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16. Abstract In the Port and Tanker Safety Act of 1978 the U.S. Congress directed the Department of Transportation to perform a study on the desirability and feasibility of a shore-station system for monitoring vessels (including fishing vessels) offshore within the 200-nm U.S. Fishery Conservation Zone (FCZ). This is the final report which documents the study; it will be delivered to Congress in October 1980. The analysis of Coast Guard requirements for offshore vessel monitoring service indicated that major benefits to the government would accrue in: Port and Environmental Safety, Enforcement of Laws and Treaties, and Search and Rescue. Most other missions would receive secondary benefits. A limited survey of vessel owners and masters indicated that 80 percent of the large commercial vessels would cooperatively report to a CG monitoring system, while 22 percent of the small commercial and domestic fishing vessels and 12 percent of the recreational vessels would participate. Major benefits of a monitoring system to the marine user are: operating cost savings and improved safety at sea. A system concept called the Offshore Traffic Information System (OTIS) was developed. This system utilizes computer correlation techniques to derive vessel tracking information from available vessel movement data augmented with vessel reports and remote sensor data. The goal of OTIS is to collect, process, and provide to both the decision-maker and field personnel all available data bearing on a situation or event. A reliable ship-to-shore communications system is an essential element of the system. Alternative OTIS system implementations were evaluated in terms of cost, effectiveness, benefits, and implementation considerations. A phased implementation of OTIS is recommended, based on these evaluations, with initial effort directed to integrating all current CG programs related to OTIS.

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ABBREVIATIONS

AMVER	Automated Mutual-Assistance Vessel Rescue
AOSS	Airborne Oil Surveillance System
BA	Bridge Administration
BATF	Bureau of Alcohol, Tobacco, and Firearms
C^2	Command and Control
CAS	Collision Avoidance Systems
CCIR	International Radio Consultative Committee
CCZ	Coastal Confluence Zone
C.F.R.	Code of Federal Regulations
CG	Coast Guard (also, USCG)
CHRS	Coastal Harbor Radiotelephone Service
CONUS	Continental United States
COTP	Captain of the Port
CR	Contact Report
CVS	Commercial Vessel Safety
CW	Continuous Wavelength
DEA	Drug Enforcement Administration
DF	Direction Finding
DI	Domestic Ice Operations
DOC	Department of Commerce
DOD	Department of Defense
drms	Distance Root Mean Square
ELT	Enforcement of Laws and Treaties
EMIS	Enforcement Management Information System
EPA	Environmental Protection Agency
EPIC	El Paso Intelligence Center
EPIRB	Emergency Position Indicating Radio Beacon
ERMA	Electronic Relative Motion Analyzer
ETA	Estimated Time of Arrival
FAA	Federal Aviation Administration
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission; or Fleet Command Center
FCMA	Fishery Conservation and Management Act
FCZ	Fishery Conservation Zone

ABBREVIATIONS (Cont.)

MSO	Marine Safety Office
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration (also DOC-NOAA)
NOSIC	Naval Ocean Surveillance Information Center
OC	Operational Commander
OCC	Operational Computer Center
OEZ	Offshore Economic Zone
OSIS	Ocean Surveillance Information System
OSS	Ocean Surface Surveillance
OTH-R	Over-the-Horizon Radar
OTI	Ocean Traffic Identification
OTIS	Offshore Traffic Information System
OVTM	Offshore Vessel Traffic Management
OVTS	Offshore Vessel Traffic Safety
PES	Port and Environmental Safety
PIRS	Pollution Information Reporting System
P.L.	Public Law
PIO	Polar Ice Operations
PPI	Plan-Position-Indicator
PREC	Pollution Response and Environmental Coordination
PSS	Port Safety and Security
QPSK	Quadraphase-Shift-Key
RA	Radionavigation Aids
RACON	Radar Beacon (transponder type)
R&D C^2	Command and Control Research and Development
RBS	Recreational Boating Safety
RCS	Radar Cross Section
RDF	Radio Direction Finder
RF	Radio Frequency
RPV	Remotely-Piloted Vehicles
RSS	Remote Sensing System
RT	Reserve Training
SAR	Search and Rescue
SAR	Synthetic Aperture Radar
SARSAT	Synthetic Aperture Radar Satellite

APPENDIX A

SECTION 3 OF THE PORT AND TANKER SAFETY ACT (P.L. 95-474), 17 OCTOBER 1978

APPENDIX B

MONITORING AND ENFORCEMENT PROCESSES APPLIED TO FOREIGN FISHING VESSELS IN THE U.S. FISHERY CONSERVATION ZONE

The enforcement process follows these steps:

1. Alert of illegal fishing*
2. Notification of local Coast Guard Marine vessels
3. Determination of subject vessel's position location
4. Search for the subject vessel
5. Detection of the subject vessel
6. Identification of subject vessel
7. Assessment of the situation
8. Intervention
9. Boarding of the vessel and factual determination of illegality
10. Prosecution.

*Some violations of the Fishery Conservation and Management Act are: fishing in closed areas of the FCZ, exceeding catch quotas on fish size and species, and ignoring gear restrictions.

APPENDIX C

DATA FOR THE ENFORCEMENT OF LAWS AND TREATIES MISSION

TABLE C-3. FCMA ENFORCEMENT DATA FOR FOREIGN FISHING VESSELS (1978)

Foreign Fishing Vessels Present	3,858
Vessel Boardings (Planned)	1,200
Vessels Boarded	1,076
Citations Issued	206
Reports of Violations Issued	94
Seizures	10
Penalities Collected in Seizure Cases	$682,600
Proposed Civil Penalties	$ 87,500
Civil Penalties Paid	0

TABLE C-4. FCMA ENFORCEMENT DATA FOR DOMESTIC FISHING VESSELS (1978)

Vessel Boardings	1,424
Vessels Boarded	1,318
Citations Issued	43
Reports of Violations Issued	47
Seizures	0
Proposed Civil Penalties	$19,922
Civil Penalties Paid	$ 3,656

Sources: U.S. Coast Guard
National Marine Fisheries Service

APPENDIX D

THE UNITED NATIONS CONFERENCE ON THE LAW OF THE SEA: A SUMMARY OF OBJECTIVES AND AN UPDATE OF RESOLUTIONS

4. General acceptance has been won to set new rules which would strengthen the right of a coastal state to impose penalties within its territorial sea. These rules would emphasize that a coastal state can act to mitigate pollution following a massive casualty; and they would clearly state the power of a coastal state to board, inspect, and detain ships which have made illegal discharges within its exclusive economic zone.

5. The most sensitive issue of the conference is the mining of seabed resources. Under the American compromise proposal which was accepted during negotiations in 1977 and 1978, there would be an International Seabed Authority. Private corporations and state enterprises would mine under license of the Authority for a share of revenues. The Authority through its organ called the Enterprise, would mine for the Third World financial advantage. The richer nations offered to make available to the Enterprise both seabed mining technology and capital needed for such a large, sophisticated, and high-technology business.

APPENDIX E

DATA FOR THE SEARCH AND RESCUE MISSION
(1977)

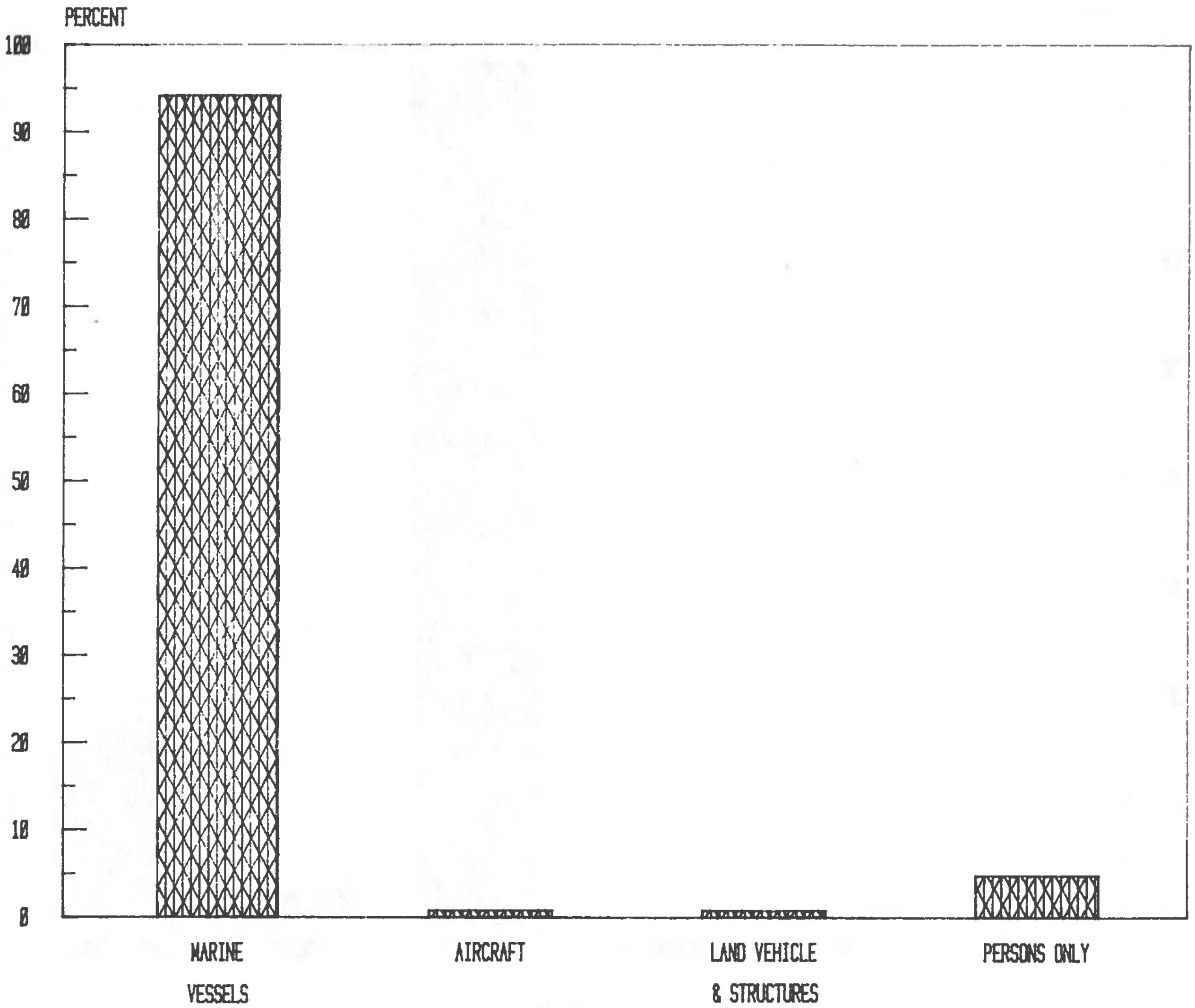

FIGURE E-2. PROFILE OF SAR SUBJECTS

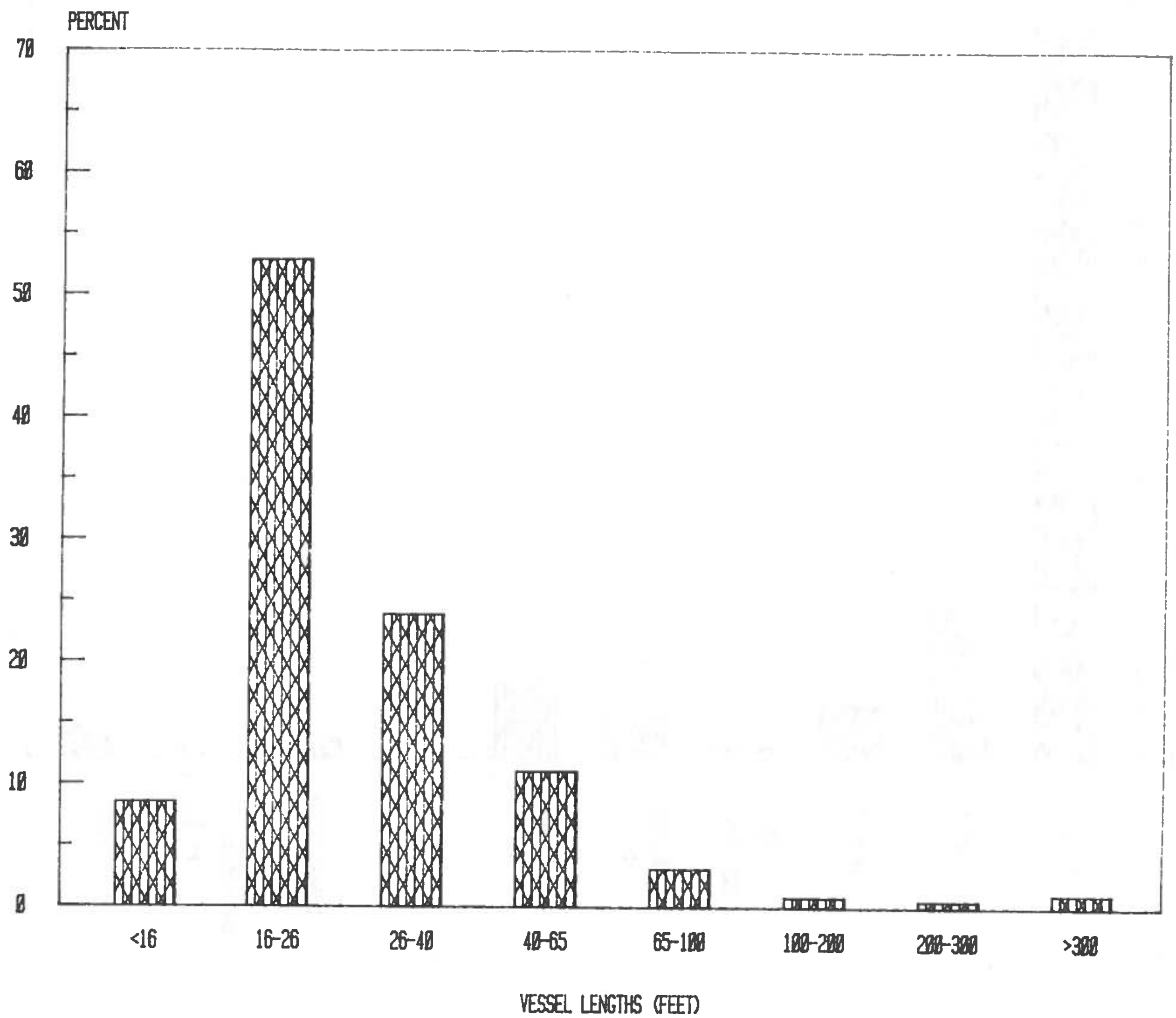

FIGURE E-4. COMPARATIVE LENGTHS OF SAR-ASSISTED MARINE VESSELS

TABLE E-1. SAR CASELOAD DISTRIBUTION, PAST AND PROJECTED

DISTANCE OFFSHORE	NO. OF CASES	FY-78 % OF CASES	CUMM %	FY-93 PROJECTION NO. OF CASES	FY-93 PROJECTION % OF CASES
LAND	3205	4.8	4.8	7153	5.9
0-3m	51716	76.8	81.6	92537	77.3
3-10m	7964	11.7	93.3	19394	12.3
10-20m	2426	3.6	96.9	4341	3.3
20-50m	910	1.3	98.2	1017	0.7
50-100m	574	0.9	99.1	636	0.4
100-150m	150	0.2	99.3	96	0.1
150-300m	169	0.3	99.6	123	0.1

Table E-1 presents the distribution of requests for assistance received in FY78 by distance offshore. The growth rates presented are based upon regression.

APPENDIX F

DISCUSSION OF MISSIONS WITH SECONDARY REQUIREMENTS FOR A VESSEL MONITORING SYSTEM

F.1 MARINE SCIENCE ACTIVITIES (MSA)

Through its Marine Science Activities (MSA) mission, the Coast Guard conducts oceanographic data collection surveys that support the other missions of Search and Rescue (SAR), Marine Environmental Protection (MEP), and the International Ice Partol (IIP). The detailed functions of the MSA mission are directed toward the collection of specific data in support of drift forecast verification or other R&D related to iceberg movement. Likewise, the MSA mission procedures are contingent upon the particular objectives of the supported missions (SAR, MEP and IIP). This conditional nature of MSA's multi-mission support role makes it difficult to clearly enumerate mission functions, processes, and requirements for any given time. The oceanographic surveys require the use of one cutter specifically assigned to MSA. Depending upon availability, other cutters may be assigned.

One principal MSA-supported mission that can illustrate select MSA functions and requirements relative to a vessel monitoring system application is the International Ice Patrol. The major function of the IIP is to provide information, via radio broadcast, about iceberg location and movement in the North Atlantic to vessels that sail the routes in this area. The Coast Guard conducts the IIP on behalf of the international North Atlantic users, who pay back about 90 percent of the patrol's operating costs.

Current IIP operational procedures for determining iceberg movements involve monthly aircraft flights to spot icebergs along the east coast of Newfoundland and the southern Labrador Sea; current movement monitoring by satellite-tracked drifting buoys; and computerized forecasting to predict iceberg movements for the next bulletin (14). Data from these flights allow a map of the major ice fields to be charted. However, the existing IIP system does not provide accurate information on icebergs located on the outer edge of the iceberg zone. This limitation is critical because, as the ice fields approach warmer waters, the outer-zone icebergs frequently break off and move separately, necessitating routing diversions for vessels in the area.

IIP functions would be improved by a vessel monitoring system with all-weather capability to monitor icebergs on the outer edge of the ice field at a frequency of once every three days. A VMS providing iceberg data from remote sensors included with the sighting reports already supplied on a cooperative

Pollution Fund, and providing Coast Guard representation in interagency, industry, and international groups involved in emergency response technology and planning.

Similar to several other missions, PREC does not have any requirements for an offshore monitoring system (VMS), but this mission would receive some benefits if one were operating. These benefits would probably be in the form of supporting data about the occurrence, the size, and the movement of an oil or hazardous cargo spill.

However, a cost-effective monitoring system designed to detect vessels is not likely to have the capability to reliably detect petroleum or chemical discharges on the ocean waters because of the different reflective properties of vessel structures and petroleum or chemical materials. In addition, the monitoring revisit periods must be more frequent for fluids and chemicals than for vessels because of these substances' dispersive properties. Therefore, no quantifiable benefits of a VMS have been identified for this mission.

F.4 WATERWAYS MANAGEMENT (WM)

Waterways Management is a newly defined program which includes and combines parts of two previous programs: Marine Environmental Protection and Port Safety and Security. Waterways Management includes the following major activities:

(1) development and implementation of Vessel Traffic Services (VTS) for U.S. ports and inland waterways;

(2) development of national marine traffic management plan;

(3) supervision of regulations and administration of Federal anchorages, safety and security zones, and regulated navigation areas;

(4) development of rules and regulations for the prevention of collisions, groundings, and rammings (including Rules of the Road, vessel equipment requirements, and pilotage areas);

(5) provision of U.S. representation and leadership in the following groups: IMCO Navigation Safety Subcommittee, Rules of the Road Advisory Committee and SOLAS subcommittee working group on navigation safety; and

to fishing operations; and

operating a system of information and notification.

This system consists of (1) nautical charts published by National Ocean Survey, showing aids to navigation; (2) United States Coast Pilots (also published by the National Ocean Survey) containing detailed supplementary navigation information; (3) light lists published by the Coast Guard that provide more complete and detailed information regarding the aids (including radionavigation aids) than is normally found on charts; (4) Local Notices to Mariners, published by each of the twelve Coast Guard Districts, to advise mariners concerning changes or discrepancies in the system of aids; and (5) Weekly Notices to Mariners published by the Defense Mapping Agency Hydrographic/Topographic Center, which compiles more extensive advisory information including foreign marine information.

F.6 LONG-RANGE RADIONAVIGATION AIDS (RA)

The U.S. Coast Guard operates or assists in the operation of these navigation systems:

1. LORAN-A: This service will be terminated by 31 December 1980.

2. LORAN-C: This is the radionavigation system provided by the U.S. Government for civil marine use in the coastal and confluence zone. With the exception of one station operated by Canada, the stations providing coverage for the U.S. are operated by the Coast Guard. This system has a useful range of approximately 1000 nm and will, after 1980, provide complete coverage for the Coastal Confluence Zone (CCZ) of the contiguous 48 states and southern Alaska. (Figures F.6-1 and F.6-2 illustrate LORAN-C coverage areas.) The adequacy of radionavigation service in the areas of Hawaii, Puerto Rico, and the U.S. Virgin Islands is under study to determine the need for future expansion of LORAN-C service to these areas. State-of-the-art LORAN-C receivers used with the latest edition LORAN-C charts can provide position with predictable accuracy of 0.25 nm (2-drms) or better throughout the present coverage area. By 1980, there will be a total of 39 LORAN-C transmitting stations, reflecting a Government investment of $218 million. The Coast Guard is pursuing these improvements in LORAN-C utilization:

(1) Cost-effective receiver design;

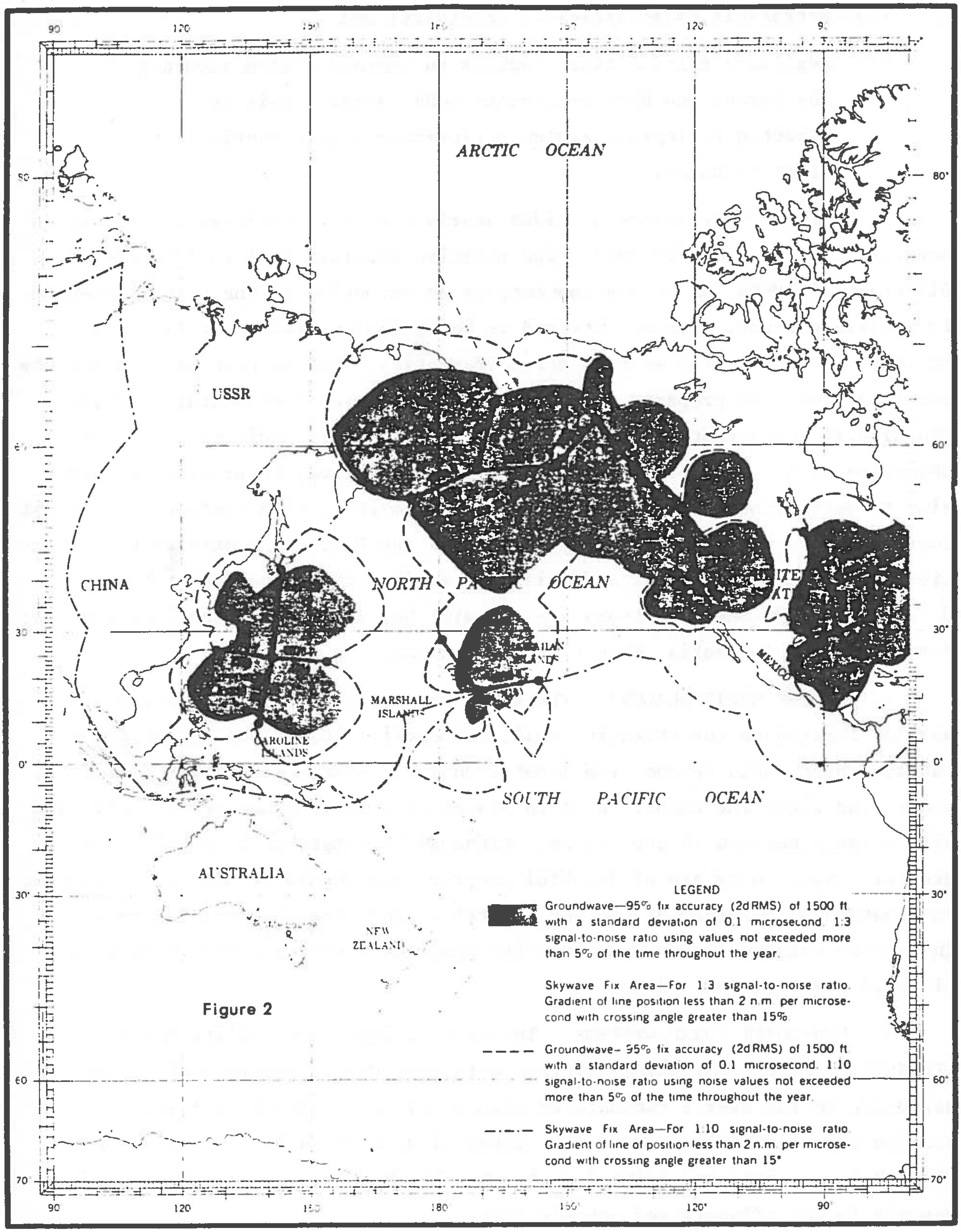

FIGURE F.6-2. PACIFIC COVERAGE OF LORAN-C

F.7 COMMERCIAL VESSEL SAFETY (CVS)

The objectives of this mission are to regulate and promote safety in the following marine elements:

1. U.S. vessel design, construction, maintenance and operation, and manning
2. All offshore oil and gas exploitation installations
3. All foreign flag vessels operating in waters subject to U.S. jurisdiction, and in conformance with applicable international agreements, resolutions, and conventions.

The Commercial Vessel Safety mission is mandated by statutes. The workload for the mission is affected directly by the expansion and construction of the marine transportation and ocean industries, the economic aspects of which are governed by law. It should be noted that some portions of marine and vessel safety dealing with foreign flag vessels pertain to the Port and Environmental Safety mission.

The Commercial Vessel Safety Program may be divided into three functions: (1) analysis of statutes and treaties, and development of implementing regulations therefrom; (2) planning of review and inspection of vessels under construction, and once constructed, periodically while in service; (3) investigation of marine casualties and reports of seamen misconduct, incompetence. negligence, or violation of narcotic drug laws.

In response to the Presidential Initiatives of 1977 and the Port and Tanker Safety Act of 1978, the Coast Guard is implementing a comprehensive Marine Safety Information System (MSIS). The interim MSIS, which has been operating for three years, is being phased out in favor of an interactive, transaction-oriented system which has been under development since 1973. This MSIS will contain information on all U.S. and foreign vessels of interest to the Commercial Vessel Safety, Environmental Protection, or Port Safety and Security Programs. This information will be used and largely supplied by field units to insure compliance with safety standards, The Military Operation/Preparedness mission involves the following major elements:

1. To allow ready and effective use of its military equipment and personnel in times of national emergency and war;

2. In the course of the overall Coast Guard mission of traffic facilitation and law enforcement, to gather intelligence of value to National Security and the DOD;

3. To direct and operate civil defense operations in marine waters;

4. To provide military support to adjacent 200-mile exclusive economic zone operations by the U.S., in the absence of an international treaty governing such operations; and

5. To combat terrorist activities in the U.S. waters.

Coast Guard vessels are equipped with communications gear and short-range weapons. Through periodic at-sea cooperative training exercises, vessel crews are trained to operate the vessel and weapons in accordance with DOD standards. Coast Guard personnel involved in this mission are kept informed by the DOD of naval weapons and sensor technology for weapons/mine detection.

APPENDIX G

DATA FOR THE VESSEL POPULATION PROFILE

TABLE G-2. OFFSHORE VESSEL POPULATION-SMALL COMMERCIAL VESSELS

		REGION			
YR	SUBZONES	EAST COAST	GULF COAST AND CARIBBEAN	PACIFIC COAST	ALASKAN COAST
1979	0-3 nm	840	120	345	12
	3-200 nm	210	180	85	3
	TOTAL NO. OF VESSELS	1,050	300	430	15
1985	0-3 nm	1,000	145	410	14
	3-200 nm	260	215	100	4
	TOTAL NO. OF VESSELS	1,260	360	510	18
1990	0-3 nm	1,150	165	470	17
	3-200 nm	300	250	120	4
	TOTAL NO. OF VESSELS	1,450	415	590	21

TABLE G-4. OFFSHORE VESSEL POPULATION-RECREATIONAL VESSELS

		REGION			
YR	SUBZONES	EAST COAST	GULF COAST AND CARIBBEAN	PACIFIC COAST	ALASKAN COAST
1979	0-3 nm	7,400	7,000	5,400	200
	3-200 nm	1,850	1,750	1,350	50
	TOTAL NO. OF VESSELS	9,250	8,750	6,750	250
1985	0-3 nm	8,800	8,240	6,400	240
	3-200 nm	2,200	2,060	1,600	60
	TOTAL NO. OF VESSELS	11,000	10,300	8,000	300
1990	0-3 nm	9,600	9,120	7,040	260
	3-200 nm	2,400	2,280	1,760	65
	TOTAL NO. OF VESSELS	12,000	11,400	8,800	325

TABLE G-6. AREAS OF VESSEL CONCENTRATION-GULF REGION (VESSELS ≥40' LONG)

PEAK DATE	TOTAL REPORTED SIGHTINGS	% VESSELS ≥40' LONG	WINDOW/AREA	CONCENTRATION	NUMBER OF VESSELS	VESSEL TYPE
3/13/80	96	.78	24°56'N-25°06'N 82°31'W-82°41'W	Moderate	10	Fishing
			25°04'N-25°14'N 82°13'W-82°23'W	Low	8	Fishing
			25°18'N-25°28'N 82°23'W-82°33'W	Low	9	Fishing
			25°20'N-25°30'N 81°51'W-82°01'W	Low	9	Fishing
			25°25'N-25°35'N 82°01'W-82°11'W	Low	9	Fishing
			24°30'N-24°40'N 82°07'W-82°17'W	Moderate	10	Fishing
			24°41'N-24°51'N 81°56'W-82°06'W	Moderate	18	Fishing
			24°56'N-25°06'N 81°50'W-82°00'W	Low	8	Fishing
			25°31'N-25°41'N 83°35'W-83°45'W	Moderate	12	Fishing

APPENDIX H

SURVEY OF VESSEL MASTERS/OWNERS

OFFSHORE VESSEL ANALYTICAL SUPPORT

VESSEL MASTERS/OWNERS SURVEY

INTRODUCTION

Hello, my name is ____ and my company Input Output Computer Services is doing some research for the Department of Transportation and the Coast Guard. You were recently contacted about participating in a survey and agreed to discuss several questions with us at this time. As mentioned the last time we spoke with you, the purpose of this survey is to determine if your constituents would be willing to participate in a system designed for the Coast Guard to track vessels in the U.S. Fishery Conservation Zone (0-200 nm from shore). This system would greatly improve the Coast Guard's ability to provide emergency services to vessels. We would like you to answer the survey questions in a manner that you believe represents the predominant view of vessel masters/owners that make up your constituency. (INTERESTED IN VESSELS 40 FEET OR MORE IN LENGTH. IF RESPONDENT REQUESTS MORE INFORMATION ABOUT THE PURPOSE OF SURVEY, REFER TO THE PROJECT FACT SHEET.)

5. What percentage of these vessels are of United States Registry?

   a) Percent of U.S. Registry ___________
   b) Percent Foreign Registry ___________

6. On average, how many days per month are your constituents' vessels used?

7. Are the vessels used more frequently during the weekends than during the week? (Try to determine if the vessels are used more frequently during any particualr part of the week.)

8. Are the vessels used uniformly throughout the year or does their use peak at various times during the year?

11. The required information on vessel location could be transmitted to the Coast Guard shore station by voice radio, by teletype, or by an automatic radio report.

If necessary, do you think your constituents would be interested in purchasing an additional piece of equipment so they could transmit their position automatically with ID protection to the Coast Guard shore station?

(INDICATE THAT A BENEFIT OF THIS SYSTEM WOULD BE IMPROVED COAST GUARD SEARCH AND RESCUE CAPABILITIES.)

Percent Interested	Percent Unsure	Percent Not Interested
______	______	______

12. Do you have any suggestions of other ways the Coast Guard could gather this information in a manner agreeable to vessel operators?

____

____

____

____

____

THAT COMPLETES THIS SURVEY. WE APPRECIATE YOUR ASSISTANCE. PLEASE BE ASSURED THAT THE INFORMATION YOU PROVIDED WILL BE KEPT IN STRICT CONFIDENCE.

APPENDIX I

EFFECTIVENESS ASSESSMENT

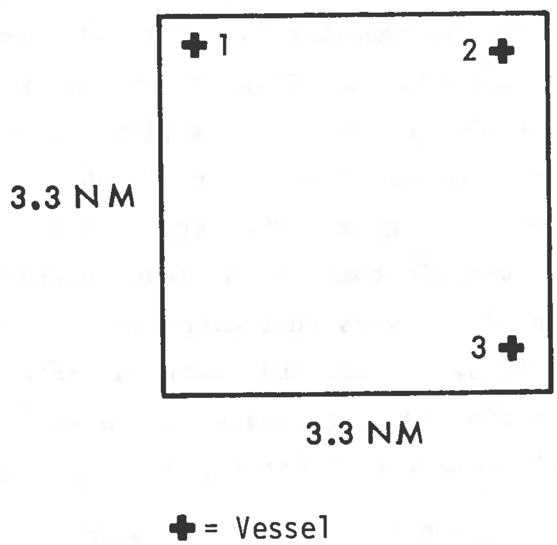

FIGURE I-1. 10-NM AREA WITH 3 VESSELS AT TIME 0

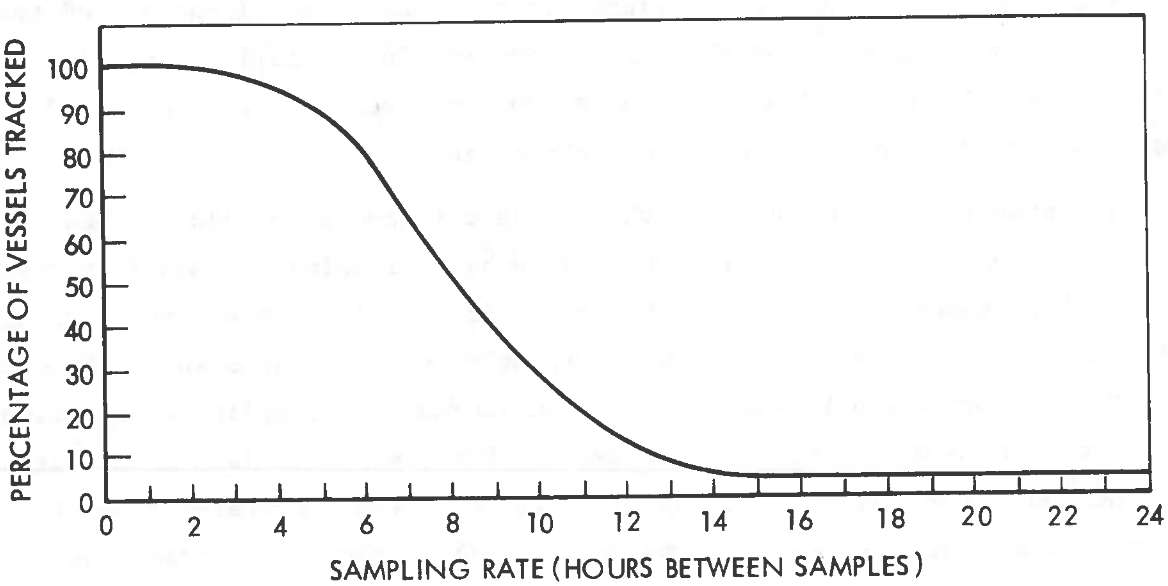

FIGURE I-2. TOTAL COOPERATIVE POPULATION

TABLE I-1. OTIS COSTS VERSUS SYTEM SAMPLING PERIOD ($M)

Sampling Period (Hours)	0.25	0.5	1	2	3	4	5	6	7	8	9	10	11	12
Aircraft Modification ($M) (Commercial & C130)	28.8	14.4	7.2	4.8	4.8	2.4	2.4	2.4	2.4	1.6	1.6	1.6	1.6	1.2
Sensors	432.0	216.0	108.0	72.0	72.0	36.0	36.0	36.0	36.0	24.0	24.0	24.0	24.0	18.0
Operating Costs: Commercial	184.08	92.04	46.02	23.01	15.34	11.505	7.67	7.67	7.67	5.12	5.12	5.12	5.12	3.84
C130	7884.0	3942.0	1971.0	985.5	657.0	492.75	410.625	328.5	328.5	220.1	220.1	220.1	220.1	164.25
Communications (Equip. & Operations)	6.9	3.45	2.07	1.38	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Computer (Equip. & Operations)	421.38	252.828	168.552	105.345	84.276	84.276	84.276	84.276	84.276	81.276	81.276	81.276	81.276	81.276
Vessel Monitoring System	15.281	15.281	15.281	15.281	15.281	15.281	15.281	15.281	15.281	15.281	15.281	15.281	15.281	15.281
Development (Computer included above)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Prototype Evaluation (Operating costs only; equip. included above)	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61
Total ($M)	8988.751	4552.309	2334.433	1223.626	865.697	659.212	575.652	491.127	491.127	364.377	364.377	364.377	364.377	300.847

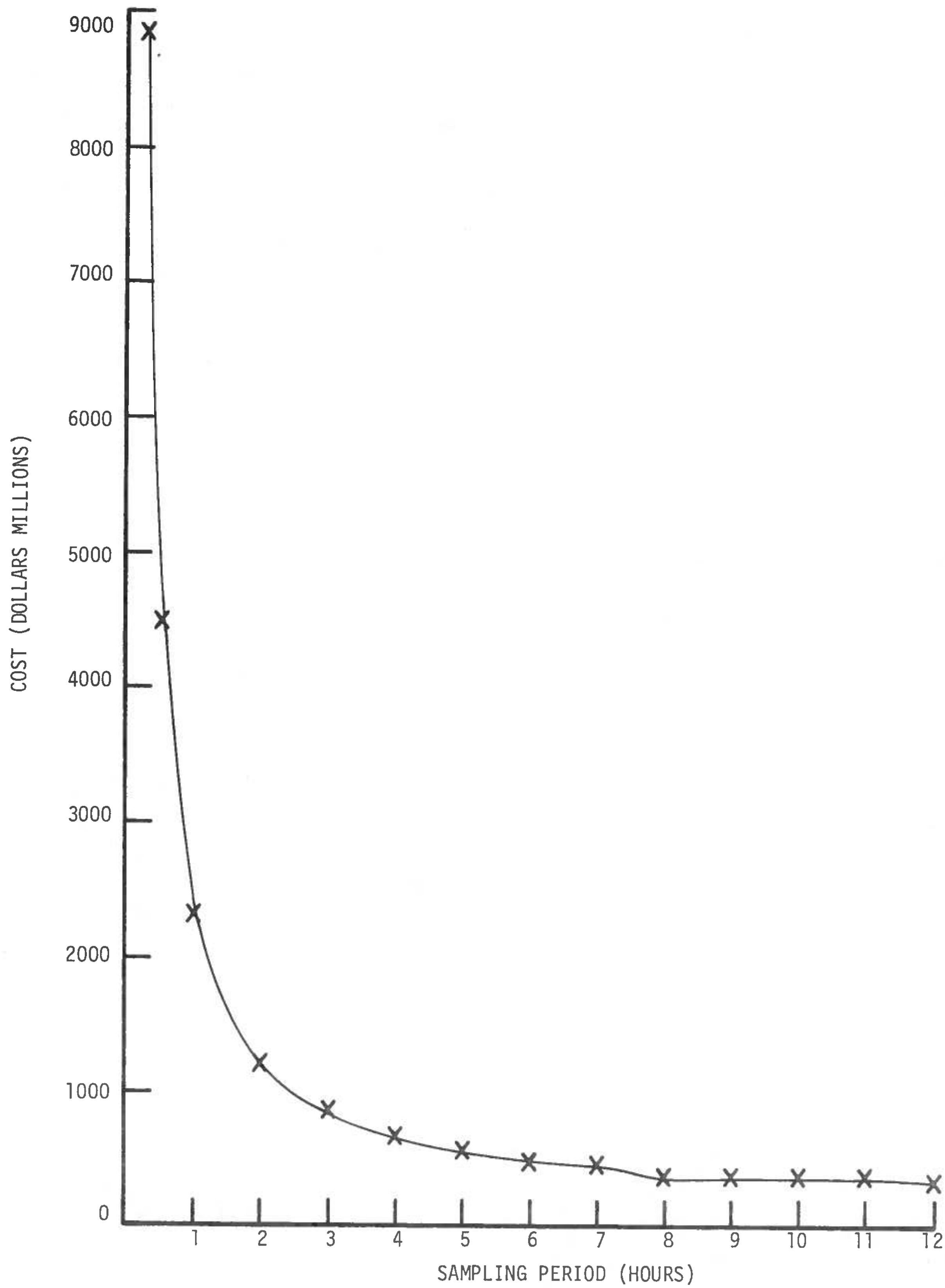

FIGURE I-3. TOTAL OTIS COSTS VERSUS SYSTEM SAMPLING PERIOD

APPENDIX J

COMMUNICATIONS DESIGN CONSIDERATIONS

Sky-wave propagation is the dominant mechanism in communication from 5 to 25 MHz beyond 100 miles. In this transmission mode, radio waves are reflected back to earth from ionospheric layers which provide a sharp dielectric gradient to the transmitted wave. Unfortunately the layers vary in location and strength diurnally, seasonally, and with sunspot activity. A communications link in this frequency band would be subject to frequent loss of contact with ships beyond 100 miles range. Fading, which results from out-of-phase interference between groundwaves and skywaves, would cause loss of contact closer in for higher frequencies. In addition, interference from ship and non-ship transmitters several hundred miles away would be problematical.

Line-of-sight propagation considerations apply to frequencies above 30 MHz, although sky-wave signals are occasionally experienced at these frequencies as well. Reflections from the ocean can occasionally result in severe fading under smooth sea conditions; this effect is most noticeable at short ranges (less than 5 miles) and high frequencies (greather than 3 GHz). At frequencies above 10 GHz, horizon communication is often lost because of attenuation by rain; X-band radars (9.4 GHz) suffer reduced range because of heavy rainfall. High altitude platform relays could be used to 150 miles (blimps), or even out to 500 miles (high-altitude aircraft), with similar rainfall limitations. Satellite communication, on the other hand, can be attained up to 15 GHz, since the vertical thickness of the attenuating medium is small, typically less than 2 miles; even with satellites, attenuation by rain can cause signal dropout at low-elevation angles.

In order to provide vessels with emergency and traffic control services, it is necessary to have a continuous shore-to-ship communications. Outages (e.g., by fades) of more than a few seconds would not be tolerable. Therefore, the frequency band from about 4 to 20 MHz would not be adequate. Likewise, the use of communication by meteor trails would not be adequate for this purpose.

For obtaining initial information about the ship, this limitation does not apply, because the information is not time-critical.

J.2 USE OF EXISTING COAST GUARD RADIO SYSTEMS

The maritime mobile radiotelegraph segment, from 415 to 490 kHz, is used for distress alert, Automated Marine Mututal-assistance Emergency Rescue

J.3 VOICE/DATA MULTIPLEXING

If data were transmitted over the same channel as voice, it could occupy one of three audio bands within the channel: subaudible (0-300 Hz), audible (300 - 3000 Hz), or superaudible (3000-10,000 Hz). Subaudible data multiplexing is limited to low-data rates, namely 100 baud. Audible data multiplexing would result in "beeps" being heard each time a data transmission from a neighboring ship or shore station occurs - this is potentially irritating. Superaudible data multiplexing is technologically feasible now, because of the availability of inexpensive crystals which have good frequency stability. Up to now, the frequency drift of receivers limited the useful bandwidth of a 25 kHz channel to about 12 kHz (double sideband AM). This capability should be considered in any system design requiring data transmissions.

J.4 SATELLITES

Satellite marine communication via MARISAT is finding wider application and increased usage in the civilian sector. Costs per message are decreasing, and reliability is high; availability is continuous. Satellite terminals can be leased as well as purchased, so that the capital investment of a shipping company need not be high during a trial period. While this alternative has the initial appearance of an "overkill" approach, the fact that it has application in other areas of the maritime industry, and for other Coast Guard missions, renders it worthy of future consideration.

Satellite communication can be used by equipped vessels to transmit initial ship data from out at sea, i.e., beyond line-of-sight communications. The expense of the equipment is still too high for use by smaller vessels, so that satellite communication cannot be chosen as the exclusive means of communication for any function.

J.5 PROBLEMS OF OVERCOVERAGE

If the communications range significantly exceeds the system range requirement, transmissions by vessels (or by ground stations, vehicles, or aircraft) can cause interference in several ways:

a. The unwanted transmissions may obscure or overpower transmissions from ships within the coverage zone.

the coverage zone into small enough areas that a. through c. will not ultimately limit the system capacity. The following cautions should be noted, however:

a. If too many sectors are required, shore watchstanders (SWS) will spend an undue amount of time in handoff procedures, distracting them from their primary traffic control duties.

b. If too much time is spent in bookkeeping duties (i.e., obtaining ship's positions and course data, keying in data, writing data on logs, advancing plotting board targets, etc.) the SWS's effectiveness will be reduced.

In VTS stations at Houston, San Francisco, and Puget Sound, the capacity per operator is 20-30 vessels, with the higher figure able to be sustained for limited periods of time. As a rule of thumb for all-verbal type systems, about N/20 operators would be required to man a station whose coverage incorporated N vessels on the average. Thus, if a station were expected to have 200 vessels at a time within its coverage, about 10 operators would be required. Of course, as more SWS duties are automated, each SWS can handle more traffic comfortably.

Complications stemming from the fact that all SWS's may be using the same channel, and from the fact that adjacent shore stations will have overlapping coverage areas, must be considered in the final assessment of system capacity. For the purposes of this discussion, these complications will be ignored.

The capacity of a communications channel depends on the average message length per vessel, the number of minutes between position reports (update period) and the utilization factor. The utilization factor is the acceptable fraction of time that a given channel can be in use before users begin to encounter excessive waiting time. In a study for the New York VTS, a useful model was developed for the purpose of assessing this problem. It showed that for the New York system, a utilization factor of 0.50 resulted in an expected waiting time of 17 seconds, while a factor of 0.66 resulted in a 33-second waiting time. Waiting times of more than 15 seconds will be iritating to vessel watchstanders (VWS), so that utilization factors higher than 0.5 are to be avoided. Message lengths for position of course reporting is expected

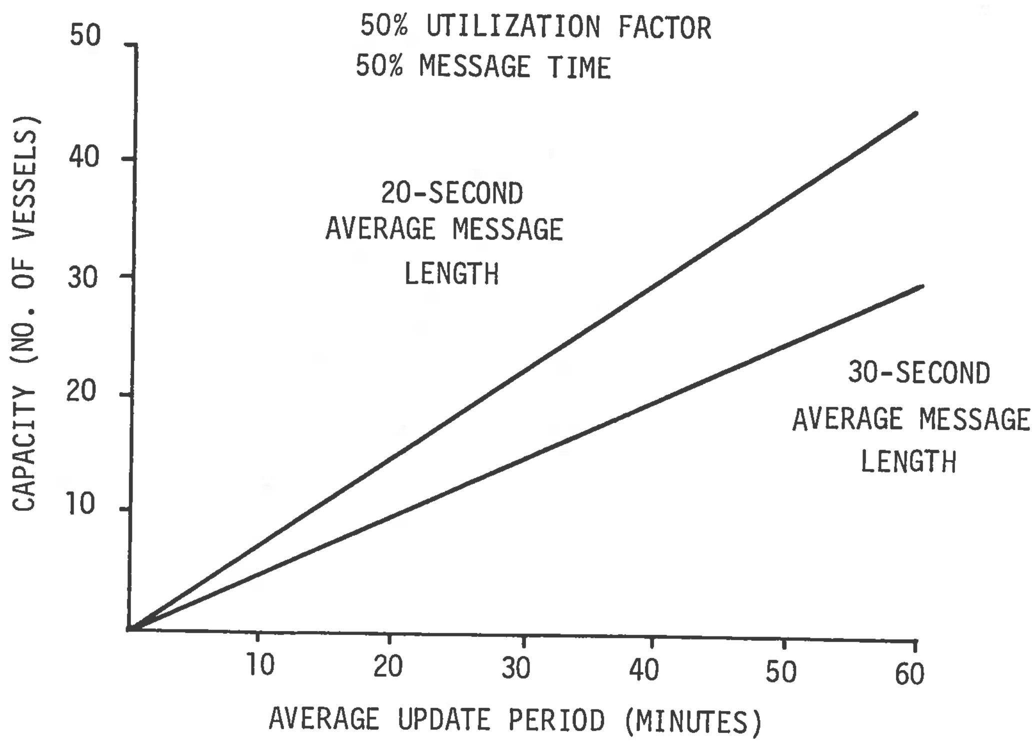

FIGURE J-1. COMMUNICATION CHANNEL CAPACITY AS A FUNCTION OF UPDATE RATE

APPENDIX K

COOPERATIVE MONITORING SYSTEM CONCEPTS

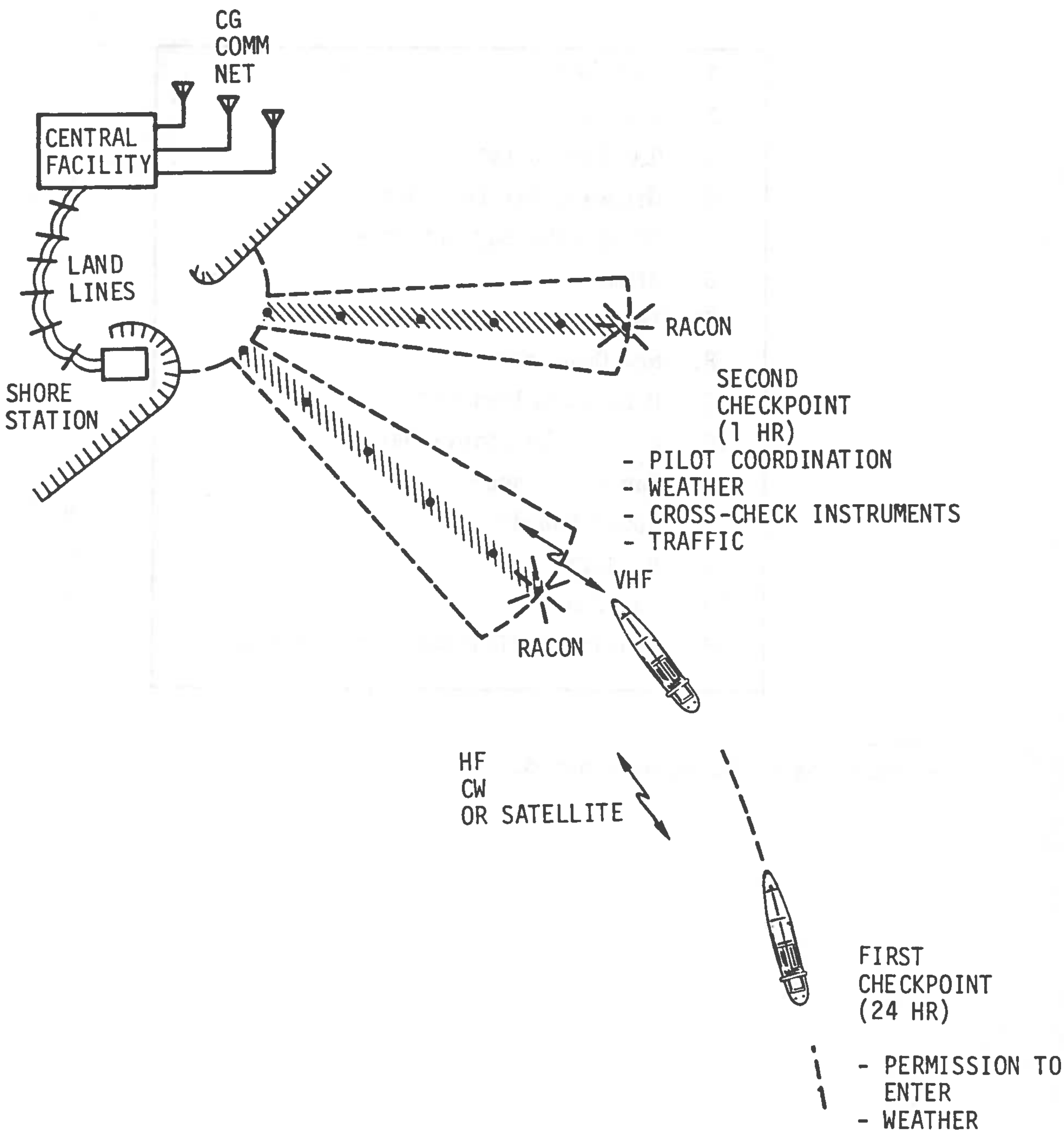

FIGURE K-1. VESSEL PASSPORT SYSTEM

K.2.1 Ship-Initiated Waypoint Reporting--Verbal

In this system, the vessel watchstander (VWS) calls the shore station when a course maneuver is being initiated, when an agreed upon waypoint is reached, or when the voyage plan is altered. The initiative is left primarily with the vessel master; however, if no report has been received within a short time after a scheduled waypoint should have been reached, the shore operator will initiate the call.

In this system the procedure for acquiring new information and assessing the situation would typically consist of the following steps (approximate times, in seconds, are inlcuded parenthetically):

a. VWS calls the shore station (3)

b. Shore Operator (SO) acknowledges call (5)

c. VWS reports t_A, t_B, (LORAN-C coordinates), course, speed, and ETA at the next waypoint (20)

d. (Optional) SO reports data back, receives acknowledgement (20)

e. SO keys in data (15)

f. Computer compares data with projections (5)

g. Computer updates display (5)

h. SO reassesses conflict situation (7).

The total time involved for this exchange is typically 70-90 seconds, depending on whether verification (step d) is included. In VTS systems, verification is not normally performed unless there is an uncertainty on the part of the SO.

The shipboard equipment needed to function in the system consists of a LORAN-C receiver (or equivalent), ship's log, compass, and communications gear (Figure K-2). All of these will normally be on board, but the communications gear may be new. The ship's navigator has to use his skill to correct the heading information to estimate his ship's track or course over ground. In high winds and heavy seas, the vessel courses so estimated are subject to errors of several degrees, so that the shore station should not expect highly accurate predictions of position based on reported course and speed.

The shore station equipment consists of communications gear, a plotting board or other display, handwritten voyage plans, and a computer with a keyboard console. For each vessel the computer keeps a ship's file on her progress, corrects ETA's, and searches for possible conflicts. In a "barebones" version, the operator would perform all functions, without a computer or computer-driven display.

This system has the advantages of familiarity, simplicity of concept, minimal shipboard equipment, and moderate demands on the vessel master for communications. Since the shore operator acts as a backup by calling up the vessel if a waypoint ETA has been exceeded, there is some desirable redundancy in the system.

On the other hand, the system is limited in capacity and forces the SO to spend an excessive portion of his time performing bookkeeping duties (the means to the end), rather than assessing problems and promoting efficient traffic flow (the objectives). As increased traffic causes the communication load factor to increase, the VWS's will encounter frustrating delays in relaying their positions. Also, shore operators will find themselves competing for the access to the channel (assuming that there is one common frequency).

From Figure J-1 (Appendix J) it is apparent that requiring position reports more than once per hour limits the amount of traffic that can be handled to 30 vessels at most. To get an update rate that would enable a shore operator to provide collision assistance, an update period of 15 minutes or less would be required. This would limit capacity to 7-8 vessels. Consequently, it would be most effective precisely where it is least needed, i.e., in areas of low density traffic.

From these considerations and others involving the different purposes of VTS and offshore systems, it is therefore concluded that there is no case that can be made for monitoring systems using verbal reports of position.

K.2.2 Automatic Coded Roll-Call, Coded Reply

In this system it is assumed that the onboard encoder module is driven directly by the LORAN-C navigation unit, the ship's log, and a heading indicator; the vessel master and vessel watchstander are not involved in the transmission. Course is calculated on shore using consecutive fixed and

Advisories would provide helpful information which might not be available or known to him.

The capacity of this system is limited by the time spent in communicating with unequipped vessels and logging new entries into the system.

The equipment implications are shown in Figure K-3. The ship must have navigation gear, interface equipment, an encoder module, and a data transmitter and receiver (if separate voice and data channels are required).

This system has a high inherent capacity and allows for a high operator workload; it makes minimal demands on the vesselmaster. It does, however, require sophisticated equipment.

K.3 SURVEILLANCE SYSTEMS

Surveillance systems can be ship-initiated or roll-call; their detection can be cooperative or noncooperative; they can use radar, range/range, or multilateration techniques to establish ship's positions. Fundamentally, however, there are two surveillance system types:

a. Those in which the surveillance position measurement is primary, and the ship's reported position is used only for verification, if at all.

b. Those in which the surveillance data is used as a check and a backup in case of the ship's failures, and the ship's reported position is primary.

As stated earlier, the surveillance system range must be matched by the communication range to be useful. Thus, if a satellite system enabled the shore to know ship position accurately anywhere on the globe, it would be of limited usefulness if immediate radio contact were limited to VHF. Therefore, a satellite surveillance system must have the capability of rapid selective calling via voice circuits to be effective.

There are several other considerations. One is that with the requirement of LORAN-C or satellite navigation, ships will know their own position quite accurately; a surveillance system would only help establish position where coverage gaps exist or where onboard gear is malfunctioning. Another is that the loss of position information by a ship is not as critical a situation as for an aircraft in an air traffic system; ships have several ways of navigating. In fact, only a minority of ships have accurate navigation gear today.

These considerations all indicate the limited additional service provided by surveillance. However, the three systems discussed below could offer some real benefits.

K.3.1 Direction-Finding (DF) Surveillance

This is an inexpensive system which can be used as a backup where a ship's navigation equipment is questionable. Figure K-4 shows a DF system which provides cross-bearings upon receiving a VHF transmission from a vessel. A vessel master requesting such assistance would radio the shore station. The shore operator would set up the DF switches and ask the master to key his VHF transmitter on a particular channel. The SO would then provide the master with LORAN-C time or latitude/longitude coordinates or references to radar targets or visual cues.

DF systems are now being used (single-bearing) to determine the identity of radar targets.*

K.3.2 Radar

Radars are used in VTS systems to provide shore operators with a display of vessels and land/buoy echoes. They are expensive to install and maintain and are limited to 20-30 miles of range. Their biggest advantages are the update rate (typically 15-20 scans per minute) and the references provided to coastal features. There is also the subjective confidence that "you know it's there if the radar says it's there" whereas a synthetic display of data obtained in an automatic monitoring system would occasionally exhibit jumps in a ship's positions.

Radars can be used to advantage where they already exist in VTS installations.

As transponders are introduced on board ships, they will provide radars with identity of ships; this is not possible at present.

*Thompson, P.M., and J.C. Reame, "Identification of Vessels on a Radar PPI by VHF Direction Findings," Symposium Papers, Vol. 2, Radio Technical Commission for Marine Services, April 1978.

K.3.3 Satellite Surveillance

Since there is presently considerable interest in the applications of satellites to the civil sector, a discussion is included here. Figure K-5 shows how a typical satellite surveillance system would operate. Interrogations from shore would trigger a shipboard transponder; the replies would be received and the time-of-arrival (TOA) measured. The shore station would calculate the ship's position, knowing the TOA's and the satellites' positions. Clearly, this information is of no value without the capability of immediate communications with the interrogated ship. Thus, either a satellite or other long-range communications system is also required.

APPENDIX L

OTH-RADAR APPLIED TO COASTAL SURVEILLANCE

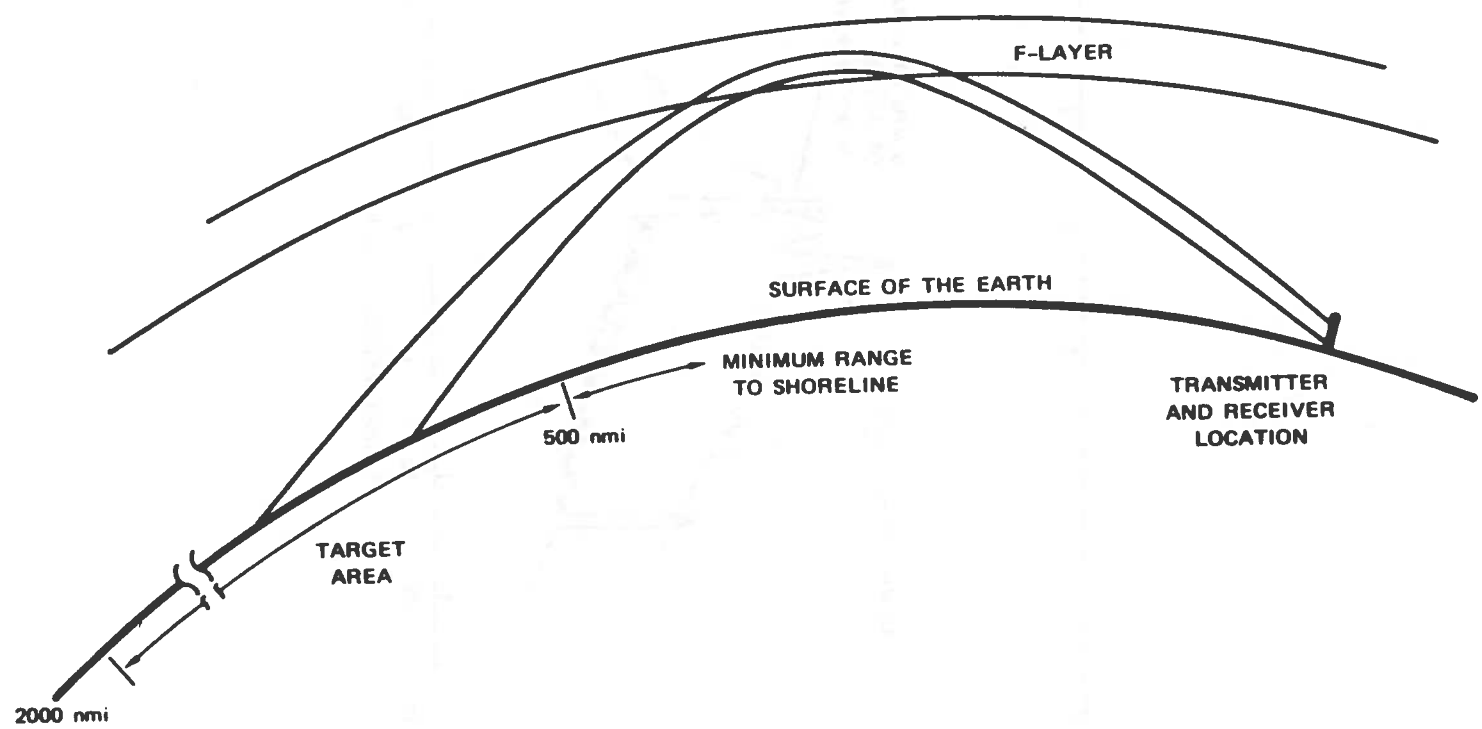

FIGURE L-1. SKY-WAVE OTH-R

clutter amplitude is relatively low because the resonant components are generally small compared to the long wavelength of the operating frequency. In the case of sky-wave, the clutter amplitude is appreciably higher. This has two causes. First, the scattering area is far greater and more clutter is returned. Second, higher operating frequencies must be used (in this case, 16 MHz) and the resonant components of the sea surface have effectively larger cross sections. The radar cross-section of a vessel for the two mechanisms does not differ sufficiently to make up for the difference in clutter levels. Therefore, it is more difficult to detect a target by sky-wave than by surface-wave.

A third difficulty with the clutter of a sky-wave return is the smearing or broadening of the Doppler spectrum. The sky-wave signal must transit the ionosphere at least twice. The motion and turbulence in the ionosphere adds its own components to the Doppler spectrum of the clutter return, causing a broadening of the spectrum. This further restricts the radial velocities that can be detected because the clutter spikes that can mask a target are now wider.

However, the surface-wave technique is not without problems. When using conventional pulse techinques, the pulse length must be rather long--up to 0.5 ms. This will leave a blanked zone of 75 km around the station where no targets can be detected. To cover this area, some other techinique must be used.

L.3 SURFACE-WAVE RADAR

The attenuation of surface waves over water is much less than it is over land. This makes it possible for a radar mounted on the coast to detect vessels the size of fishing boats out to distances of 200 nm. The surface-wave radar, which must use vertical polarization, takes advantage of the fact that nearly all boats have a vertical dimension of at least 35 feet. Even sailing vessels have a mast with a light at the top connected by a wire to a battery, one side of which is grounded. Thus, the vessels provide an adequate target to be detected, but only by a rather large, expensive, and complex radar system. The receiving antenna must be very large, consisting of an array 40 m high by 2.5 km wide. In addition, an average transmitting power on the order of 100 kW is required. In order to get continuous coastal coverage, such radars would have to be set about 300 nm apart all around CONUS, Alaska, and Hawaii. Each radar is estimated to cost about $10 million. As a result, the overall cost is prohibitive and the likelihood of putting so many ungainly structures along our

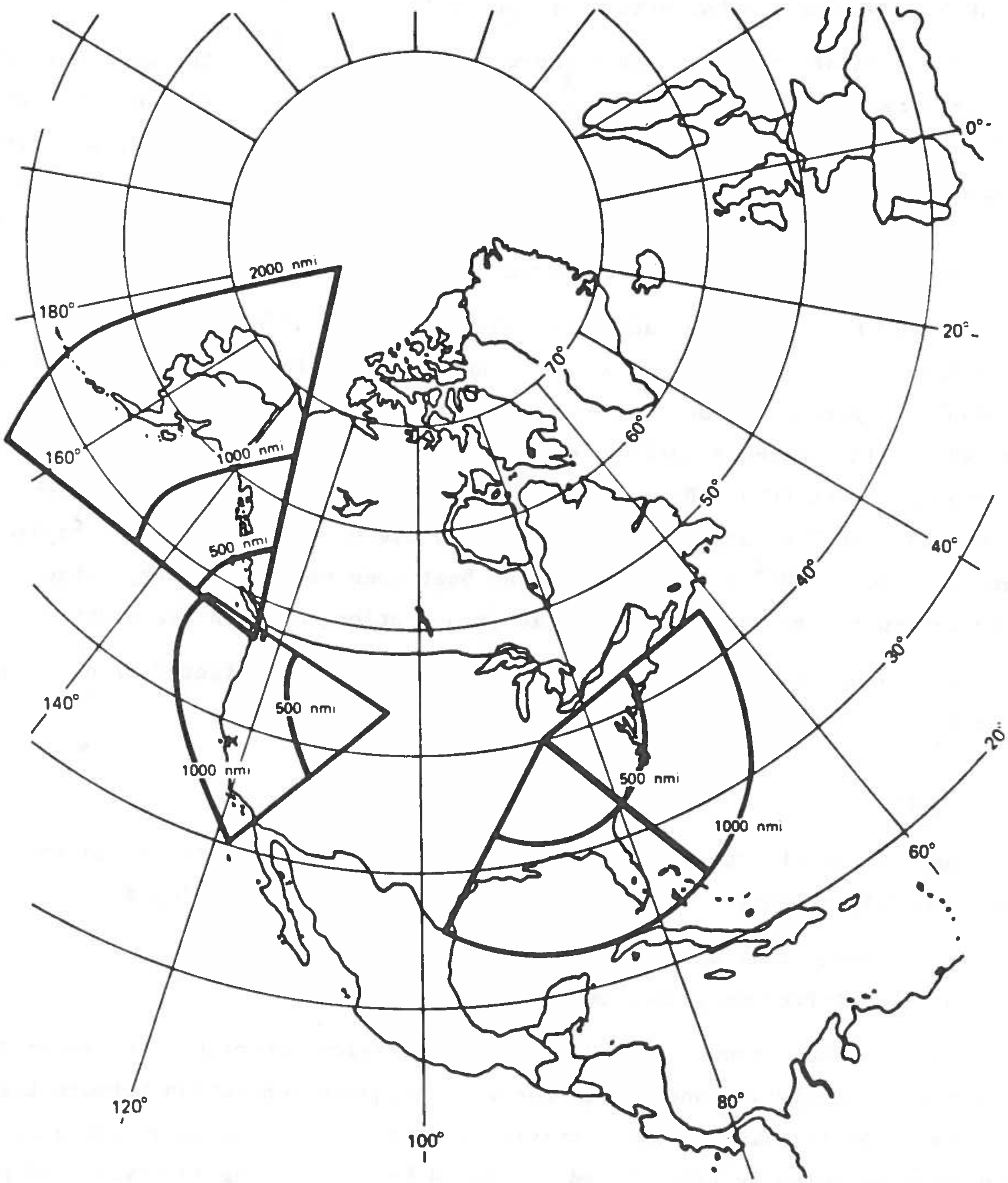

FIGURE L-3. OVER-THE-HORIZON RADAR COVERAGE

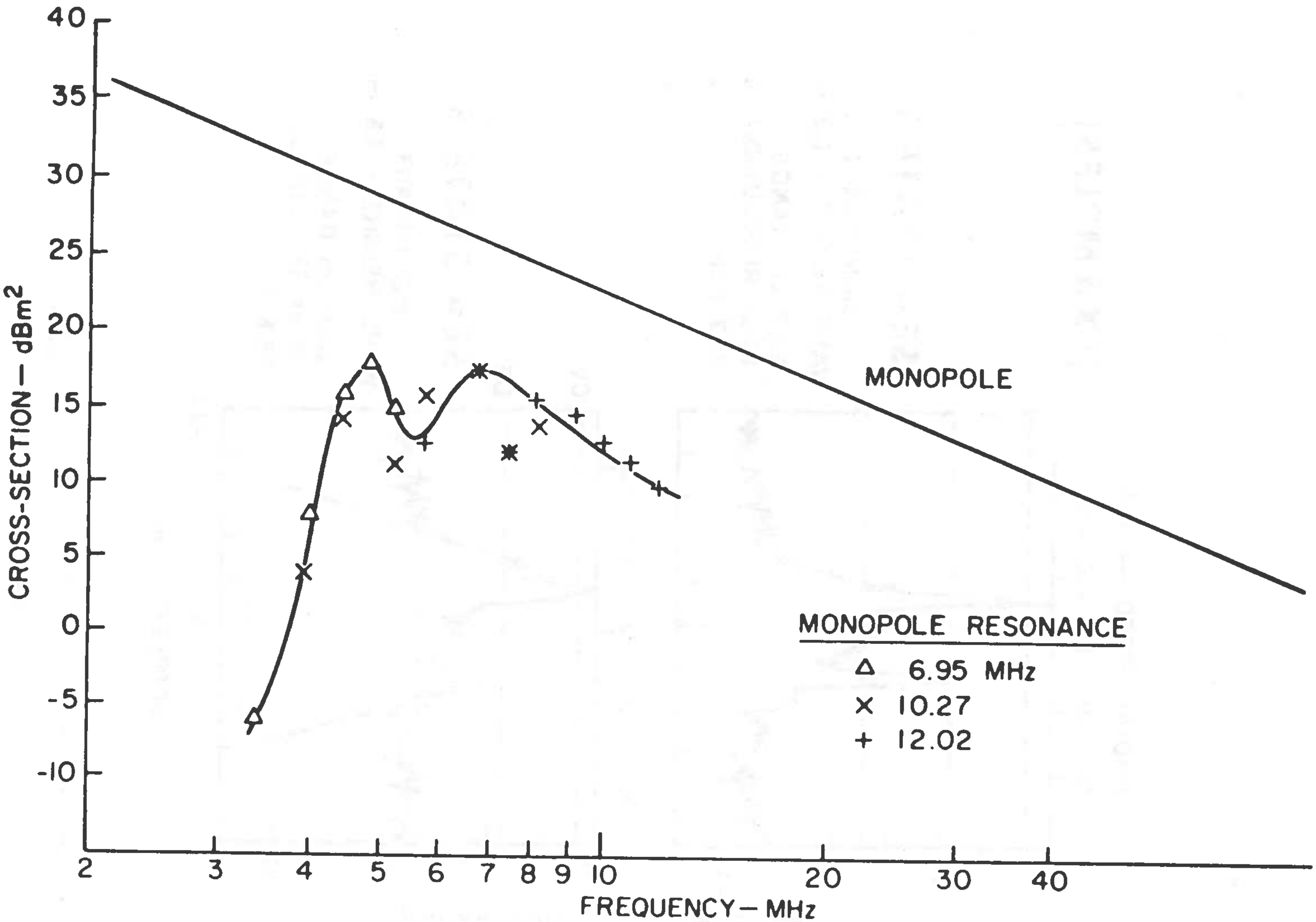

FIGURE L-4. THE CROSS-SECTION AS A FUNCTION OF RADAR FREQUENCY OF A 42-FT FISHING BOAT AS MEASURED FROM A STERN-ON VIEW. BOW-ON VIEW IS ESSENTIALLY IDENTICAL quire a peak output capability that varied as the inverse of the duty cycle. Both types of equipment are readily available.

Table L-1 gives an indication of the size of the equipment needed. To this must be added the receivers, data processors, and displays.

L.6 OPERATIONS AND MAINTENANCE

It is estimated that a minimum of 10 operators would be required per site (two per shift). Not fewer than two maintenance technicians would be required, plus the usual support persons. On can easily envisage 15 personnel at each site if the site is located on or near a facility that can provide support such as housing and meals. The number would be far greater if the site were unsupported.

L.7 CONCLUSIONS AND RECOMMENDATIONS

This appendix summarizes the works of several authors and covers the practicability of detecting small boats (> 40 ft) between 3 and 200 nm off the coastline of the U.S., including Hawaii and Alaska. The detection techniques considered were those of HF surface-wave and HF sky-wave.

TABLE L-1. HF TRANSMITTER CHARACTERISTICS*

AVERAGE POWER (kW)	ESTIMATED TRANSMITTER WEIGHT (LB)	AREA REQUIRED+
1	350	--
5	1,500	--
10	2,500	5 x 20 ft (van)
50	9,000	5 x 30 ft (van)
100	20,000	Simple to put in one van
250	30,000±	< 400 ft^2
500	45,000	900 ft^2

* These data are based on HF transmitters developed by Continential Electronics, Dallas TX.

\+ All vans are assumed to be 10 feet high.

± Based on 300-kW unit--does not include water tank or water for heat exchanger.

APPENDIX M

PARAMETER ANALYSIS OF SLAR AND SAR FOR OCEAN TRAFFIC DETECTION AND LOCATION

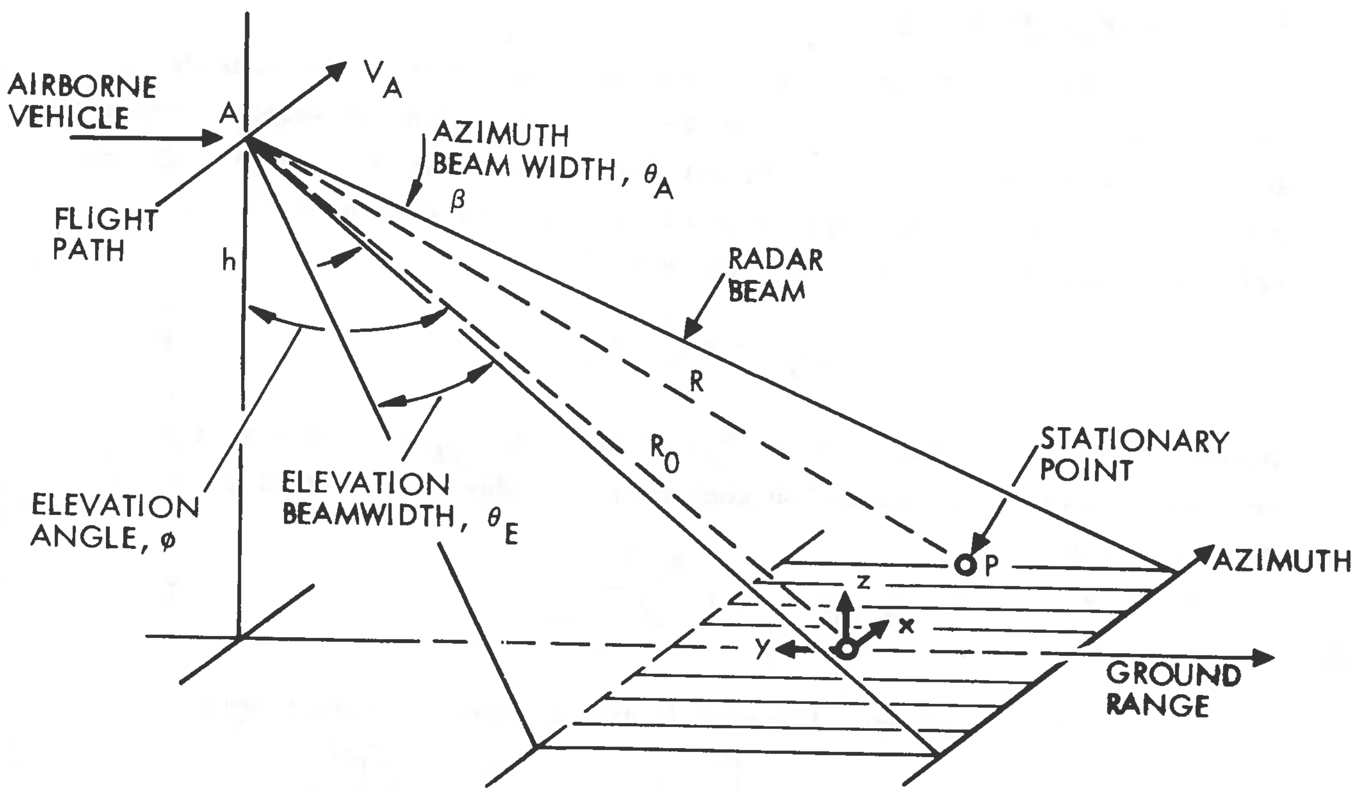

FIGURE M-1. CONVENTIONAL SIDE LOOKING AIRBORNE RADAR (SLAR) by cancelling terms we obtain:

$$S'_{az} = \left[S_{az}^2 + \left(\frac{2\ L_{SA}}{v} \right)^2 V_a^2 + \left(\frac{L_{SA}\ R}{v^z} \right) a_r^2 \right]^{1/2}$$

We see that the sensitivity coefficients, $2\ L_{SA}/v$ and $L_{SA}\ R/v^2$, both reduce with increased aircraft velocity. Further, we see that low velocities such as would be maintained with lighter than aircraft would result in high sensitivity to target motion. It may be mistakenly assumed that sensitivity can be reduced by reducing L_{SA}; this is not effective because a reduction in L_{SA} causes a corresponding increase in S_{az} so that no net benefit is realized.

Image smear in the range direction results from a radial component of velocity motion V_r (ref. 2). The distance the target moves during the processing time T is V_rT. If this distance is small relative to S_p no smear is observed. Since processing times are expected to be large (one second or more) it can be seen that even relatively small components of radial velocity (say 1 m/sec) can cause smear in high-resolution radars. At 10 m/sec (about 20 knot) the smear would range from 10 m to 100 m for T ranging from 1 to 10 seconds. Unless compensation is employed in the signal processing, range smear can be a significant problem. It can be shown that the bound on radial velocity required to avoid range smear is:

$$\left| V_r \right| < \frac{z\ S_{az}}{\alpha R}\ v\ S_R = \frac{v}{L_{SA}}\ S_R$$

The magnitude of radial velocity, which is tolerable, increases with radar velocity. Thus, we see that high radar velocity reduces the sensitivity to both azimuth defocus and to range smear.

Roll, pitch, and vertical motion of the vessel due to waves, cause additional defocus and smear, in proportion to the azimuth and radial components of the motion.

Another important motion effect is defocus and range smear due to uncompensated radar motion (ref. 1). The magnitude of defocus and smear is given by the same relationships as for target ratio, but with vehicle velocity and acceleration used in place of target values. Again, the sensitivity reduces with vehicle speed.

In case the ship motion is primarily in a direction parallel to the aircraft track (such as in narrow shipping lanes) the magnitude of translocation will be relatively small. On the other hand, when shipping is orthogonal to the aircraft track, translocation may be substantial.

M.1.3 Signal Level

The processing system compresses the frequency-modulated signals received during the integration period into a short pulse. The Doppler bandwidth is $2\ \theta/\alpha$ and the maximum time-bandwidth product is $2\ \theta_A^2\ R/\alpha$ (ref. 2). A component of target velocity perpendicular to the track causes the effective velocity v to be larger or smaller depending on the target direction and results in a bandwidth mismatch in the processor. This mismatch results in signal suppression in proportion to the magnitude of the mismatch. Thus, the signal-to-clutter ratio for moving vessels will be reduced in proportion to the radial component of target velocity. When the velocity is sufficiently large, the radar becomes blind. The condition to avoid blind targets is to ensure that the ratio of target radial velocity to aircraft velocity satisfies (refs. 2, 9):

$$\left| \frac{V_r}{v} \right| < \frac{\lambda}{2\ S_{az}} = \frac{L_{SA}}{R} = \theta_A$$

This result shows that small azimuth beamwidths place severe restrictions on the target radial velocity. Since narrow beamwidth is desirable to obtain maximum antenna gain, we see that a tradeoff is required. At short ranges, the beamwidth must be wide to obtain a useful synthetic aperture. At longer ranges, however, narrow beamwidths will be required. The only option in this case appears to be higher aircraft velocity.

When the target moves parallel to aircraft path, the effective processing time is either increased or reduced depending on the direction of motion. This results in a signal with larger or smaller time-bandwidth product and again results in mismatch in the signal processor with resultant signal suppression.

M.2. THE SYNTHETIC APERTURE RADAR (SAR)

The SAR is similar in operation and technique to the SLAR (ref. 1); the major difference is in geometry and specifically, the much larger radar velocity

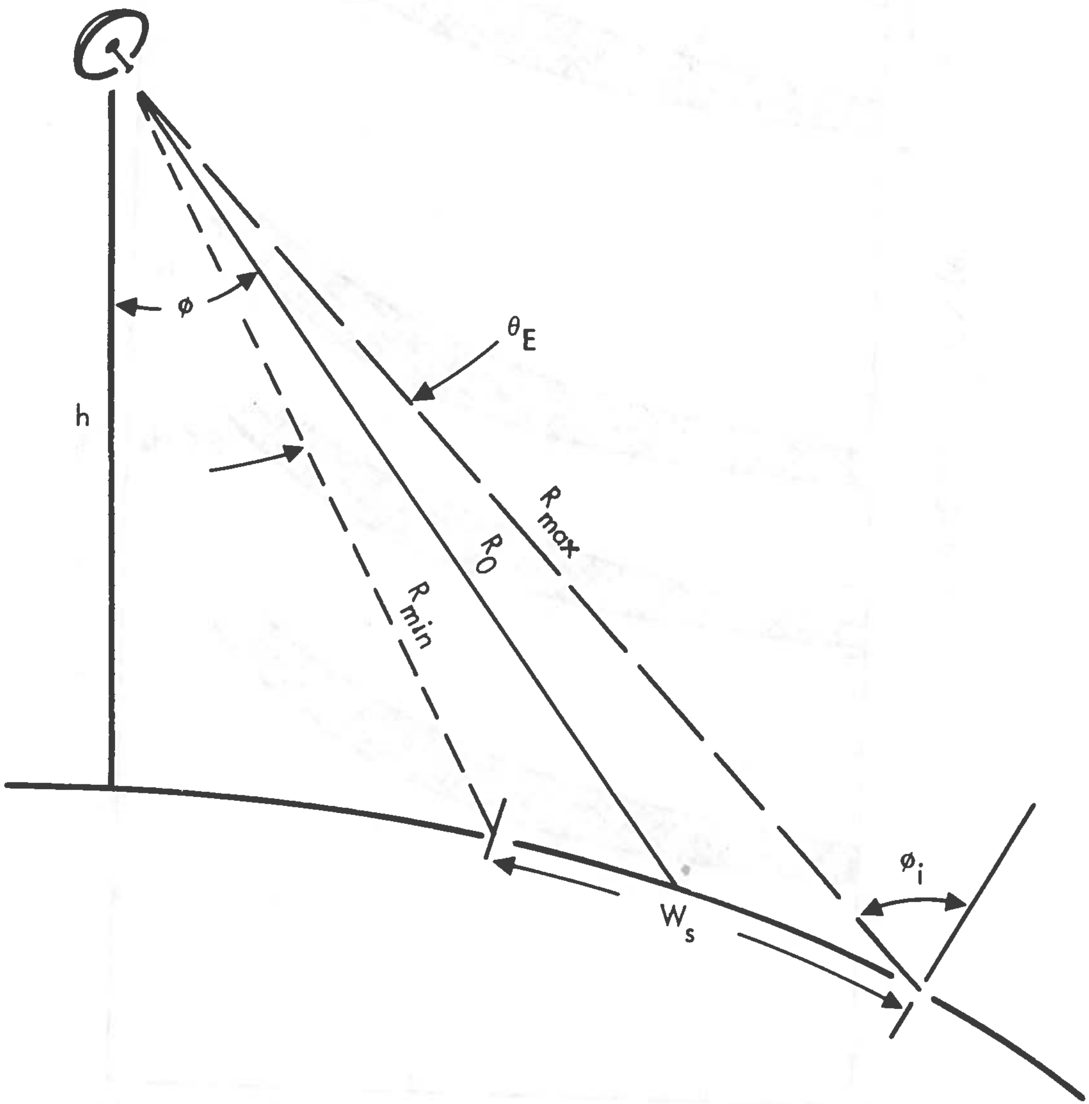

FIGURE M-2. GEOMETRY OF SAR

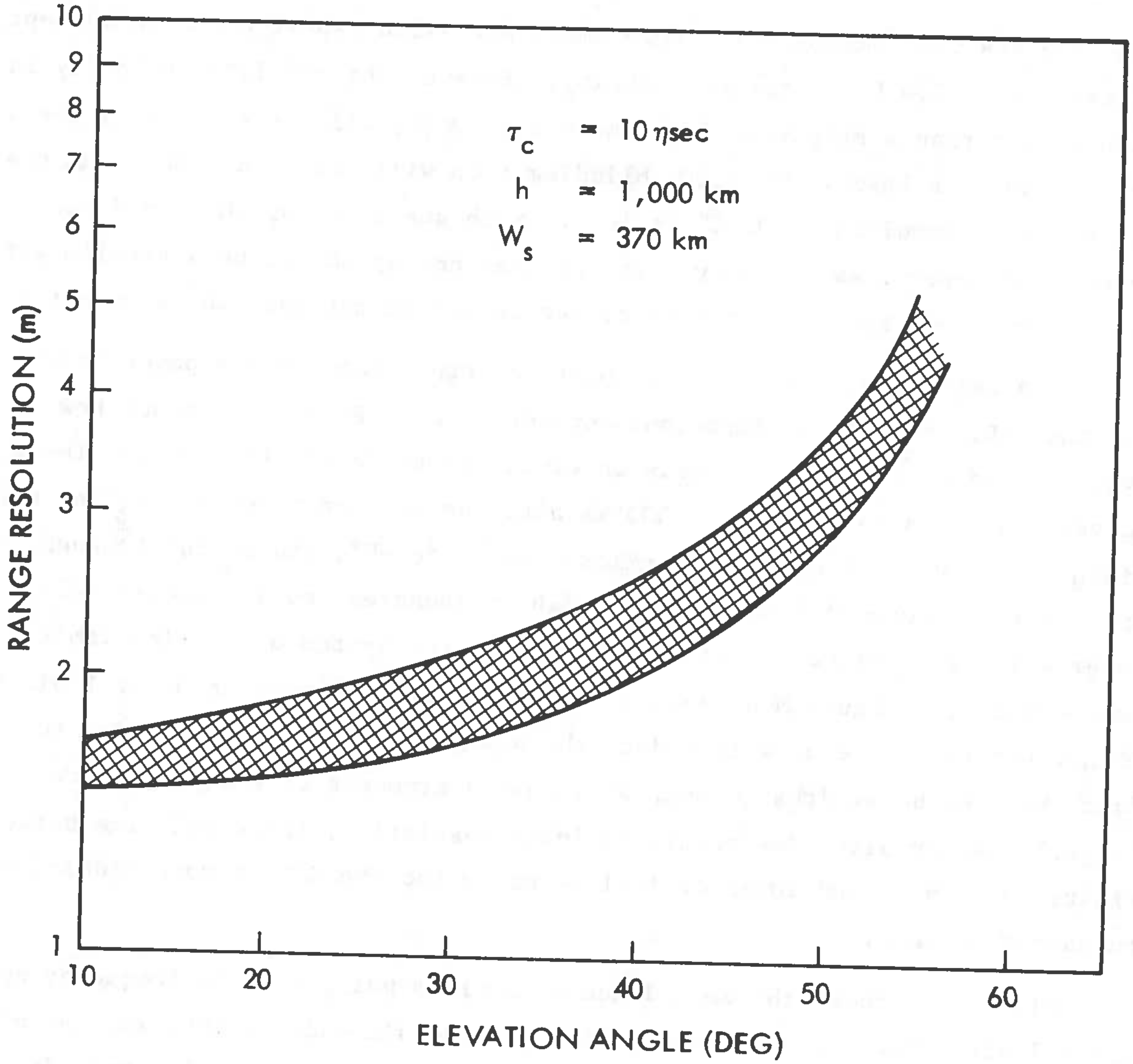

FIGURE M-4. RANGE RESOLUTION

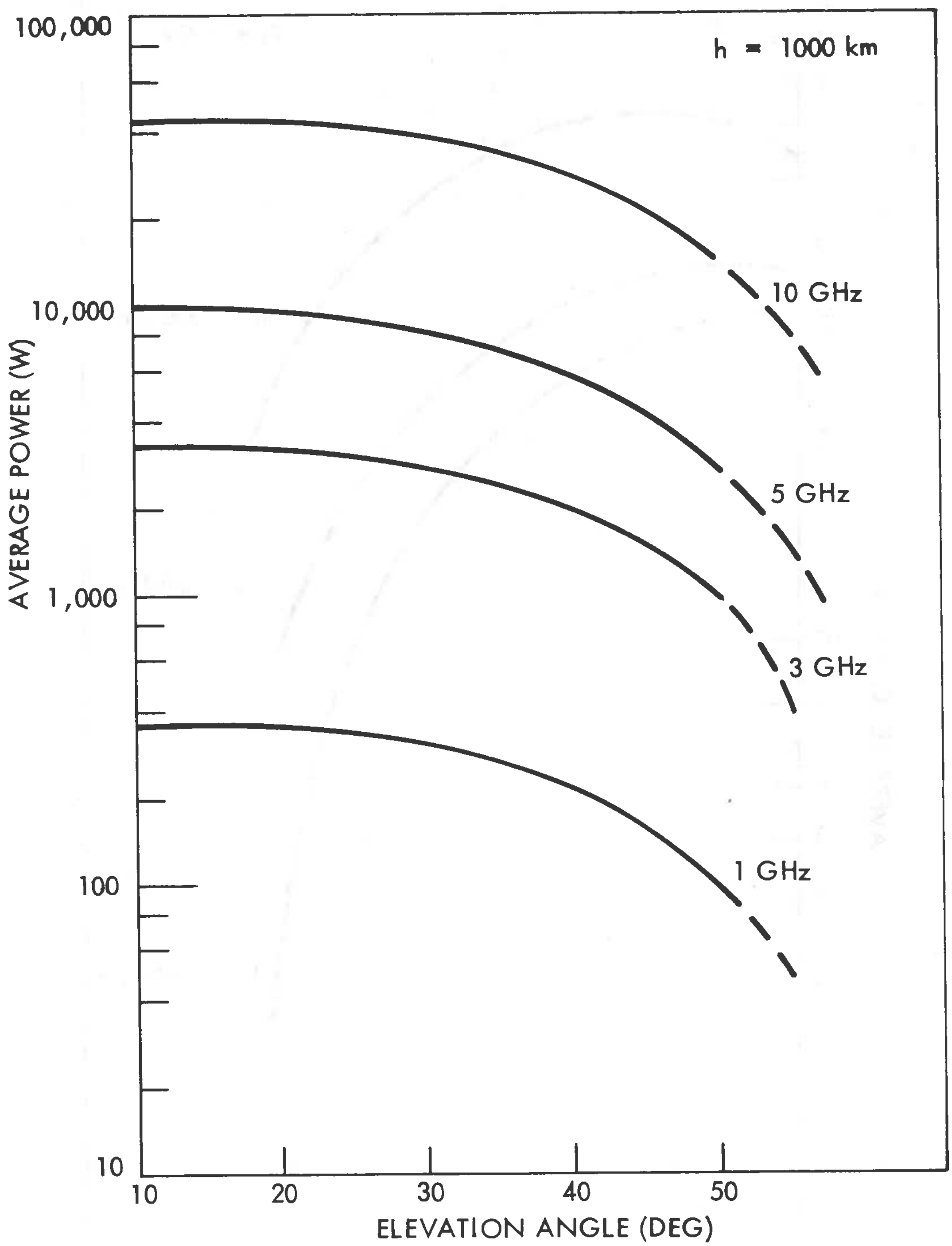

FIGURE M-5. DEPENDENCE OF COVERAGE POWER ON FREQUENCY

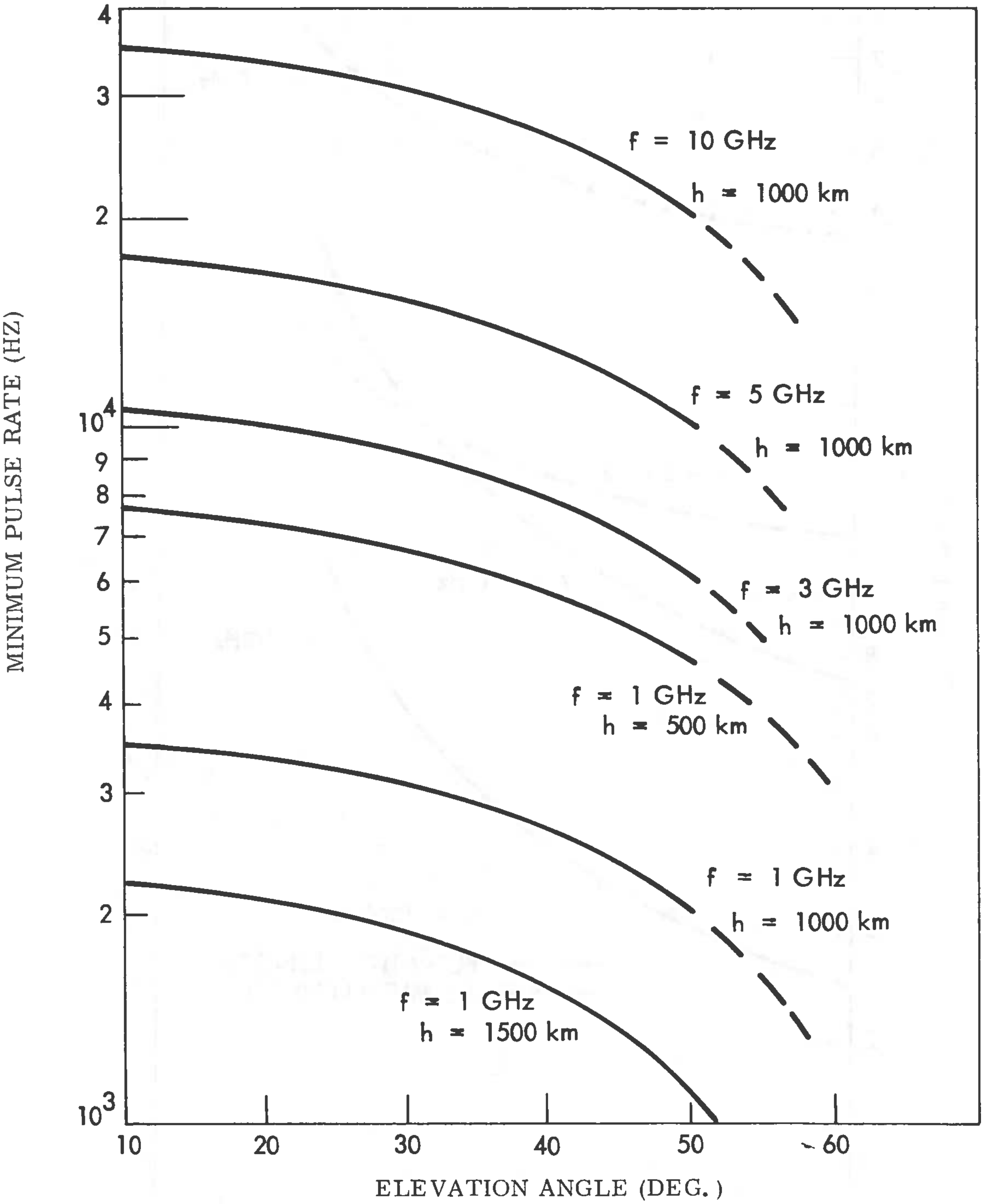

FIGURE M-7. DEPENDENCE OF MINIMUM PULSE RATE ON FREQUENCY AND ORBITAL ALTITUDE

A remaining question concerns the best elevation angle. We see from Figure M-9 that sea clutter reduces with increasing angle of incidence (which corresponds to increasing elevation angle) (ref. 10). The smaller set of curves show how cross section increases with wind speed. Figure M-10 shows how the signal-to-clutter ratio of a container ship depends on incidence angle. It is apparent that incidence angles between 40^o and 55^o are desirable. The desired values of elevations angle then are in the range of 40^o to 50^o.

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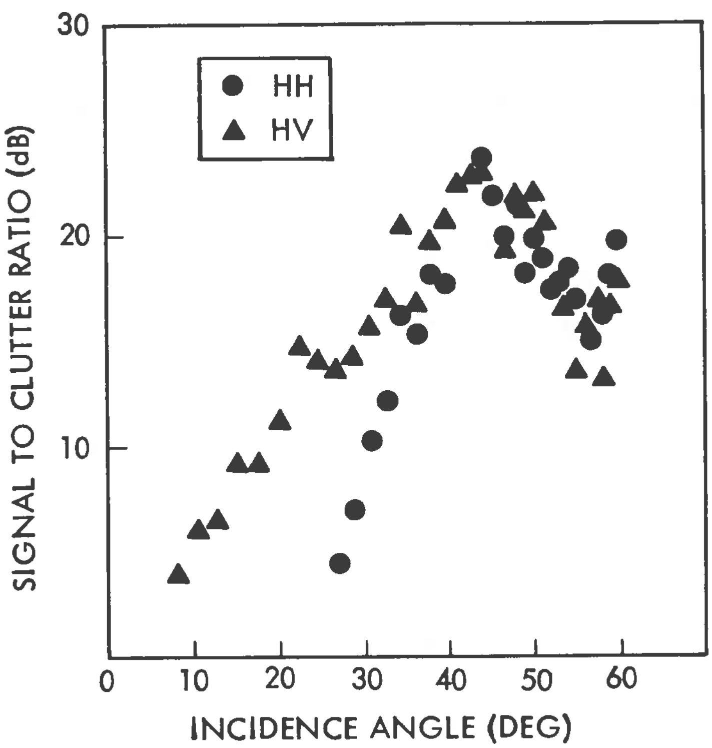

FIGURE M-10. SIGNAL TO CLUTTER RATIO FOR THE CONTAINER SHIP AS A FUNCTION OF INCIDENCE ANGLE. THE FALL OFF IN SCR ABOVE 45" IS DUE TO NON-BEAM FILLING CONDITIONS

APPENDIX N

LOWCOSS SYSTEM DESCRIPTION

generator and would have its own position and attitude sensing equipment. Figure N-4 presents the two potential locations of an OTIS/LOWCOSS pod on 747, L-1011, 727, and 737 aircraft. It is estimated that the maximum increase in drag resulting from such pods would be one-half of one percent. Figure N-5 presents a layout of the equipment in the pod. (The structural and aerodynamic details of this installation concept warrant further technical analysis.) An attractive installation alternative for commercial aircraft is to mount the sensor system in the cargo or baggage compartment with quick-latch fasteners. This approach also requires additional engineering and analysis to determine feasibility and acceptability.

The system will provide pitch and roll rates on detected vessels with a large radar cross-section. This will be done by a spectral analysis of the data to remove the azimuthal smearing of the return caused by the system platform pitch and roll. Further study of this problem is necessary to determine accuracies.

There may be some problem with land clutter leaking through the azimuth and range sidelobes into the imaging filter if the clutter is at the same range as the target vessel. However, it is doubtful that any targets of interest would remain adjacent to land continuously and therefore would be detected by the system on the next shuttle along the coast.

The navigation and attitude determination subsystem presented in the LOWCOSS configuration is the Delco Carosel IV. It was selected as a matter of convenience since a U.S. Air Force version of LOWCOSS is using it at the present time and it satisfies the requirement for reporting of 75 micro g's and 3 percent velocity error.

There are many other methods and techniques for providing the navigation input to LOWCOSS. A combination of input from the Global Positioning Satellite with a simple rate gyro package is one approach. Another method could utilize fixed transponders of known location whose position and identification data could be processed as part of the normal data stream and used to normalize and adjust all other locations and movements relative to these known fixed sites.

The majority of the sensor test systems will be built into the processor. In-addition, a test signal will be processed through the system in some unused

TABLE N-1. LOWCOSS PERFORMANCE CHARACTERISTICS

Range		8 nm to 200 nm
Range Resolution		115 m
Azimuth Resolution		115 m
Radars	VHF (2)	UHF (1)
Wavelength (approx.)	2.1 m	0.68 m
Bandwidth	1.25 MHz	2.5 MHz
Pulse Compression	Digital 4Φ	Digital 4Φ
Pulse Width	100, 400 μsec	200 μsec
TW Product	512	1024
Maximum PRF	350 Hz	60 Hz
Maximum Duty Cycle	4%, 15%	1.2%
Peak Power	1.2 kw	11 to 15 kw
Antenna Type (number)	Slot (1)	Slot (11)

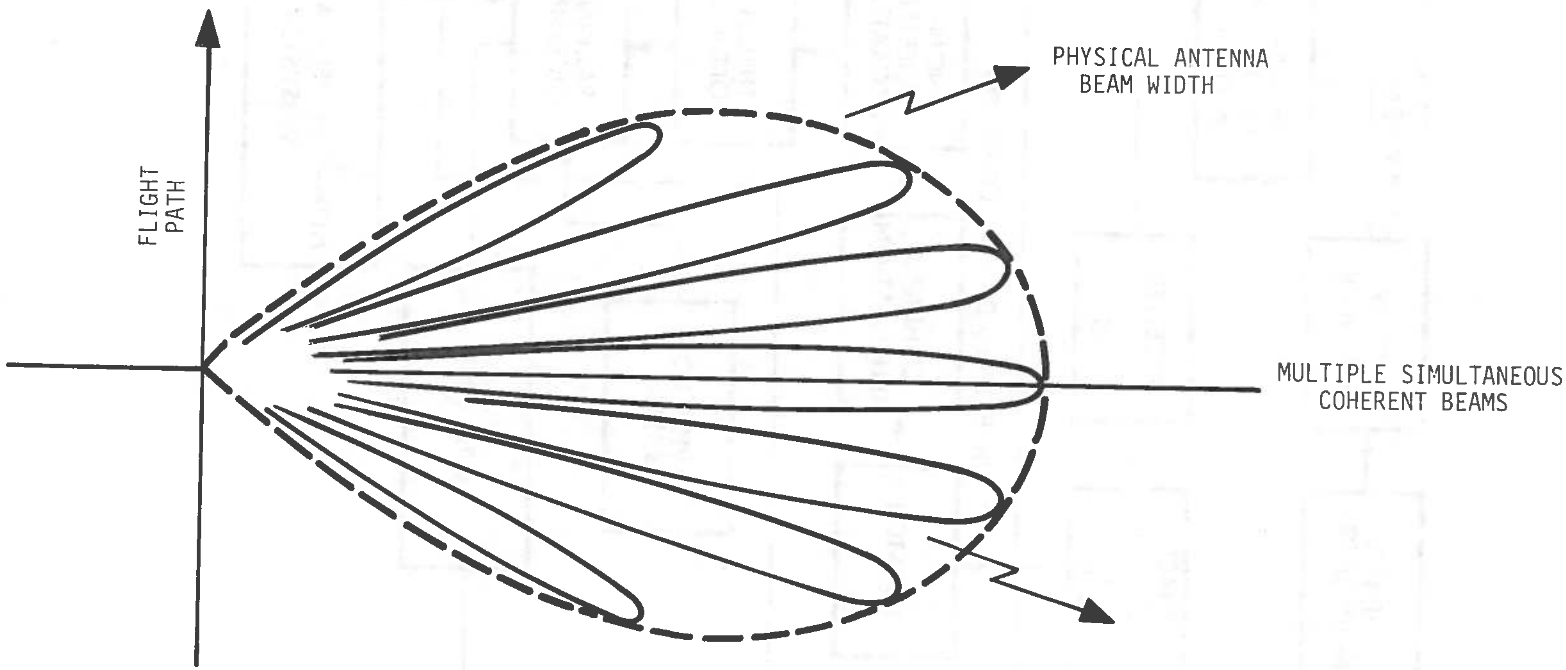

FIGURE N-2. LOWCOSS ELECTRONIC COHERENT BEAM STEERING

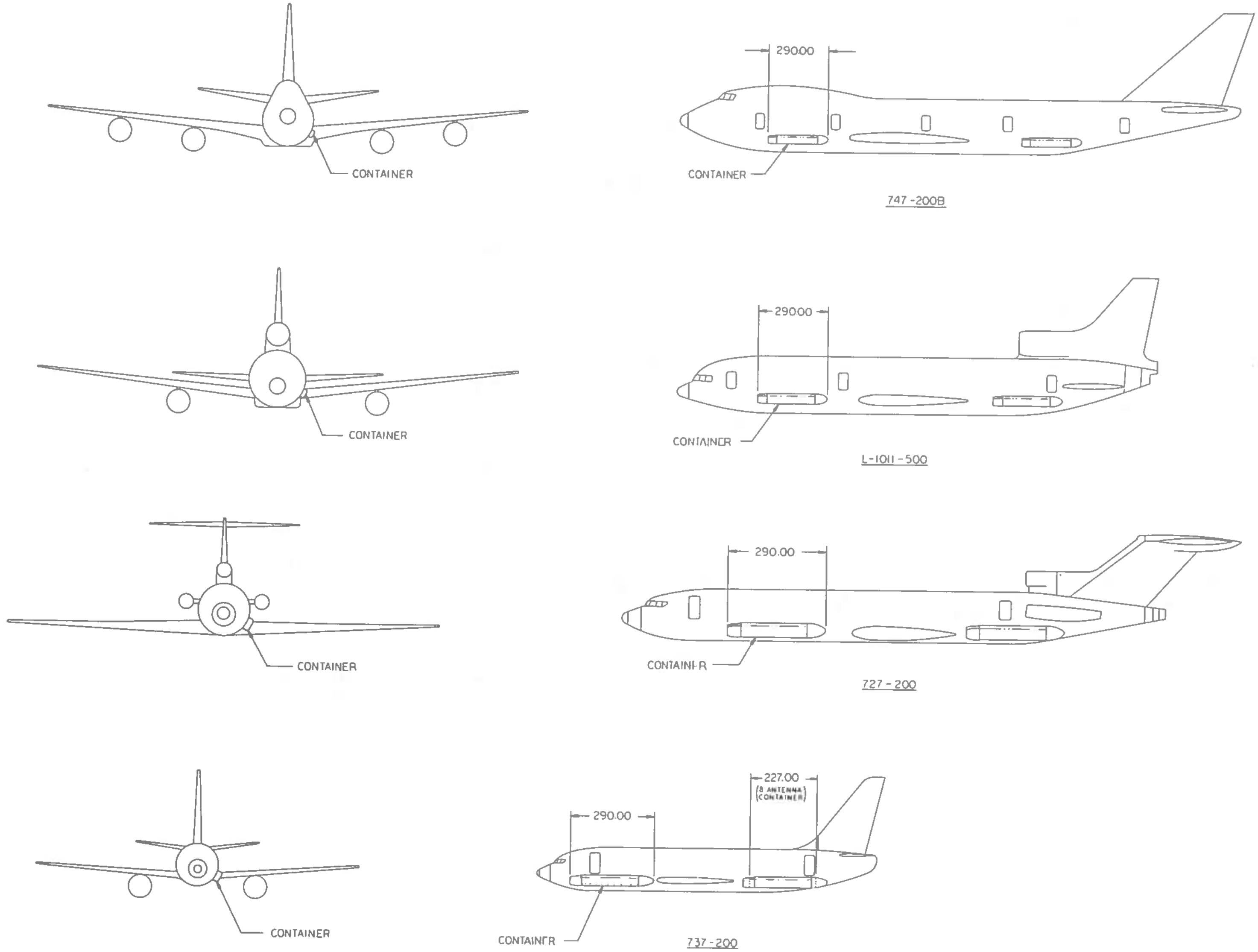

FIGURE N-4. AIRCRAFT POD LOCATIONS

TABLE N-2. LOWCOSS ELECTRICAL AND MECHANICAL CHARACTERISTICS: POD POWER AND WEIGHT REQUIREMENTS

1.

Item	Power (kw)	Wt. (lb)
VHF Radar	1.2	50
UHF Radar	11 to 15	60
VHF Data Processor	1.3	60
UHF Data Processor	0.425	50
Nav. Unit	1.15 warm-up/ 0.45 running	55
Battery	-	27
TOTAL		302 + Outside Structure and Attachment

2. POD

Overall Dimensions

With Air Turbine	Without Air Turbine
Length = 290 in*	Length = 200 in*
Height = 38 in	Height = 30 in
Width = 19 in	Width = 6 in

3. A Field of View of Antenna = 90° (Horizon)
(See Figure N-1)

4. Drag of POD - With Air Turbine = 1 to 2%
- Without Air Turbine = <1%

*Antenna Options (UHF w/11 elements) POD Length = 290 in
(UHF w/6 elements) POD Length = 227 in

APPENDIX P

OTIS SOFTWARE LIFE CYCLE COST

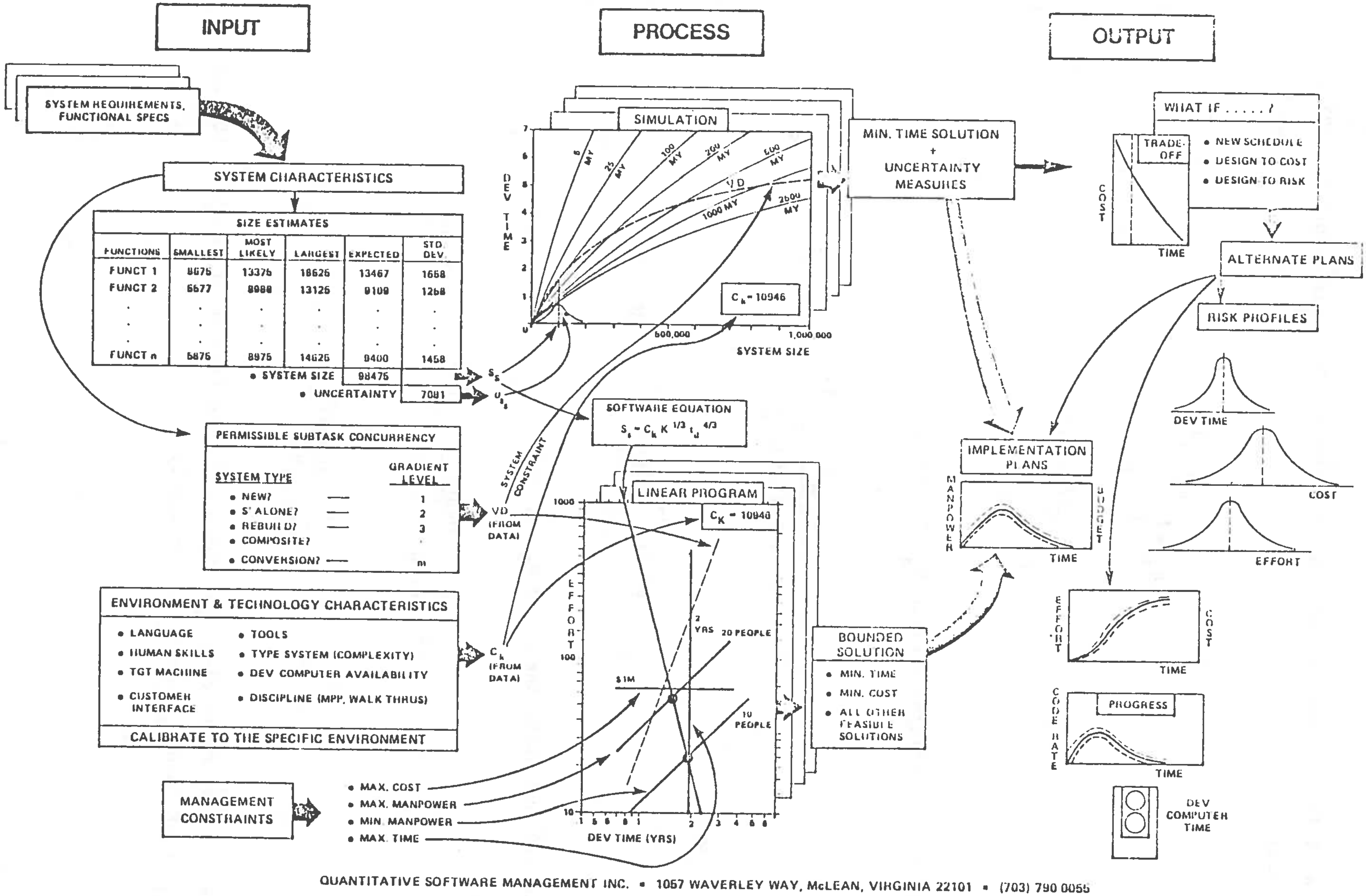

FIGURE P-1. SOFTWARE LIFE CYCLE METHODOLOGY

The output of the Putnam model, as shown in Figure P-2, is a graph of the man-level ($\dot{y}$) on the x axis and the time (t) in man years on the y axis. The peak (t_d) is software delivery for final test, the period following t_d are maintenance and modifications to a typical system.

REFERENCE

Lawrence H. Putnam, "General Empirical Solutions to the Macro Software Size and Estimating Problem," Rev., July 1978.

APPENDIX Q

OPERATING COSTS OF CUTTERS, AIRCRAFT, AND SHORE UNITS BY DISTRICT

TABLE Q-1. SUMMARY: OPERATING COST OF COAST GUARD CUTTERS BY DISTRICT

DISTRICT	PERSONNEL COMPENSATION	OPERATING AND MAINTENANCE COSTS		ELECTRONICS PROGRAM	VESSEL PROGRAM	OTHER COSTS	TOTAL COSTS	OPERATING COSTS	AVERAGE COST PER OPERATING HOUR
		FUEL	ALL OTHER						
One	$13,694,962	$ 2,141,767	$ 2,982,997	$ 688,429	$ 5,149,159	$ 7,521	$ 24,664,835	$ 42,380	$582
Two	1,488,505	502,385	255,965	-	627,565	61,764	2,936,184	25,838	114
Three	10,533,174	1,417,198	2,034,633	506,903	2,483,494	18,001	16,993,403	110,076	154
Five	11,490,417	1,848,762	2,625,321	426,130	3,880,588	4,558	20,275,776	42,560	476
Seven	8,588,211	1,145,803	1,843,887	178,874	1,781,885	14,705	13,553,365	50,012	271
Eight	6,702,880	1,179,252	2,043,186	72,685	1,258,602	4,509	11,261,114	45,841	246
Nine	6,556,772	1,191,824	1,535,549	88,321	2,230,515	385	11,603,366	19,705	589
Eleven	4,709,523	793,790	1,359,737	39,197	3,513,172	46,268	9,461,687	22,684	417
Twelve	9,363,110	1,297,508	2,138,554	486,966	2,900,904	19,672	16,206,714	21,219	764
Thirteen	13,132,030	2,237,137	3,193,760	605,157	5,018,976	8,334	24,340,394	28,213	866
Fourteen	6,109,799	631,535	1,386,739	240,135	2,049,710	13,429	10,431,347	14,083	741
Seventeen	6,912,505	666,744	1,707,069	293,872	1,393,095	30,956	11,004,241	23,984	459
TOTALS	$99,281,888	$15,153,705	$23,107,397	$3,671,669	$31,287,665	$230,102	$172,732,426	$446,585	

*The total costs by district differ from the actual due to rounding of the numbers.

TABLE Q-3. AVIATION OPERATING COSTS: SUPPORT FACILITY COSTS

SUPPORT FACILITIES	PERSONNEL COMPENSATION	OPERATING AND MAINTENANCE COSTS		ELECTRONICS PROGRAM	AIRCRAFT PROGRAM	SHORE UNIT PROGRAM	OTHER COSTS	TOTAL COSTS
		FUEL	ALL OTHER					
AV TRACEN Mobile	$ 5,120,100	$732,998	$1,515,245	$ 3,296	$ -69,046	$155,545	$ 180,515	$ 7,628,653
AV TECH TRACEN	3,130,313	-	672,307	-	502,819	-	94,489	4,399,928
AR & SC	670,881	-	1,147,700	-	2,117,648	-	46,801	2,500,736
HQ EAE	648,863	-	212,856	-	12,116	-	103,916	977,751
A/C Little Rock	446,487	-	-	-	-	-	-	446,487
A/C Grand Prairie	31,281	-	-	-	-	-	-	31,281
Naval Air Tech TRACEN	246,475	-	-	-	-	-	-	246,475
Naval A/B TRACEN	1,063,858	-	-	-	-	-	-	1,063,858
Misc. Program Costs	496,236	-	3,279	-	48,138	-	872,789	1,420,442
TOTAL	$11,854,494	$732,998	$3,551,387	$1,478,998	$2,611,675	$155,545	$1,298,510	$18,725,611

TABLE Q-5. SHORE UNITS ALLOCATION OF RESOURCES BY DISTRICT AND PROGRAM

DISTRICT	SAR	SRA	RA	BA	DI	CVS	RBS	PSS	MEP	ELT	MSA	PO	MP	FUNDS IN MILLIONS OF DOLLARS
One	33.3	11.5	0.875	0.166	0.416	4.16	4.91	6.87	7.833	34.2	0.416	0.333	1.45	$15.3
Two	0.909	7.90	0.0909	0.0	0.0909	37.09	1.545	26.18	25.90	0.0	0.0	0.0	0.272	5.2
Three	59.5	12.04	0.252	0.4	0.28	0.2	4.16	5.36	7.12	4.88	0.0	0.0	1.8	30.5
Five	57.87	11.60	1.66	0.15	0.848	4.18	3.63	5.939	7.393	4.96	0.606	0.818	0.909	15.7
Seven	55.32	4.4	0.08	0.0	0.0	11.08	4.36	8.08	9.4	7.36	0.0	0.0	1.32	11.3
Eight	42.9	4.4	0.05	0.0	0.0	0.5	1.45	14.5	13.6	7.85	0.0	0.0	8.85	10.5
Nine*	59.41	7.65	1	0.28	1.35	5.789	10.40	5.70	6.68	0.736	0.0	0.0	0.19	23.4
Eleven	32	11.4	3	0.0	0.0	10.4	0.8	17.8	14.8	9.3	0.0	0.4	0.2	4.7
Twelve	45.6	2.7	0.3	0.0	0.0	7.5	115	9.4	10.8	12.5	0.0	0.0	0.1	7.6
Thirteen	60.16	10.98	0.33	0.0	0.0	3.72	8.27	2.05	6.5	3.44	0.166	0.22	0.444	13.1
Fourteen	17	0.6	0.0	0.0	0.0	37	38	16.8	206	4	0.0	0.0	0.0	2.9
Seventeen	20.09	14.25	4.375	0.625	1.25	6.65	3.93	4.59	7.28	10.68	1.875	1.875	3.78	16.7
AVERAGE	40.3	8.2	1	0.135	0.35	11	5	10.8	12	9	0.25	0.30	1.6	

*Inland Shore Units

APPENDIX R

OTIS ALTERNATIVE ONE
COST ESTIMATES FOR DEVELOPMENT, IMPLEMENTATION, AND OPERATIONS AND MAINTENANCE

TABLE R-1. OTIS RESEARCH AND DEVELOPMENT AND PROTOTYPE EVALUATION COSTS IN 1980 DOLLARS - ALTERNATIVE ONE (CONT.)

ITEM	COST
Operating and Maintenance Costs	
1. Terrestrial Communication (W/Telco Modems and Computer I/O)	$ 239,000
2. Tel. Com. Modems W/Radio Station I/O (VHF)	29,000
3. Satellite Communications	13,000
4. Personnel	509,000
5. Software Maintenance	118,000
6. Operating & Maintenance of OTIS, Operators, Commanders, Stations & Radio Stations	59,000
Sub-Total	$1,367,000
TOTAL	$1,761,000

TABLE R-3. OTIS ACQUISITION CONSTRUCTION INTEGRATION AND OPERATING AND MAINTENANCE COSTS in 1980 DOLLARS - GULF AND CARIBBEAN - ALTERNATIVE ONE

ITEM	COST
A. RADIO SHORE STATION	
Acquisition Construction Integration Costs	
1. HF Data Modems & Level I Processors	$ 41,000
2. VHF Data Modems & Level I Processors	219,000
3. VHF Station Modems & I/O for VMS OPS	66,000
Operating and Maintenance Costs (5-Year Total)	
1. Satellite Communications	63,000
2. Terrestrial Communication Links	917,000
3. Other O&M	117,000
Sub-Total	$1,423,000
B. REGIONAL OTIS FACILITY	
Acquisition Construction Integration Costs	
1. Facility Engineering/Construction	$ 34,000
2. Computer Discs, Terminal, Communication I/F	257,000
3. Voice to Digital Converter	26,000
Operating and Maintenance Costs	
1. Terrestrial Communications	848,000
2. Software Maintenance & Systems Analysts	471,000
3. Personnel	706,000
4. Other O&M	113,000
Sub-Total	$2,455,000
C. GROUP AND OPERATIONAL COMMANDER FACILITIES	
Acquisition Construction Integration Costs	
1. Computer Terminals (Graphics, Copier)	$ 139,000
2. Personnel Training	25,000
Operating and Maintenance Costs	
1. Personnel Training	19,000
2. Other O&M	94,000
Sub-Total	$ 277,000
TOTAL	$4,155,000

TABLE R-5. OTIS ACQUISITION CONSTRUCTION INTEGRATION AND OPERATING AND MAINTENANCE COSTS IN 1980 DOLLARS - ALASKA - ALTERNATIVE ONE

ITEM	COST
A. RADIO SHORE STATIONS	
Acquisition Construction Integration Costs	
1. HF Data Modems & Level I Processors	$ 68,000
2. VHF Data Modems & Level I Processors	123,000
3. VHF Station Modems & I/O for VMS OPS	8,000
4. Facilities Engineering/Construction	4,781,000
Operating and Maintenance Costs (5-year Total)	
1. Satellite Communications	63,000
2. Terrestrial Communication Links	988,000
3. Other O&M	611,000
Sub-Total	$6,642,000
B. REGIONAL OTIS FACILITY	
Acquisition Construction Integration Costs	
1. Facility Engineering/Construction	$ 34,000
2. Computer Discs, Terminal, Communication I/F	185,000
3. Voice to Digital Converter	20,000
Operating and Maintenance Costs	
1. Terrestrial Communications	630,000
2. Software Maintenance & Systems Analysts	282,000
3. Personnel	471,000
4. Other O&M	117,000
Sub-Total	$1,739,000
C. GROUP AND OPERATIONAL COMMANDER FACILITIES	
Acquisition Construction Integration Costs	
1. Computer Terminals (Graphics, Copier)	$ 70,000
2. Personnel Training	10,000
Operating and Maintenance Costs	
1. Personnel Training	12,000
2. Other O&M	48,000
Sub-Total	$ 140,000
TOTAL	$8,521,000

APPENDIX S

OTIS ALTERNATIVE TWO
COST ESTIMATES FOR DEVELOPMENT, IMPLEMENTATION,
AND OPERATIONS AND MAINTENANCE

TABLE S-2. OTIS ACQUISITION CONSTRUCTION INTEGRATION AND OPERATING AND MAINTENANCE COSTS IN 1980 DOLLARS - EAST COAST - ALTERNATIVE TWO*

ITEM	COST
A. ACQUISITION CONSTRUCTION INTEGRATION COSTS**	
1. Aircraft Modifications	$ 224,000
2. Sensor Systems	3,353,000
3. Cooperative Vessel Transponders	165,000
4. Communications Ground Site	14,000
5. Computer Data Terminals	145,000
6. Monitoring System	3,291,000
B. OPERATING AND MAINTENANCE COSTS** (4-Year-Total)	
1. Commercial Aircraft Operations (1,460 flights/year)	392,000
2. Computer Personnel	3,007,000
3. Terrestrial Communications Links	173,000
4. Other O&M	90,000
TOTAL	$10,854,000

* AC&I costs shown are for completion of the East Coast Region partially outfitted in the Evaluation Phase, Table S-1.

**Combined costs of Radio Shore Stations, Regional OTIS Facility and Group Operational Commander Facilities. This approach is continued in Tables S-3 and S-5.

TABLE S-4. OTIS ACQUISITION CONSTRUCTION INTEGRATION AND OPERATING AND MAINTENANCE COSTS IN 1980 DOLLARS - PACIFIC COAST - ALTERNATIVE TWO

ITEM	COST
A. ACQUISITION CONSTRUCTION INTEGRATION COSTS	
1. Sensor System	$ 6,707,000
2. Monitoring System	2,422,000
3. Communication Ground Site Equipment	186,000
4. Computer System	233,000
5. Computer Data Terminals	160,000
B. OPERATING AND MAINTENANCE COSTS (4-Year Total)	
1. Commercial Aircraft Operations (1,460 flights/year)	392,000
2. C-130 Operations (730 flights/year)	19,601,000
3. Computer Personnel	3,007,000
4. Terrestrial Communication Links	767,000
5. Other O&M	80,000
TOTAL	$33,555,000

APPENDIX T

OTIS ALTERNATIVE THREE
COST ESTIMATES FOR DEVELOPMENT, IMPLEMENTATION,
AND OPERATIONS AND MAINTENANCE

TABLE T-2. OTIS ACQUISITION CONSTRUCTION INTEGRATION AND OPERATING AND MAINTENANCE COSTS IN 1980 DOLLARS - EAST COAST-ALTERNATIVE THREE

ITEM	COST
A. ACQUISITION CONSTRUCTION INTEGRATION COSTS	
1. Data Modems and Level I Processors	$ 65,000
2. Computer System	16,000
3. Voice to Digital Converter	6,000
4. Computer Terminal (Field Sites)	32,000
5. Facility Engineering/Construction	3,000
6. Aircraft Modifications	190,000
7. Sensor Systems	2,850,000
8. Cooperative Vessel Transponders	140,000
9. Communications Ground Site	12,000
10. Computer Data Terminals	123,000
11. Monitoring System	2,797,000
Sub-Total	6,234,000
B. OPERATING AND MAINTENANCE COSTS (4-Year Total)	
1. Terrestrial Communication (W/Tel. Com. Modems and Computer I/O)	376,000
2. Tel. Com Modems W/Radio Station I/O (VHF)	46,000
3. Satellite Communication	10,000
4. Personnel (Engineers, Operators, Administrators)	107,000
5. Software Maintenance	86,000
6. Commercial Aircraft Operations (1,241 flight hours/year)	333,000
7. Computer Personnel	2,556,000
8. Terrestrial Communication Links	147,000
9. Other O&M	169,000
Sub-Total	$ 3,830,000
TOTAL	$10,064,000

TABLE T-4. OTIS ACQUISITION CONSTRUCTION INTEGRATION AND OPERATING AND MAINTENANCE COSTS IN 1980 DOLLARS - PACIFIC COAST - ALTERNATIVE THREE

ITEM	COST
A. ACQUISITION CONSTRUCTION INTEGRATION COSTS	
1. HF Data Modems & Level I Processors	$ 10,000
2. VHF Data Modems & Level I Processors	46,000
3. VHF Station Modems & I/O for VMS OPS	14,000
4. Facility Engineering/Construction	6,000
5. Computer Discs, Terminals, Communication I/O	41,000
6. Voice to Digital Converter	6,000
7. Computer Terminals (Graphics, Copier)	32,000
8. Personnel Training	6,000
9. Sensor System	5,701,000
10. Monitoring System	2,058,000
11. Communication Ground Site Equipment	158,000
12. Computer System	198,000
13. Computer Data Terminals	136,000
Sub-Total	$ 8,412,000
B. OPERATING AND MAINTENANCE COSTS (4-Year Total)	
1. Terrestrial Communication Links	$ 977,000
2. Commercial Aircraft Operations	333,000
3. C-130 Operations	16,661,000
4. Personnel Training	3,000
5. Other O&M	2,867,000
Sub-Total	$20,841,000
TOTAL	$39,253,000

TABLE T-6. NATIONAL FACILITY ACQUISITION CONSTRUCTION INTEGRATION AND OPERATING AND MAINTENANCE COSTS IN 1980 DOLLARS - ALTERNATIVE THREE

ITEM	COST
A. ACQUISITION CONSTRUCTION INTEGRATION COSTS	
1. Site Preparation	$ 31,000
2. Hardware	186,000
B. OPERATING AND MAINTENANCE COSTS	
1. Software and Personnel	286,000
2. Terrestrial Communication	178,000
3. Other O&M	590,000
TOTAL	$1,271,000

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