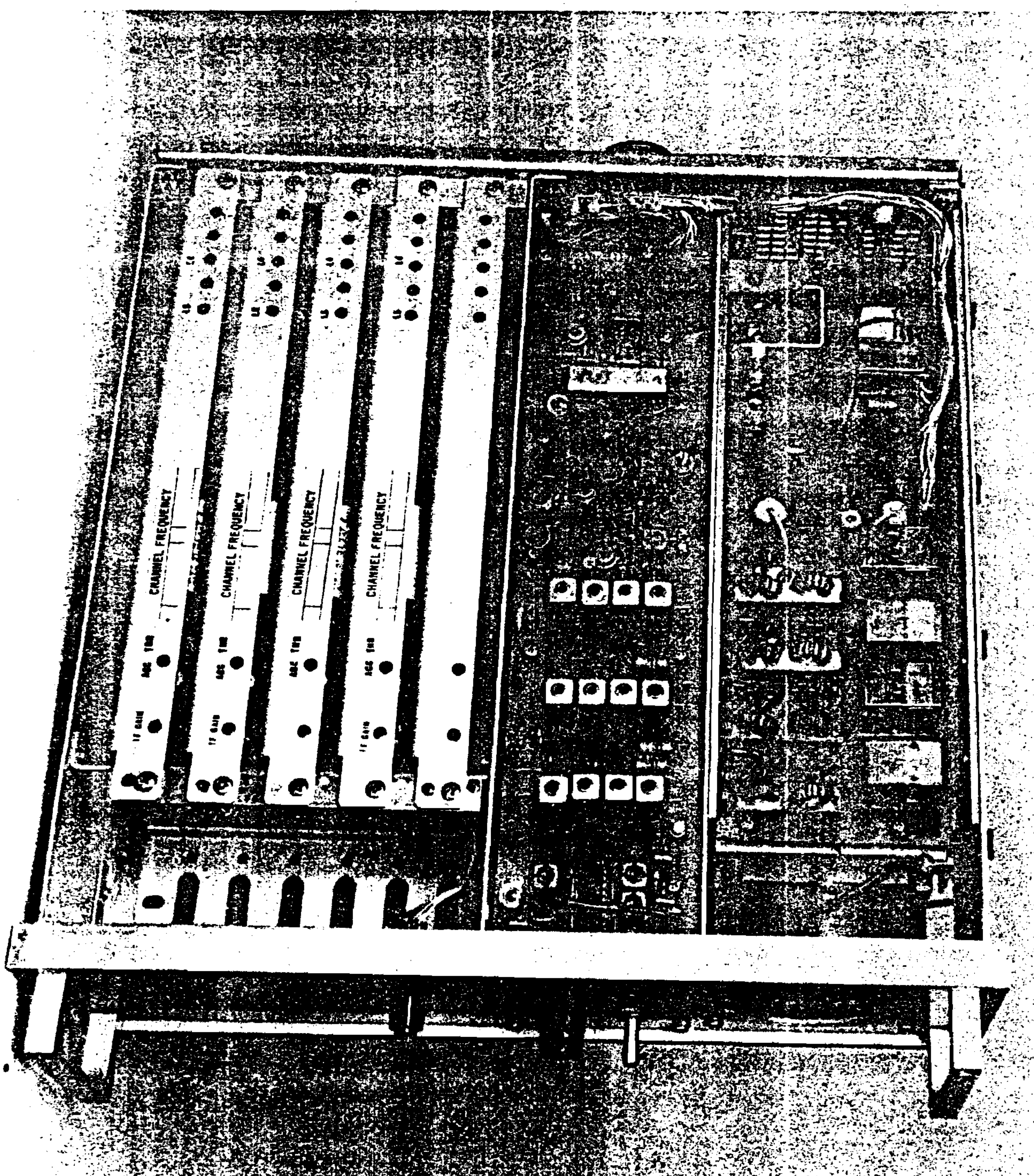
REF DESIG	NAME	PART #
---	Radio Set, HF SSB	224000
1	Transceiver Main Frame	224100
1A1	Receiver CH A Module	224800
1A2	Receiver CH B Module	224800
1A3	Receiver CH C Module	224800
1A4	Receiver CH D Module	224800
1A5	Program/Control Module	224820
1A6	Oscillator Module	224360
1A7	Exciter Module	224300
1A8	Output Filter/PPC Module	224345
1A8A1	Output Filter CH A Module	224340
1A8A2	Output Filter CH B Module	224340
1A8A3	Output Filter CH C Module	224340
1A8A4	Output Filter CH D Module	224340
1A9	PA/Driver Module	224370
1A10	Blower Inverter Module	224400
2	Antenna Coupler	624000
2A1	Matching Network Module CH A	624300
2A2	Matching Network Module CH B	624300
2A3	Matching Network Module CH C	624300
2A4	Matching Network Module CH D	624300
2A5	Receiver Multicoupler Module	624400

BEST AVAILABLE COPY



BEST AVAILABLE COPY

 BEST AVAILABLE COPY



BEST AVAILABLE COPY

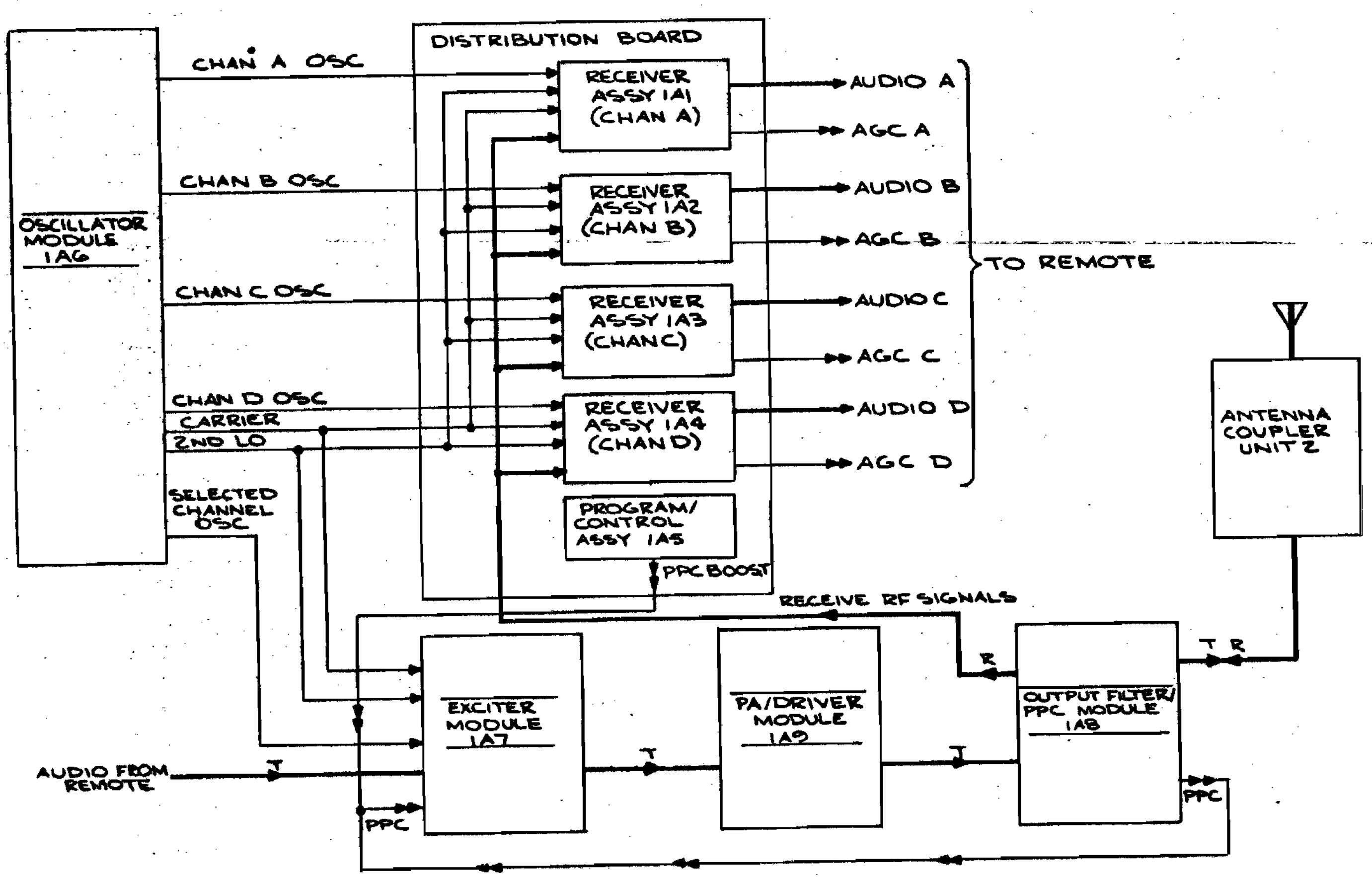


Figure 4-1. Main Signal Flow Block Diagram

310

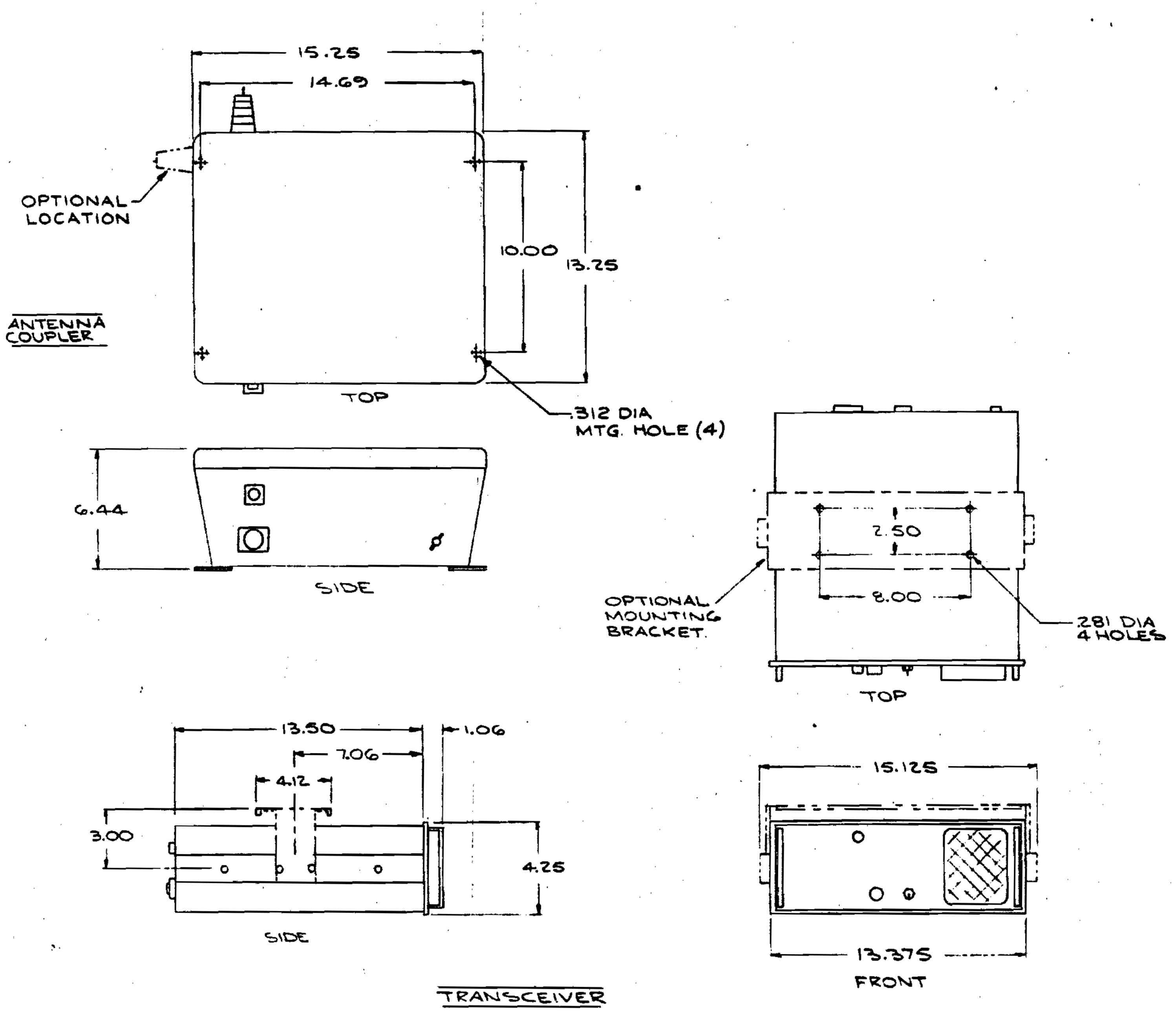


Figure 2-1. Outline and Mounting Dimensions

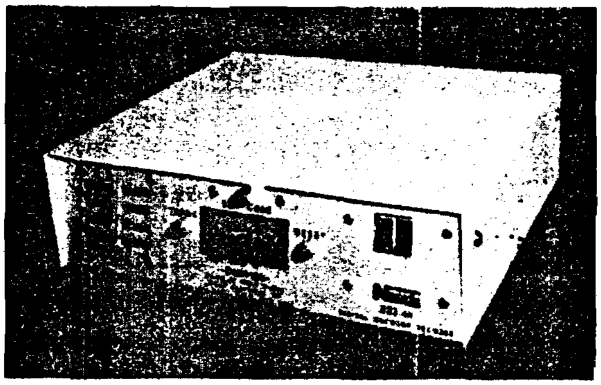
311

INTRODUCING THE NEW

NECODE 321 AR

DIGITAL ENCODER / DECODER

Binary Logic Design



Completely Solid State

SPECIALLY DESIGNED FOR USE WITH MARINE SSB

Now you can contact your vessels without schedules or constant radio monitoring. Just dial the vessel's code number and code call your vessel anytime.

321 AR FEATURES

- **Plug-in Installation**
  —All connections to Marine SSB are made through one (1) furnished plug.
- **Automatic Acknowledge**
  —A properly received code will automatically key down the transmitter and send an auditable acknowledge signal back to the calling station.
- **Identification**
  —The Necode 321 AR leaves your unit number displayed on the front of the called unit until reset.
- **Automatic Alarm and Readout Reset**
  —On conventional units the audio alarm is triggered only once and must be reset by the radio operator before another call can be received. The Necode 321 AR will automatically reset and alarm each time it is called.
- All units are supplied with a terminal strip on the rear of the unit which enables remote alarms to be placed anywhere on the vessel or station.
- All Necode 321 AR Encoder/Decoders are fully compatable with any Necode 320 presently in use.
- The Necode 321 AR is covered by a full one (1) year parts and labor warranty and is supplied with the necessary hook-up cable and plugs.

All The Features You Need In One Standard Unit

REMOTE OPTIONS

All remote hook-ups are made easy by the use of the terminal strip on the back of the unit.

1. Remote audio of ½ or 2½ watts for speaker in galley, quarters, or outside deck.
2. Remote reset at any location.
3. Keyed 12 VDC for remote lamps, sonic alarms, or relay to operate larger 115VAC bells, horns, etc.

SPECIFICATIONS

Cabinet..1/16" anodized aluminum 12" W + 3½" H + 10.7" L
Operating voltage..115VAC or 12VDC.
Operating current..115VAC = ½ A 12VDC = 2 A
Weight..9 lb. shipping

ENCODER

Transmit output (Z=100 ohm)..adj. 0 to 2 VPP
Transmit tones (1954 & 2154 HZ)..stability .0125%
Transmit on-time (inhibit)..2 sec. max.
Transmit code variable (0001 to 9999)..8421 BCD.
Transmit code fixed (00 to 99)..8421 BCD.
Speed of code..10 ms per bit
Total transmitted data 96 + 3 bits..990 ms
Internal clock..100 HZ
Acknowledge delay..4 sec.
Acknowledge on time..1 sec.

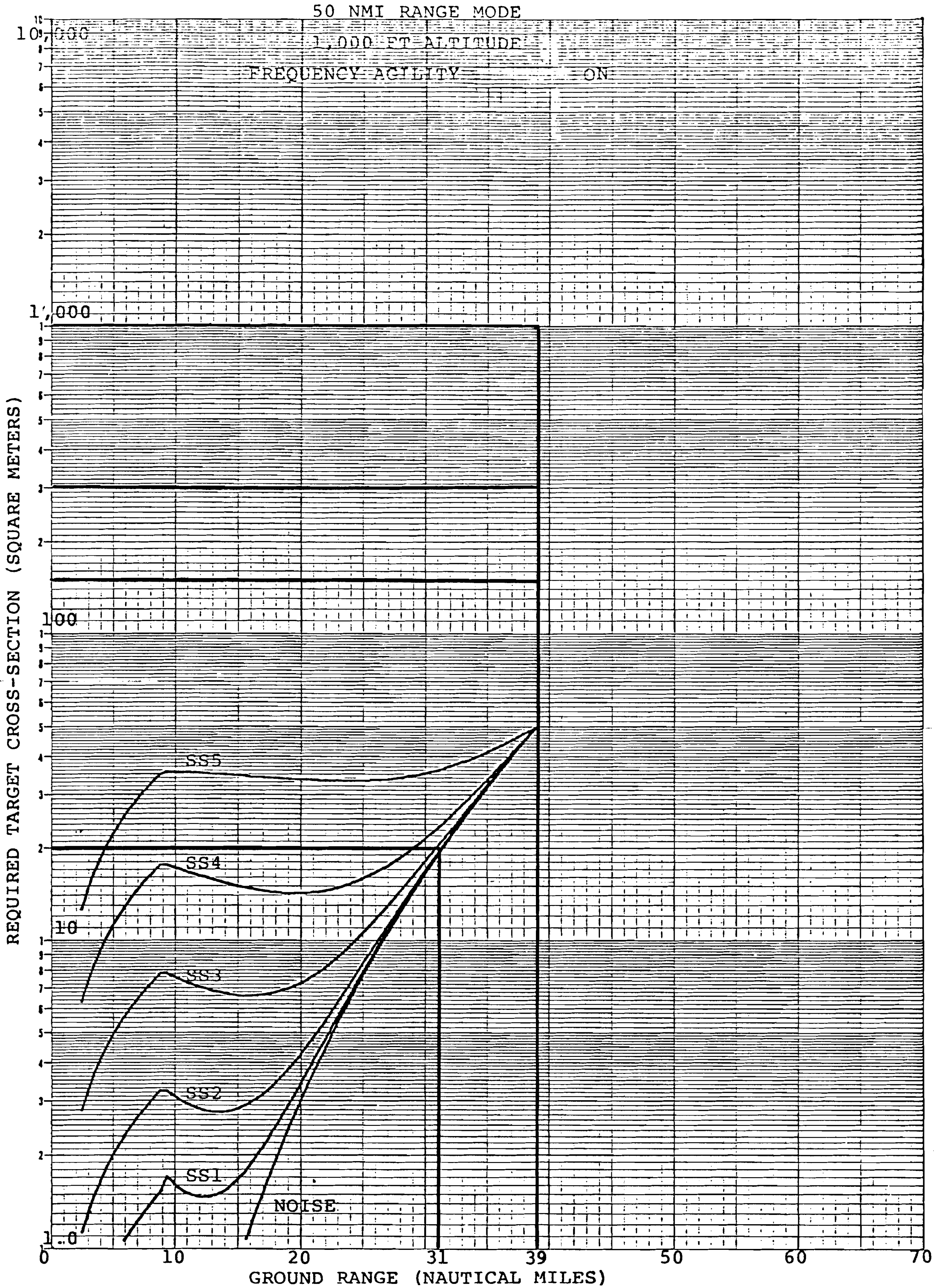
DECODER

Input audio from receiver.. .02VPP min.
Tone decoding..phase lock loop
Decode programming..0001 to 9999
Alarm on time (audible)..adj. 3 sec. to 60 sec.
Alarm (visual readout)..continuous until reset

Manufactured and distributed by Necode Electronics,
Rt. 8 Box 575, Livingston, Texas 77351—713 566-4018

APPENDIX F

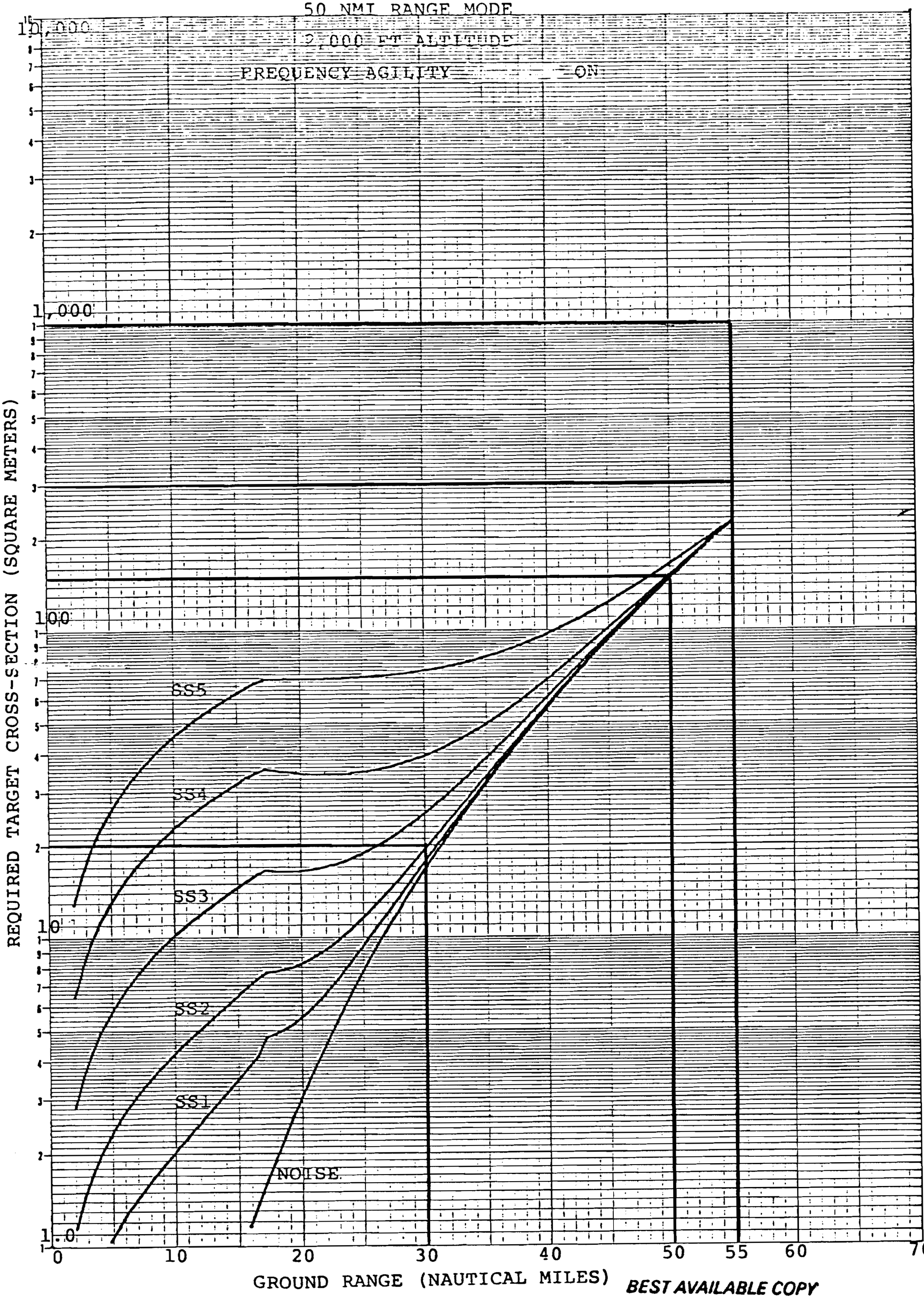
RADAR DETECTION RANGE FOR ALTERNATIVE TARGETS AS A FUNCTION OF ALTITUDE AND SEA STATE (AN/APS-128 SEA SURVEILLANCE RADAR)



BEST AVAILABLE COPY

AN/APS-128A SEARCH RADAR

50 NMI RANGE MODE



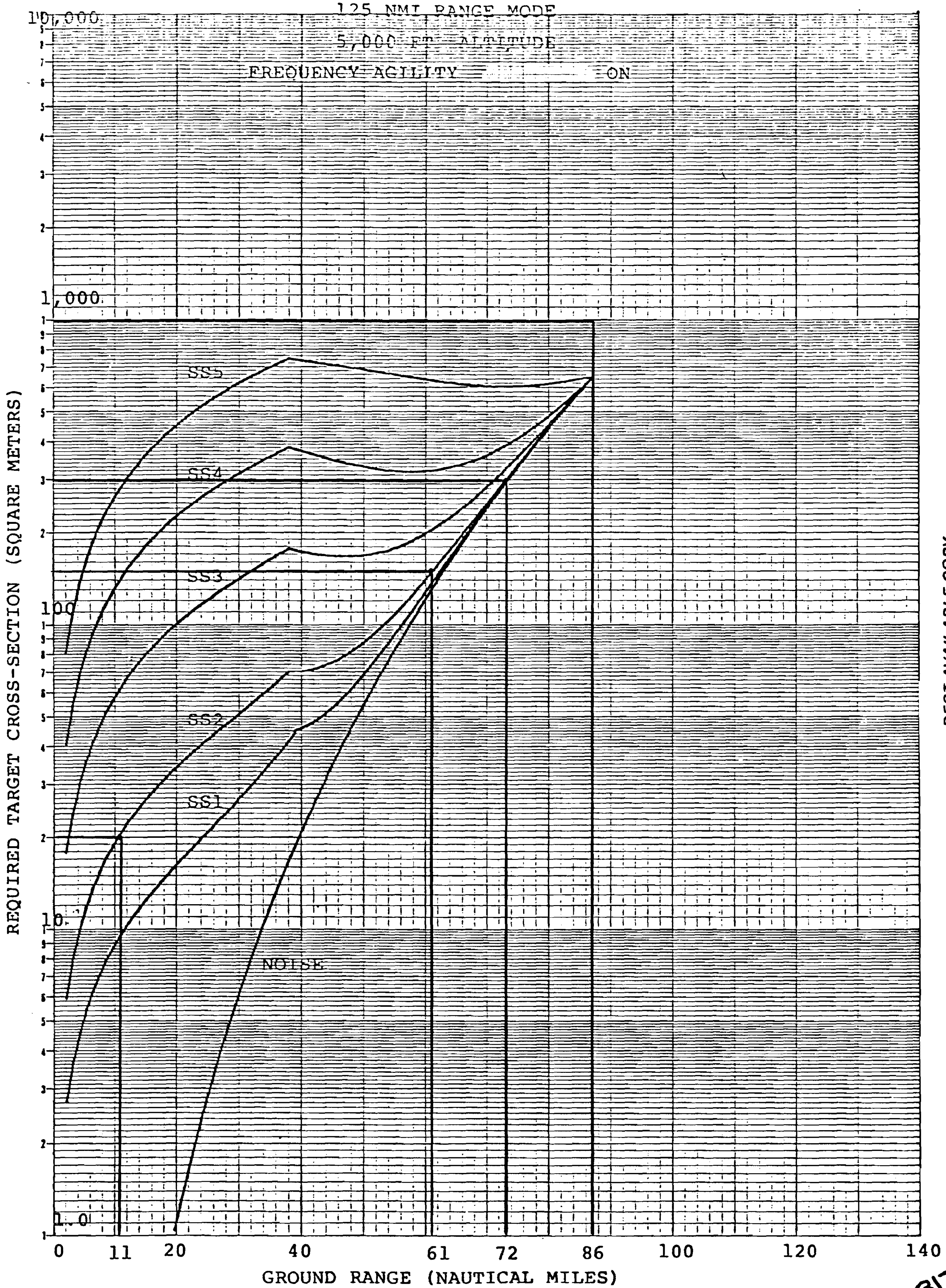
BEST AVAILABLE COPY

BEST AVAILABLE COPY

SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS

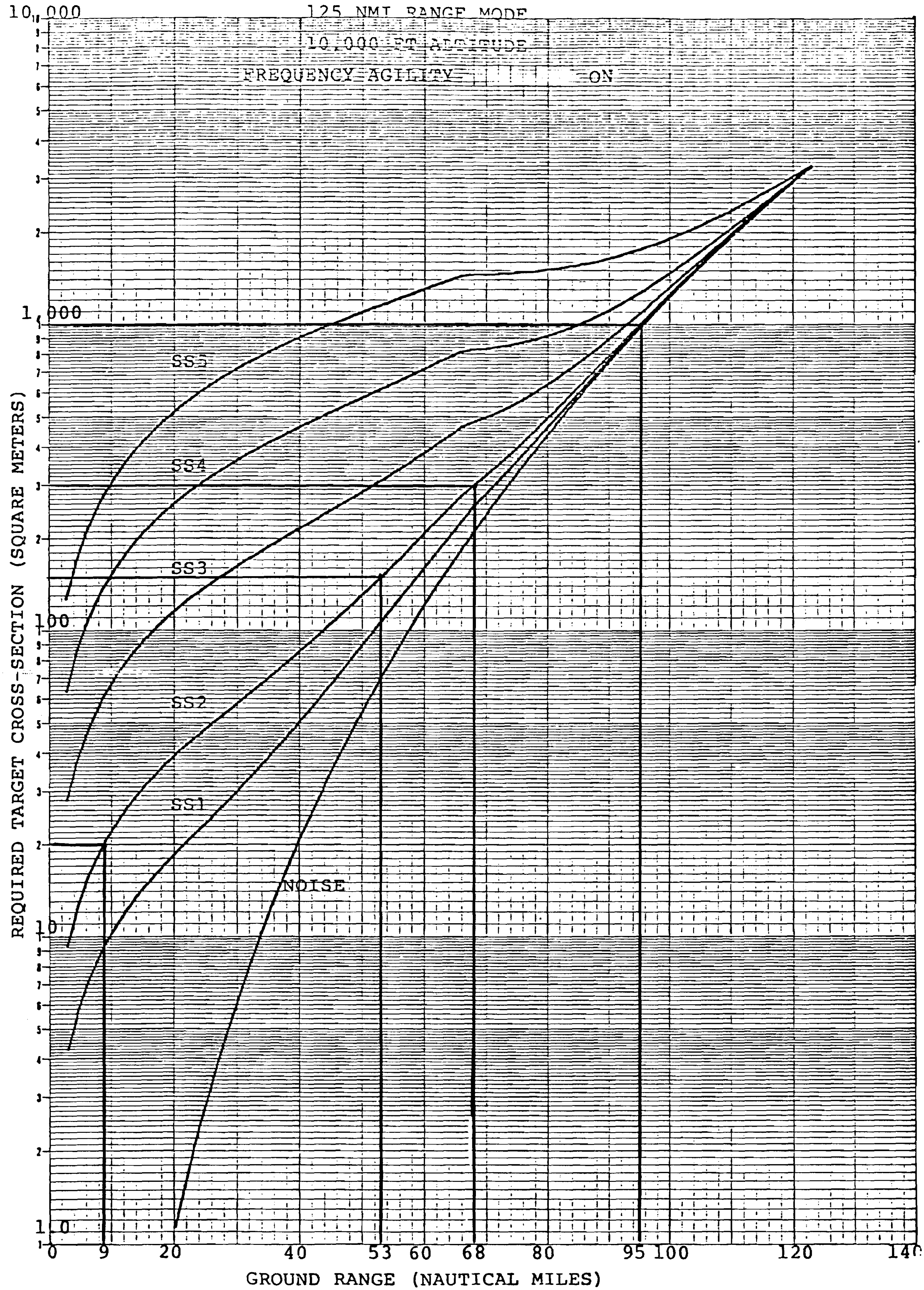
316

AN/APS-128A SEARCH RADAR



BEST AVAILABLE COPY

AN/APS 125A SEARCH RADAR



BEST AVAILABLE COPY