LEVEL II

(13)

REPORT NO. NADC-80149-60

MARITIME PATROL AIRSHIP STUDY (MPAS)

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19 MARCH 1980

FINAL REPORT
AIRTASK NO. A03P-03PA-001B/0F41-411-000
Work Unit No. DH814

USCG MIPR No. Z-70099-8-85, 101-9B

Approved for Public Release; Distribution Unlimited

Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy

and

U.S. COAST GUARD OFFICE OF RESEARCH AND DEVELOPMENT
Department of Transportation
Washington, DC

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NADC-80149-60	2. GOVT ACCESSION NO.: AD-A089 483
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Maritime Patrol Airship Study (MPAS)	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): David B. Bailey and Harold K. Rappoport	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Air Development Center, Warminster, PA 18974, and Summit Research Corporation, Gaithersburg, MD 20760	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AIRTASK A03P-03PA-001B/ 0F41-411-000, WU DH814
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Air Systems Command (AIR-03E), Washington, DC, and U.S. Coast Guard (Office of R&D), Washington, DC	12. REPORT DATE: 19 March 1980
	13. NUMBER OF PAGES: 359
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Naval Air Development Center (605B) Warminster, PA 18974	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Maritime Patrol, Energy Efficient Aircraft, Lighter-Than-Air (LTA), Long Endurance Aircraft, Airship, Surveillance Aircraft

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Maritime Patrol Airship Study is an airship system applications study sponsored by the U.S. Navy and U.S. Coast Guard. Eight Major Coast Guard programs are analyzed for cost effective benefits of modern Lighter-Than-Air (LTA) vehicles. Representative script scenarios are developed for the eight programs based on actual Coast Guard mission

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) experience. The scenarios are then used to size conceptual vehicles. In addition to in-house vehicle analysis, two independent efforts for comparative purposes based on the same scenarios were performed by contractor support.

Once conceptual vehicles were in hand Life Cycle Costing (LCC) was computed. This data was used to examine the mission cost effectiveness for airships. Some comparisons with existing Coast Guard assets are presented to place the results in context.

The study results indicate a very positive potential for modern airships performing these Coast Guard missions.

A C K N O W L E D G E M E N T S

The authors would like to acknowledge many individual contributions to this study.

In the initial planning phase several U.S. Coast Guard personnel provided inputs to the study team. These were Mr. John Daly, Mr. Tom Milton, LCDR Ken Williams, Mr. John Tom, and Mr. Jerry Kursban.

Special appreciation is expressed to many persons whose assistance directly contributed to the implementation of the study. These were Mr. D. Kobus (NAVAIR-DEVCEN), Mr. B. Levitt (Summitt Research Corporation), Mr. Jon W. Lancaster (Lancaster Analytics, Inc.), and at the U.S. Coast Guard, Mr. Tom Milton, Mr. R. Anthony, LCDR K. Holleman, CDR T. Leigh, LT R. Cook, Mr. L. Espanshade, LT S. Wehner, LT D. Henrickson, LT Gregory, LT J. Anthony, CAPT Garret, LT J. T. Clarke, CDR J. Andrews, LCDR Adams, LCDR D. Wheet, and LT P. Olsen.

For their comments and suggestions during the final documentation of the study, the authors wish to thank Mr. J. A. Eney (NAVAIRDEVCEN), Mr. N. J. Mayer (NASA Headquarters), and from the Coast Guard Office of Research and Development, LCDR K. Williams, LT R. Glover, and Mr. L. Nivert.

And finally, for lasting persistance in typing this voluminous document, Mrs. P. Grant (NAVAIRDEVCEN) merits a special thank you for a job well done.

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CHAPTER I
EXECUTIVE SUMMARY

INTRODUCTION

This executive summary highlights the results of a two year joint study by the U.S. Navy and the U.S. Coast Guard. The purpose of this study was to address the feasibility of using modern Lighter-Than-Air (LTA) vehicles in U.S. Coast Guard maritime patrol operations. The Maritime Patrol Airship Study (MPAS) was conceived as a first-order systems application study. It is intended that the results serve as data inputs to on-going Navy and Coast Guard LTA programs[1]. The principal elements of the study were as follows:

1. Mission Requirements and Rationale
2. Mission Analysis and Effectiveness
3. Vehicle Sizing and Parametrics
4. Estimated Life Cycle Costs (LCC) and Logistics
5. Vehicle Case Studies

BACKGROUND

Historically airships are categorized by three different approaches to the hull structure: rigid, semi-rigid, and non-rigid. This study concentrates on non-rigid airship designs since their performance abilities match the Coast Guard mission requirements.

The potential of airships for coastal patrol operations is based upon demonstrated capabilities. The following features typified airship operations by the U.S. Navy throughout World War II[2, 3, 4] and the Cold War years[5] following:

- Long Endurance
- Comfortable Crew Accommodations
- Stable, Low Vibration Sensor Platform
- Low Installed Power Requirements
- High Degree of Survivability
- High Fuel Efficiency
- High Availability
- Broad Weather Envelope

With the recent advent of the Coast Guard's 200 mile coastal patrol zone these same features appear highly desirable. Recent technology studies[6-32] and professional meetings[33-38] indicate that state-of-the-art materials, structures, propulsion and flight controls make modern airships viable for long endurance multi-mission applications.

The renewed development of modern airships has been hampered by the perception of some that airships are large and unwieldy, vulnerable to both damage and the environment. Much of this opinion is based upon misconception. The facts are:

1. Airships do not burst like balloons when punctured. Holes of many square meters are necessary to rapidly bring down an airship. Vital components are widely spaced.

2. Under normal operating conditions airships do not need hangars at each airship base. Initial erection and major overhaul require hangar facilities but at the operational bases airships can be maintained outdoors at fixed or mobile mooring masts.

3. Modern ground handling equipment minimizes the size of the ground crew. With a hover capable airship the ground handling operations should be performed by a crew of less than ten[13, 27].

4. A modern airship should be no more vulnerable to adverse weather than modern aircraft. Historical operations have shown that airships can maintain station in extremely severe weather.

STUDY ASSUMPTIONS

Based on the past performance of airships and the infusion of modern technology for propulsion, structures, materials, and flight controls, the attributes of airships assumed for MPAS are:

- Hover Capable
- 90 knot max speed
- Vertical Takeoff or Landing
- Able to Tow (sensors and vessels)
- Broad weather envelope
- Low power requirements

The lifting gas presumed for all vehicles is 95 percent pure helium[39]. In the interest of expediency, the avionics and sensor suites for the conceptual designs were not optimized for airship use but were assumed to be the same as those designed for the Coast Guard's HU-25 jet aircraft intended for medium range search operations.

SCOPE

The emphasis of this study has been on the determination of the suitability of LTA platforms in performance of current Coast Guard operations. Consideration has been given only to operations as they are currently being performed in a manner consistent with the utilization of the Coast Guard's available air and sea assets. No consideration was given to missions that required handoff of operations from one airship to another or to another platform type. Nor was consideration made of operations requiring refueling or remanning of the airship; both of which are feasible and consistent with past airship operations.

If a mission was expected to exceed the capabilities of a single airship, it was not evaluated as part of this analysis.

APPROACH

Because of the broad scope of this study, a general approach was required. Potential missions were identified under the existing Coast Guard program structure. These missions were then subdivided into a set of mission segments or of tasks. These tasks were generic in nature and realistic missions were composed by selecting the required mix of tasks. This approach provides a broad but systematic method for evaluating airships for Coast Guard missions. The emphasis is not on detailed task analysis but rather on the multi-mission effectiveness. The most important aspects of the approach are the determination of the total airship force level requirement and the missions that airships can perform.

ANALYSIS

To approach this effort, a review of existing Coast Guard operations was undertaken. The Coast Guard's operations are organized into thirteen programs[40, 32]. Of these, with the assistance of Coast Guard operational personnel, the following eight were identified for possible airship participation:

1. Short-Range Aids to Navigation (A/N)

2. Enforcement of Laws and Treaties (ELT)

3. Marine Environmental Protection (MEP)

4. Military Operation/Preparedness (MO/MP)

5. Marine Science Activities (MSA)

6. Port Safety and Security (PSS)

7. Search and Rescue (SAR)

8. Ice Operations (IO)

After review of these programs, the important features of airship utilization can be summarized for each of these programs as follows:

A/N Program

Airships could be utilized for:

1. Discrepancy Reporting

- After severe weather, survey for lost, disabled, and displaced buoys

2. Buoy Placement

   - Through precise navigational techniques, mark placement of buoys

3. Logistics Support

<u>ELT Program</u>

Airships can be used for:

1. Drug Enforcement

2. Fisheries Enforcement

Airships can provide:

1. Combined Characteristics of Ships and Aircraft

   - Higher speed than ships

   - Not affected by sea state and corrosive environment

   - High sweep rate due to speed and altitude

   - Long endurance

   - Slow speed and hover capability

   - Ability to board

2. Presence

3. "Hot Pursuit" Capability

<u>MEP Program</u>

Airship participation in MEP operations can include:

1. Surveillance

   - Including sea water sampling

2. Logistics Supply

   - Delivery skimmers and large pumps

   - Not limited by sea state

3. Command, Control, and Communications Platform for Large Clean-Up Operations

- Provide illumination for night time operations

MO/MP Program

Potential mission areas for airship participation in MO/MP operations are:

- Patrol
- Anti-submarine Warfare (ASW) sonar and sonobuoy surveillance/attack
- Ocean Industry Protection (OIP) surveillance/inspection
- Convoy Escort
- Logistics and supply
- Inshore, undersea warfare

NOTE: While the MO/MP Program does not have dedicated assets, operations would typify past airship military roles.

MSA Program

There is potential for airship utilization in the following MSA operations:

1. International Ice Patrol (IIP)
   - Has high endurance and payload capability
   - Less constrained by poor visibility and ceiling than HC-130
2. Airborne Radiation Thermometry (ART)
   - Has high endurance and payload capability
   - Instrumentation can be isolated from heat and vibration sources
   - Safe low altitude (500 feet or less) platform
3. NOAA Data Buoy Office Support (NDBO)
   - Investigation of disabled buoys
   - Search for drifting buoys
4. Miscellaneous
   - Ferrying cargo and personnel

- Aerial photography
- Environment survey

PSS Program

For the PSS program the following missions have been identified for airship utilization:

1. Escort of vessels carrying hazardous cargoes
   - Station keeping in vicinity of vessel
   - Large area surveillance
   - Direct communication
   - Quick response
2. Port traffic control
   - Mini-Vessel Traffic Services (VTS)
   - Simultaneous observation, command, control, and communications platform
   - Quick response
3. Provide fire fighting equipment
   - Logistics support
   - Command and control

SAR Program

Airship utilization has been considered for long range rescue operations ten miles or greater from the shore. Airships could be particularly useful for such operations because airships:

1. Have high sweep rates
2. Provide evacuation capability
3. Can deliver large payloads
4. Can be used for boarding vessels
5. Can tow vessels in distress
6. Possess long endurance ability

IO Program

The airship has great potential for Aerial Ice Reconnaissance (AIR) operations of the IO program since this platform:

1. Would have sufficient range to survey most areas
2. Will utilize Side Looking Airborne Radar (SLAR)
3. Should be capable of carrying the Radar Image Processor (RIP)

Mission Analysis

For each of the eight programs, realistic missions were identified. Each mission was keyed to an actual Coast Guard operation, in most cases involving more than one asset (for example helicopter and cutter). These missions for all eight programs total 264 mixed-task missions. In order that conceptual vehicles could be formulated it was necessary to provide detailed representative profiles for each program. These representations or script scenarios represented a median level of difficulty and complexity for each program. These scenarios specified each of the operations in sequence, the parameters associated with the operations (speed, weight, payload, etc.) and the duration of the operation. A summary of these scenarios is given in Table I-I. The maximum required capability for each of the parameters is underlined.

Vehicle Sizing and Parameters

Based on the mission requirements specified by the script scenarios, a computer sizing and performance program was utilized to arrive at conceptual vehicles. The program, Naval Airship Program for Sizing and Performance (NAPSAP)[41], is a tool developed by the LTA Project Office at NAVAIRDEVCEN for use in analyzing model LTA vehicles performing various missions.

The program has been designed to operate on a minimum of input data (only five cards are necessary), but has the capability to evaluate the influence of over 40 key parameters. NAPSAP provides easy parametric analysis for several optional levels of detail. Once the design section of NAPSAP converges on a vehicle which meets the input requirements, this vehicle can then be evaluated against a specified mission profile with all key parameters monitored at preselected time intervals.

The data input for NAPSAP was determined primarily by the eight, predetermined mission profiles. Variables such as design speed, design altitude, payload, endurance, and crew size are examples. Other design variables used for MPAS are based on other recent Navy parametric analyses of modern LTA vehicles[13, 27]. Variables in this category include buoyancy ratio at take-off, hull fineness ratio (length over diameter), number and type of engines, and propeller characteristics.

TABLE I-I
MARITIME PATROL AIRSHIP STUDY
MISSIONS SUMMARY

TASKS	ENFORCE LAWS AND TREATIES; SEARCH AND BOARD	MARINE ENVIRONMENTAL PROTECTION; CLEAN-UP	MIL. OP./MIL. PREPAREDNESS: TOW ASW ARRAYS; ATTACK	PORT SAFETY AND SECURITY; HAZARDOUS VESSEL ESCORT	SEARCH AND RESCUE; SEARCH, BOARD, AND TOW	AIDS TO NAVIGATION; BUOY MAINTENANCE	MARINE SCIENCE ACTIVITIES; ICE PATROL (ST. JOHNS)	ICE OPERATIONS: ICE MAPPING (GREAT LAKES)
Duration (Hours)	27.5	12.5	26.5	8.35	13.6	17.0	35.5	20.5
Total Payload (lb.)	7,669	22,372	10,929	6,237	7,910	7,396	7,761	7,482
Cruise Speed (Knots)	50	50	40	40	60	50	60	60
Dash Speed (Knots)	90	—	90	—	90	—	—	—
Crew (200 lb. each)	11	6	11	6	8	8	—	—
Maximum Altitude (Feet)	5,000	5,000	5,000	5,000	5,000	1,000	5,000	5,000
Tow	—	—	Sonar	—	Ship	—	—	—

NAPSAP was exercised to arrive at eight conceptual vehicles (one for each of the different profiles). These vehicles are described in Table I-II. Note that factors such as payload, design speed, and endurance requirements result in a wide variety of vehicle sizes for different requirements.

To continue MPAS, the eight conceptual vehicles were examined to select one vehicle capable of performing all profiles. It was decided, in the interest of minimizing vehicle size (cost), that the vehicle sized for the MEP profile was able to perform all profiles (the MSA profile was flown at a lower altitude). This conceptual vehicle was designated the ZP-X and was used to complete MPAS in terms of cost-effectiveness considerations. ZP-X characteristics are shown in Table I-III.

Additional analyses were conducted on the ZP-X to explore the effects of parameter variation. Parameters addressed were design dash speed, design altitude, structural weight, and total drag coefficient. An example of the resulting sensitivity data is presented for design dash speed variation in Table I-IV.

Estimated Life Cycle Cost (LCC) and Logistics

The cost estimates contained in this study are based upon projections of historical data, and upon comparison of cost of construction and operation of modern heavier-than-air craft. All of the data used are based upon the extrapolation of cost data generated in other recent studies[42, 43, 7, 15]. Two costing approaches were used: Life Cycle Cost (LCC) and Standard Rate Cost. LCC, the total lifetime build-up approach, is emphasized. Standard rate costs, or costs calculated on an hourly basis for the time personnel or an asset is utilized, were also calculated. Both approaches were based on current Coast Guard procedures.

Based upon an initial estimate of the total Coast Guard mission requirements, a potential annual utilization of airships was projected to be 100,000 to 125,000 hours per year. It was assumed that each airship flies 2,400 hours per year resulting in a requirement of from 42 to 52 airships. A geographic distribution of airships similar to the MRS basing was assumed, resulting in nine airship bases. If each base has 5 airships, a total of 45 airships for operations would be required. An additional 5 airships would be purchased for training, research and development and backup, making a total buy of 50 airships.

This study, being a first order study, has not evaluated the real estate requirements of the airship operations and the analysis of the availability of the real estate at the MRS bases. Hangar facilities would not be provided at each base. Hangars will exist at depot maintenance facilities. Routine maintenance would be provided at the mast.

Based upon the current Coast Guard requirement that restricts aircrews to 800 hours flying time a year, it will be assumed that three crews are required per airship, and that an airship will be utilized for 2,400 flight hours per

TABLE I-II
VEHICLES SIZED FOR EIGHT USCG REPRESENTATIVE PROFILES

MISSION	ELT	MEP	MO/MP	PSS	SAR	A/N	MSA	IO
Volume (ft^3)	586,494	783,696	700,045	282,390	392,154	447,330	992,165	607,678
Static Lift (lbs)	32,092	46,917	38,305	15,452	21,458	24,477	54,289	33,251
Dynamic Lift (lbs)	5,224	7,638	6,236	2,515	3,493	3,985	8,838	5,413
Length (ft)	277	305	294	217	242	253	330	280
Diameter (ft)	63	69.3	67	49	55	57.5	75	64
Fitness Ratio (l/d)	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Buoyancy Ratio	.86	.86	.86	.86	.86	.86	.86	.86
Horsepower Required	1,471	1,927	1,651	942	1,142	1,236	2,076	1,506
Gross Weight (lbs)	37,316	54,544	44,541	17,967	24,951	28,462	63,127	38,664
Empty Weight (lbs)	20,850	27,674	24,527	10,816	14,478	16,289	33,717	21,540
Useful Load (lbs)	16,466	26,880	20,004	7,151	10,473	12,173	29,410	17,124
Empty Weight Fraction	.559	.507	.551	.602	.580	.572	.534	.557
Fuel Weight (lbs)	8,812	5,057	6,650	915	2,568	4,752	21,638	9,706

TABLE I-III
NAVAIRDEVCEN ZP-X DESIGN

VOLUME:	783,696 Cubic Feet
GROSS WEIGHT:	54,554 Pounds
EMPTY WEIGHT:	27,674 Pounds
HORSEPOWER REQUIRED:	1,927 (Three Gas Turbine Engines)
LENGTH:	305 Feet
DIAMETER:	69 Feet
STATIC LIFT:	46,917 Pounds
DYNAMIC LIFT:	7,638 Pounds
FINENESS RATIO:	4.4
USEFUL LOAD:	26,880 Pounds
BUOYANCY RATIO:	.86

TABLE I-IV

SENSITIVITY OF ZP-X VEHICLE TO CHANGES IN DESIGN DASH SPEED

PERCENT CHANGE IN DESIGN DASH SPEED	EFFECTS ON KEY PARAMETERS - PERCENT				
	HULL VOLUME	TOTAL MISSION TIME	EMPTY WEIGHT	USEFUL LOAD	HORSEPOWER REQUIRED
-20	-12.9	+22.8	-6.7	-6.3	-48.0
-10	-7.5	+11.7	-3.7	-3.5	-23.4
0	0	0	0	0	0
+10	+7.8	-12.9	+4.3	+4.4	+19.6
+20	+20.5	-30.5	+9.9	+10.9	+44.9

NOTE: [1]Baseline value for design speed is 90 knots.
[2]Baseline value for gross weight is 54,554 pounds.

year. This is equivalent to a 27 percent mission utilization. The airship is assumed to have a 12 year lifetime. Crew size varies from 5 to 13 depending upon mission duration.

The determination of initial LCC procurement or acquisition cost was based upon the following four approaches:

1. Costing based on speed and volume of the airship, using regression analysis of historical airships. An 80 percent learning curve was used[43].

2. Costing based on analysis of a modern non-rigid Navy design (ZPG-X) cost as calculated on a weight basis. An 80 percent learning curve was used[15].

3. Costing based upon systems weights. Learning curve a function of system[44].

4. Cost estimates of Goodyear Aerospace Corporation for a Maritime Patrol airship. An 85 percent learning curve was assumed[45].

These approaches to the unit acquisition cost have produced four different estimates which range from $3.9 to $8.45 million. Based on an analysis of the four approaches, it was determined that a unit cost for 50 airships is reasonably $5.0 million per airship. In addition, facilities cost for both bases and maintenance facilities including GSE is about $900,000 prorated for each airship. The initial training cost is projected to be $500,000[15]. Therefore, the total investment cost is approximately $6.4 million per airship.

Of all of the costs calculated, the single largest cost of operating the airship is the personnel cost. Depending on crew size (which is a function of flight duration) and composition, and assuming an 800 hour annual flight hour limit, the personnel cost varies from $235.38 to $567.88 per flight hour.

The maintenance of an airship is an area in which improvements in technology will have significant impact. With the increased reliability of systems and the advent of sophisticated electronic test equipment, there can be little comparison between the historical airship maintenance requirements and the maintenance requirements of a modern airship. The additional LCC component for direct maintenance has been assumed to be $23.20 per flight hour.

Based upon these costs, the LCC prorated on a flight hour basis runs from $750/FH to $1,150/FH. The difference in the rate depends on the type of mission in which the airship is employed. For long endurance missions, costs increase because of high crew costs. High speed operations or missions requiring lift of heavy payloads consume fuel at a higher rate and are, therefore, more expensive.

An alternative approach to calculating the cost of performing a Coast Guard mission is through the use of the Standard Rate Calculation. In this approach the costs are calculated on an hourly basis for the time personnel or an asset is utilized. Using the standard rate method, the airship's cost may vary from $446.01 to $654.28 per flight hour. This compares to the rates of $912.20 for an HH-3F, $614.90 for a HU-16E, $893.91 for a HC-130H, and $448.30 for a WMEC-210.

Vehicle Case Studies

It was deemed desirable to have some means of comparing the in-house vehicle analysis with independent thinking. Goodyear Aerospace[46] and Bell Aerospace[47] were provided identical mission profile data to that used for in-house analysis from which to size vehicles. Results could then be overlaid with the NAVAIRDEVCEN ZP-X to examine similarities (or lack thereof). The resulting designs were found to be in good agreement. Table I-V provides a side-by-side comparison of the three conceptual vehicle designs. Figures I-1 and I-2 present the Goodyear and Bell vehicles.

The NAVAIRDEVCEN ZP and Goodyear ZP3G employ a three-engine configuration with aircraft propellers while the Bell platform uses a four-engine approach with tilt-rotors. All are designed to provide precision hover helicopter-style via the use of vectored propulsive thrust. Bell chose to avoid the traditional operational practice of recovering ballast (usually sea water) to trim the vehicle by utilizing large amounts of reversible thrust on the four tilt-rotors. Since in this design less of the total lift was static buoyancy, power required was increased.

It should be noted again that these vehicles were designed to USCG missions of no more than 35.5 hours of endurance. As demonstrated in past operations, airships are capable of much greater endurance.

:tiveness Results

As previously stated, discussions with cognizant Coast Guard personnel .lted in a total of 264 mission profiles being identified for potential ship utilization. On the basis of the computer analysis, the ZP-X airship is able of performing 211 of these profiles. Of the 53 profiles beyond the ability of the airship, 43 are associated with the Military Operations/ litary Preparedness Program. Because of the contingency nature of the MO/MP ogram, the specification of these profiles was not based upon existing opera- .ons but, rather, preliminary estimates of the airship capability.

For the remaining 211 profiles there is an expected requirement of 12,860 orties. This translates into a potential for using airships 183,000 hours a year. Again assuming 2,400 flight hours per year for an airship, there is a potential requirement for over 75 airships. Of this requirement 47 percent of the flight hours are associated with operations of the ELT program. Thirty percent of the flight hours are associated with SAR operations. None of the other programs account for more than 10 percent of the flight hour requirements. MO/MP does not have any flight hour requirements due to its special nature.

To determine the significance of endurance for the airship role in Coast Guard operations, the annual flight hours requirements, grouped by ten hour intervals of mission endurance, were calculated. The flight hour requirement remains at a fairly constant level for missions of up to 50 hours. The requirement varies from 27,000 hours for missions of 20 to 30 hours, up to 39,000 hours for missions of 40 to 50 hours. The average flight duration is 14.3 hours.

TABLE I-V
MPAS CONCEPTUAL VEHICLES COMPARISON

	GAC ZP3G	BAT MPA	NADC ZP-X
Envelope Volume (ft^3)	875,000	858,437	783,696
Length (ft)	324	326	305
Diameter (ft)	73.4	72.4	69.3
Static Lift (lb) @ 2,000 Ft.	52,164	44,658	44,243
Dynamic Lift (lbs)	8,500	17,917	7,638
Horsepower Required	2,400	4,306	1,927
Gross Weight (lbs)	60,664	65,274	54,554
Empty Weight (lbs)	33,740	33,019	27,674
Useful Load (lbs)	22,504	32,256	26,880
Buoyancy Ratio	.86	.73	.86
Maximum Altitude (ft)	10,000	10,000	10,000
Maximum Speed (kt)	97	104	90

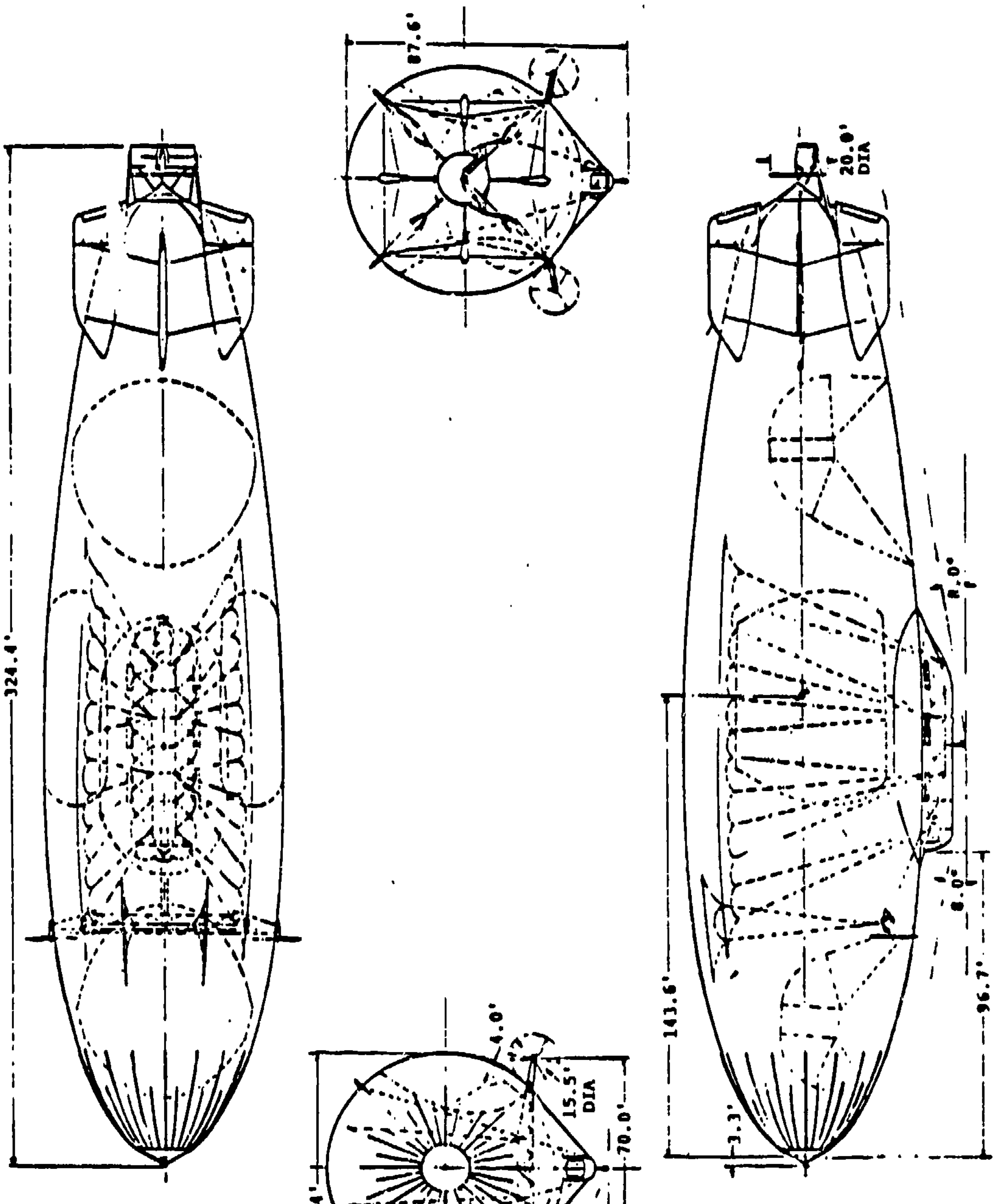


Figure I-1. ZP3G Airship (Goodyear).

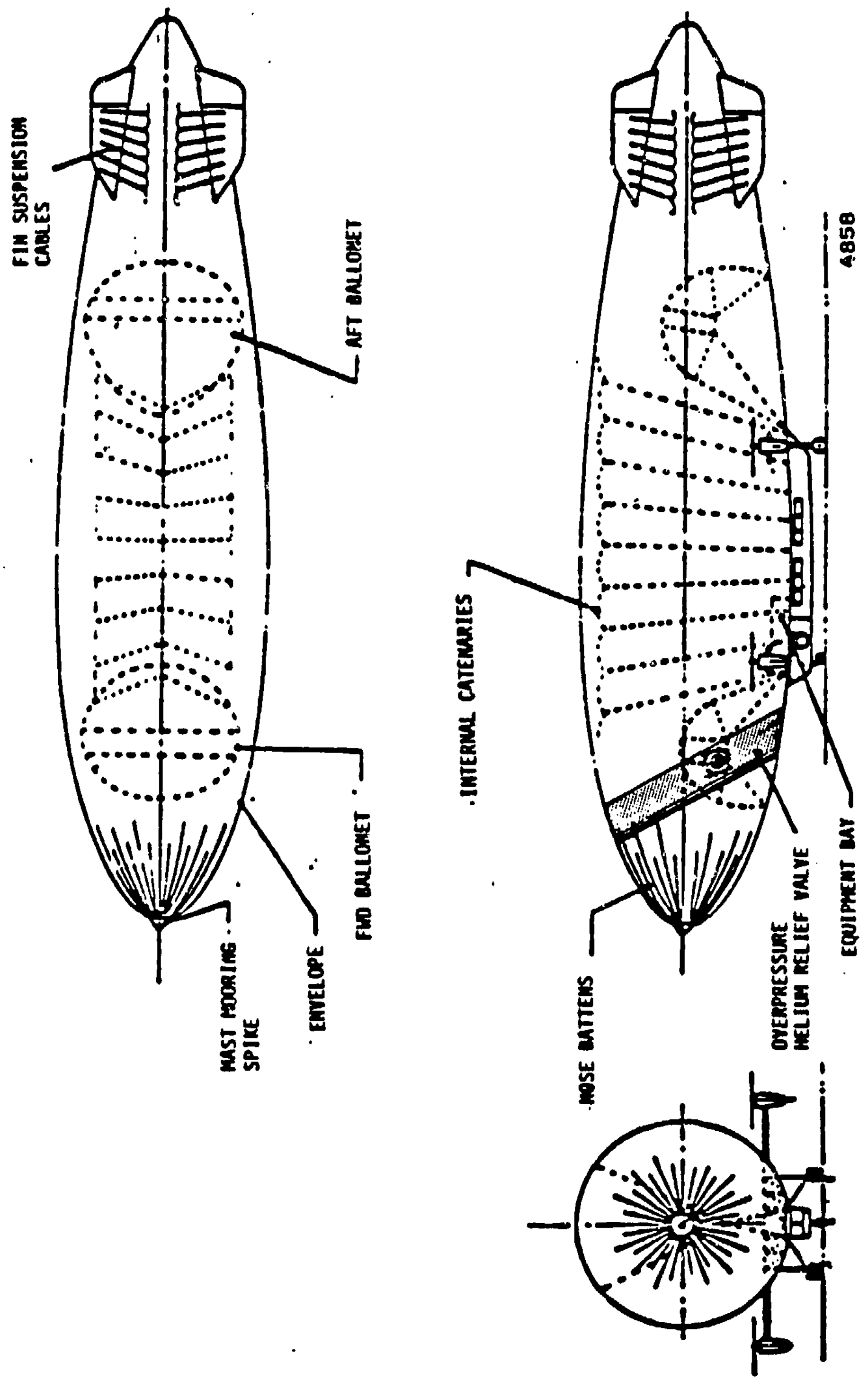


Figure I-11. Maritime Patrol Airship (Bell).

Recall that in the initial cost analysis, a buy of 50 airships was assumed. With 5 of these airships for training and research and development, there were 45 operational airships. If totally utilized the 2,400 flight hours per year, the airships would be utilized 108,000 hours. This availability is sufficient only to satisfy all requirements up to missions of between 30 to 40 hours.

Analysis of the requirement of mission duration for each of the eight programs shows two distinct groupings. In the A/N, PSS, and SAR programs, shorter missions (less than 20 hours) tend to predominate. In the ELT, MEP, MSA, and IO programs the longer missions tend to predominate. The longer missions also tend to predominate for MO/MP operations as well. This implies that there may be a requirement for the design of two distinct airships, a smaller one of about 15 hour endurance and a larger one of about 40 hour endurance. The smaller airship can be designed for more economical operation, whereas the larger airship (probably of similar design as the ZP-X) would have greater capability.

The potential utility of an airship for Coast Guard missions comes from its ability to perform a number of operations well. It is not so much that the airship excels at any one task, but given an aggregation of tasks, typical of Coast Guard missions, it should provide superior capabilities. Because of the higher speed, aircraft will generally be better search platforms than ships. Its stability and long endurance loiter speed make the airship ideal for detailed search or search for small objects. For boarding operations and long endurance requirements, ships are better. But for the large number of operations that mix these tasks, airships offer great potential with low energy costs.

Analysis of the task requirements for a maritime patrol airship indicates:

1. Over 90 percent of all of the operations analyzed utilize transit or patrol at 50–60 kts.

2. Station keeping/trail at less than 20 knots is utilized in over 60 percent of the missions.

3. Only A/N and PSS operations do not require a search capability (according to USCG program personnel). All of the ELT, SAR, and IO missions require search.

4. Hover capability for either boarding or logistics operations is only required in 33 percent of the missions. Most of the missions requiring hover are for either the SAR or ELT. However, all of the A/N operations include tasks requiring hover.

<u>Summary Cost Results</u>

For missions of less than ten hours, the hourly cost is approximately $750/hour. For missions between 10 and 20 hours, the cost is approximately $875/hour and for missions of greater than 20 hours, the approximate cost is $1,085/hour.

The cost of a mission will vary with the length of the mission. For all of the missions analyzed, the cost extremes are $1,127 for a 1 and 1/2 hour MO/MP logistics support mission to $117,659 for a 110 hour MO/MP towed array search mission. The cost of delivering ADAPTS equipment to an MEP cleanup operation ten miles off-shore is $2,823. The cost of doing a SAR operation can be as little as $1,501 for an operation 25 miles from the airbase to $13,440 for an operation 500 miles off-shore.

Putting the Results in Context

A brief comparative analysis was performed. Both the fuel efficiency and cost of performing selected missions were analyzed. The most frequently occurring proposed airship missions were chosen for this analysis. These were four ELT and nine SAR missions. The airship standard rate cost and fuel requirements for these missions were compared to those of the following Coast Guard platforms:

- HC-130B
- HH-3F
- MEC-210
- HEC-378
- HU-25A (MRS)

The cutters are always more expensive to operate than the airship. The MRS, when capable, is less expensive to operate than the airship. In the five SAR missions that the MRS is capable, it could only air-drop equipment and summon a ship. In the missions the HH-3 is capable of performing, it is always more expensive than the airship.

In one-half of the six missions of which the HC-130 is capable, it can do so at a lower cost than the airship. For two of the missions it is more expensive, and for one mission the costs are about the same. The HC-130 currently performs all six of these missions.

Airships are very efficient users of fuel. As opposed to aircraft, which are completely dependent on dynamic lift, most of an airship's lift is provided by the buoyancy of the lifting gas. In that air is less dense than water, there is much less drag on an airship than on a ship. Data for aircraft and ships were selected from optimal economical conditions.

Based upon the analysis of the comparative fuel consumption it was found that in conducting the 13 missions, the MRS and the HC-130 use from one and one-half to three times as much fuel as the airship. The HC-130 uses from four to eight times as much fuel. In many cases, the cutters use over ten times as much fuel.

CONCLUSIONS

1. Airships appear on the basis of this first order analysis to have direct, cost-effective application to many maritime patrol missions.

2. Airships appear technically feasible in maritime patrol roles.

3. Airships appear operationally feasible.

4. Airships deserve special notice for energy efficient operation.

RECOMMENDATIONS

1. LTA experimental vehicle flight demonstrations are recommended for technical and operational validation in performance of maritime patrol missions.

2. It is recommended that Coast Guard requirements be determined for logistic and operational factors (training, maintenance, basing, utilization, etc.) in light of the unique abilitites of airships.

3. It is recommended that in-depth point design studies of candidate vehicles address issues such as hover techniques, ground equipment definition, vehicle fabrication methods, detailed vehicle lay-outs, and scaling effects for a demonstration vehicle.

CHAPTER II
INTRODUCTION

The Maritime Patrol Airship Study (MPAS) is an effort designed to explore on a systems basis the potential for cost-effective application of modern Lighter-Than-Air (LTA) vehicles to current and future needs of the U.S. Coast Guard. Of the joint funding for this study (approximately 4.0 man-years), three-quarters was provided by the U.S. Navy and one-quarter by the U.S. Coast Guard. Common interest in long endurance maritime patrol vehicles is shared by Navy and Coast Guard and a technology base for LTA as developed by both these agencies and NASA in recent years served as an important prerequisite to MPAS. Table II-I describes the principal studies recently concluded.

The results of this first-order systems approach are intended to serve as an indicator for further committment on the part of the Coast Guard. Due to the dual identity of the Coast Guard (a part of the Navy in wartime), MPAS also provides input for on going Navy LTA programs.

The principal ingredients of the study are as follows:

1. Mission Requirements and Rationale. "Representative" mission scenarios are generated for Coast Guard applications using recent Coast Guard mission data for eight different programs (Chapter IV).

2. Mission Analysis and Effectiveness. Based on mission requirements, develop "representative" detailed mission profiles and a "representative" avionics suite; then generate a computer math model to analyze mission performance and effectiveness (Chapters IV and VIII).

3. Vehicle Sizing and Performance. Develop a computer program to predict sizing and mission performance of modern LTA vehicles; then exercise this program to select a conceptual point design to perform the required missions. Examine sensitivity of this vehicle to variation of selected key vehicle and performance parameters (Chapter V).

4. Estimated Life Cycle Cost (LCC) and Logistics. Establish methodology to estimate the LCC of MPAS point design and explore logistics considerations such as reliability and maintainability, manning and training requirements, basing requirements, and support requirements (Chapter VI).

5. Vehicle Case Studies. Based on the same mission requirements two contractors were to derive conceptual point designs to be used for comparative purposes with the in-house computer results (Chapter VII).

6. Conclusions/Recommendations. Conclusions and recommendations are presented in Chapters IX and X.

Figure II-1 presents the flow of the study elements.

TABLE II-I
SUMMARY OF MAJOR LTA STUDIES

DATE(S)	TITLE	SPONSOR(S) (CONTRACTOR)	DESCRIPTION	OUTPUT
1975	Feasibility of Modern Airships - Phase I	NASA (Goodyear, Boeing-Vertol)	Technical examination of modern LTA vehicles against civil applications (Ref: [6], [7])	Vehicle parametrics, three conceptual designs for civil roles, recommendation for military roles study
1976-77	Feasibility of Modern Airships - Phase II	NASA/Navy (Goodyear)	Civil point designs for Heavy Lifter and Airport Feederliner. Initial examination of naval missions. Wind tunnel test of Heavy Lifter model (Ref: [8]-[16])	Two civil point designs, Navy vehicle parametrics, two conceptual Navy designs, wind tunnel data of Heavy Lifter
1976-77	Advanced Navy Vehicle Concepts Evaluation (ANVCE)	Navy (Martin-Marietta, Goodyear, Northrop, American Power Jet Co., Turbomachines Inc.)	Examination of various advanced air and sea vehicles for naval applications in terms of technical feasibility, military worth, and cost (one air vehicle category was LTA - three different types (Ref: [17]-[31])	Vehicle parametrics; technology studies in Aerodynamics, Materials, Structures, Survivability, and Vulnerability, and Life Cycle Costs. Point Design Studies for Fully Buoyant Rigid, Semi-Buoyant Rigid, and Fully Buoyant Non-rigid
1975-78	Assessment of Selected Lighter-Than-Air Vehicles for mission tasks of the U.S. Coast Guard	USCG (Center for Naval Analyses)	Examination of LTA vehicles for USCG missions on a task basis, vehicles were designed, operational costs were compared with other current and projected CG air and sea assets (Ref: [32])	CG Missions Analysis, LTA Vehicle designs, operational costing, effectiveness comparisons with other vehicle types

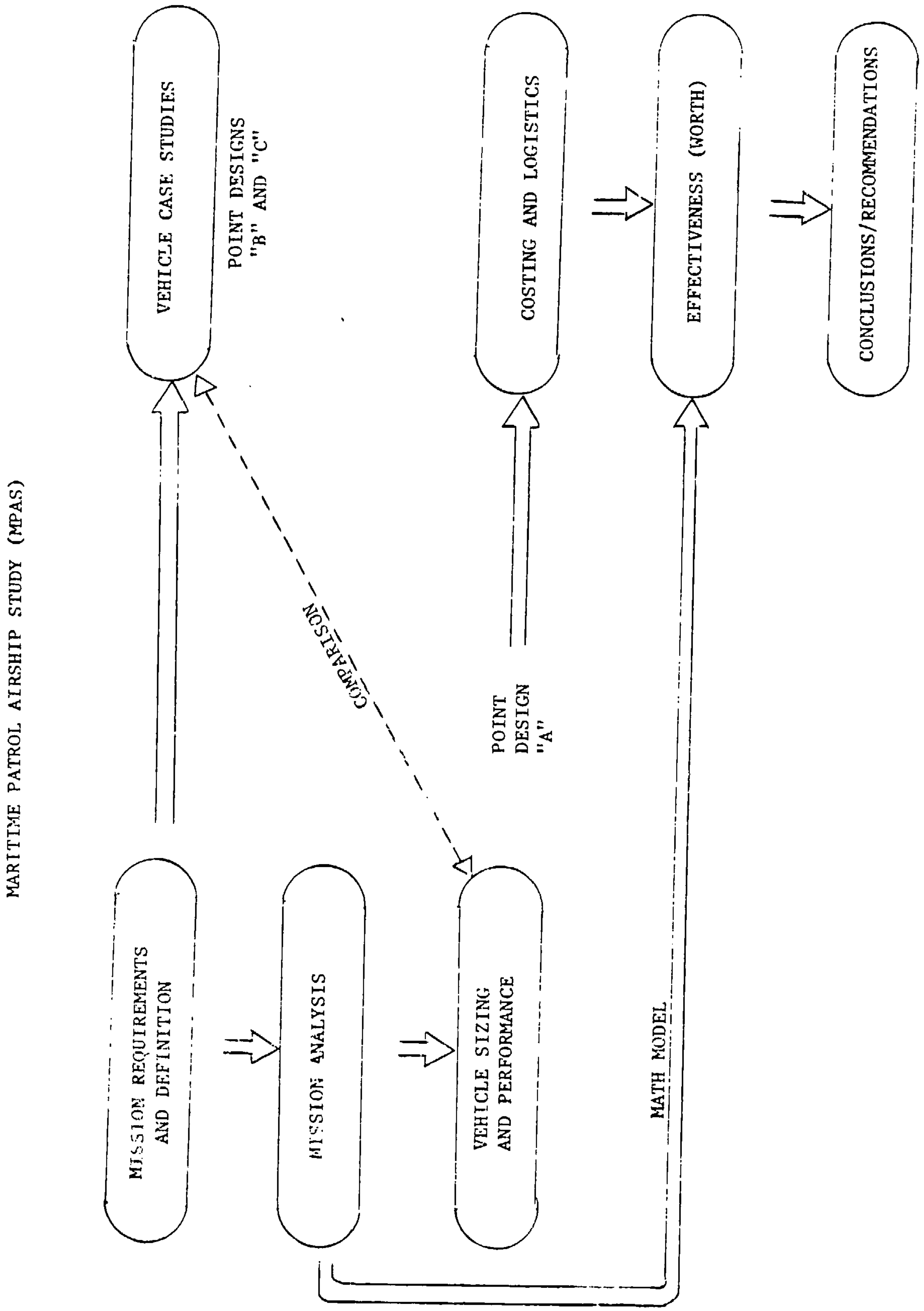


Figure II-1. Maritime Patrol Airship Study Work Flow.

While many of these separate issues could be explored in-depth as individual studies MPAS was to maintain a consistant level of effort across all tasks. This results (due to time and money) in a systems concept which is not "fine tuned." A more detailed analysis would precede an optimized concept.

Finally, the systems applicability of modern LTA vehicles was examined for roles in the total Coast Guard mix of existing assets - this was not a platform replacement study.

CHAPTER III
LTA VEHICLE CHACTERISTICS AND OPERATIONS

This Chapter is to briefly acquaint the reader with the nature and operational history of Lighter-Than-Air (LTA) vehicles and present the vehicle related assumptions presumed for MPAS.

Lighter-Than-Air vehicles are not a recently conceived idea. Manned balloon flights date back to the late 1700's. Then and now however, the fundamental buoyancy principle of LTA flight is the same. Buoyancy is a well-known fact of physics. LTA vehicles inflated with a "light" gas are buoyed up by the heavier surrounding air. A summary of light gases is shown in Figure III-1. Free balloons (flown at the mercy of prevailing air currents) developed into "dirigibles" (French for "directable" or "steerable") with the addition of control surfaces to a more streamlined shape. These "airships" as they are now known have in the last hundred years been characterized by one of three structural design types[6, 7]. A genealogy of non-rigid, semi-rigid, and rigid airships is shown in Figure III-2.

Non-rigid airships are characterized by a single flexible envelope of gas - without compartmentation - to which the propulsion, empennage, and control car are attached as shown in Figure III-3. The loads are supported along and across the envelope by catenary curtains which are attached to hard points in the car by suspension cables. At sea level the ballonets (internal flexible cells) are filled with air. As altitude is increased, the helium expands and air from the ballonets is expelled through air valves to maintain the same hull shape. At design altitude (or pressure height) the ballonets are empty. To return to sea level the process is reversed - air is scooped from the engine exhaust (sometimes aided by auxillary blowers) and forced into the ballonets. In addition to internal pressure, bow stiffeners (battens) are attached to prevent "nose cave-in" at high forward speeds. For all types of airships in order to compensate for the weight of fuel burned it is necessary to collect ballast to maintain buoyancy trim. Typically the non-rigids picked up (or pumped up) sea water as required.

Semi-rigid airships retain rigid structural members only for a rigid keel along the bottom surface of the vehicle. This type of vehicle differs from the non-rigid type in that the keel supports the primary loads and the caternary suspension system plays a much lesser role. Figure III-4 shows a semi-rigid airship.

The "rigid" airship consists of fabric covered, compartmented cells of lifting gas retained within a rigid skeleton of structural members (historically wire-braced aluminum girders) as depicted in Figure III-5. Altitude compensation is handled through expansion and contraction of individual gas cells within

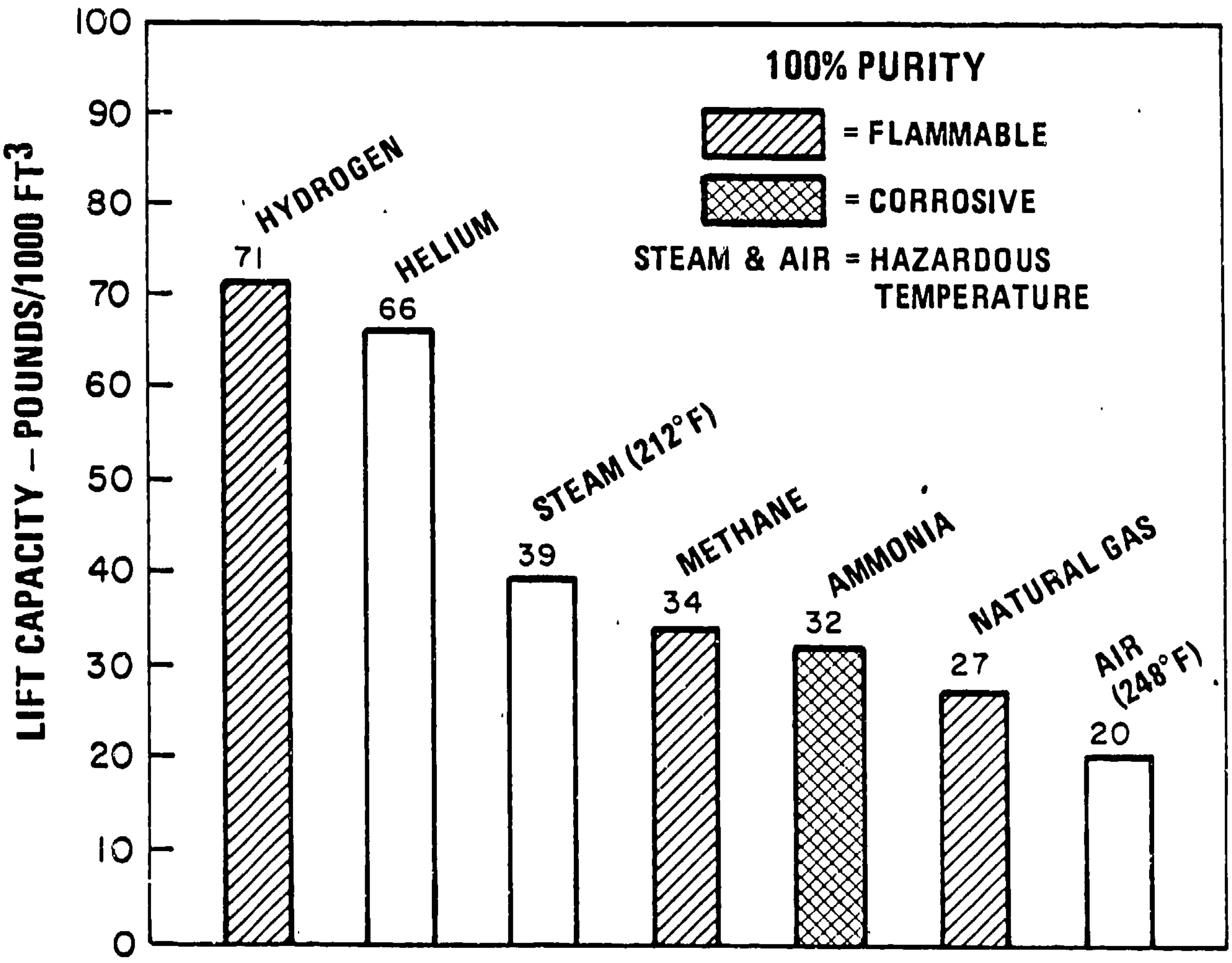


Figure III-1. Lifting Gases Comparison.

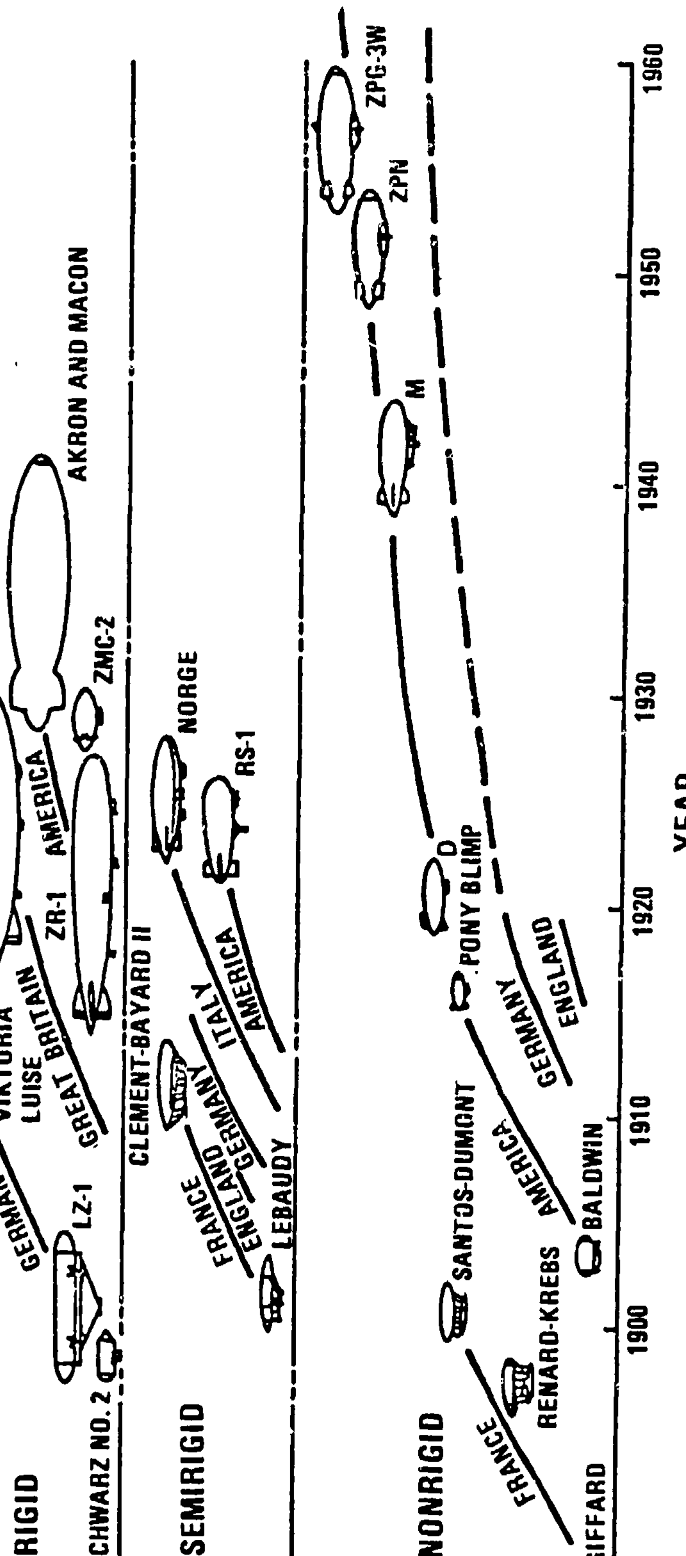
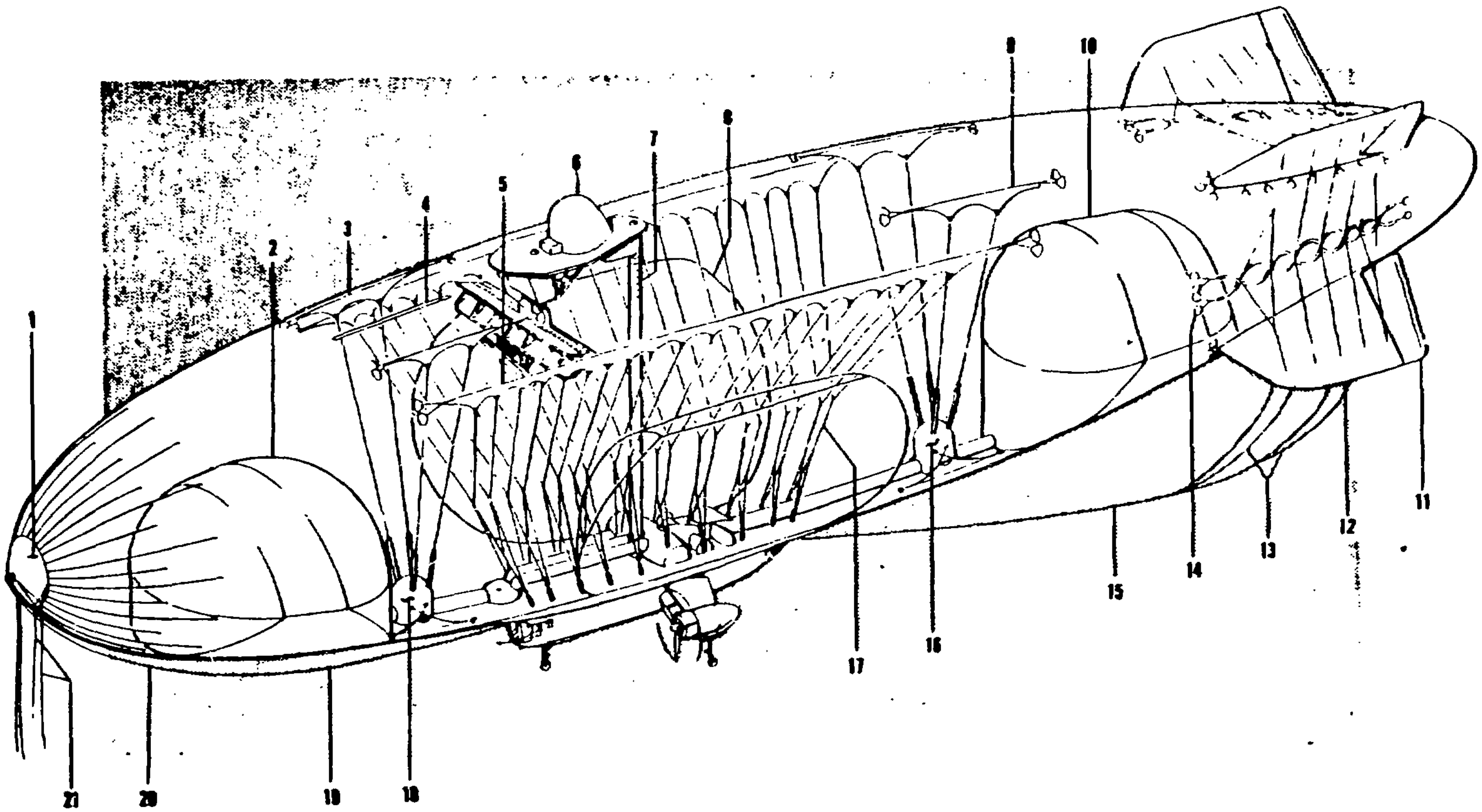


Figure III-2. History of Airship Development.



1. Nose Cone
2. Forward Ballonet
3. Forward Envelope Fuel Tank Catenary Curtain
4. Rip Panel
5. Suspension System Catenary Curtain
6. Topside Radar Platform
7. Radar Platform Access Shaft
8. Center Ballonet
9. Aft Envelope Fuel Tank Catenary Curtain
10. Aft Ballonet
11. Ruddevator
12. Fin
13. Stern Bridle Lines
14. Fin Catenary Curtain
15. Bridle Retrieving Lines
16. Aft Envelope Fuel Tank
17. Internal Suspension Cable (Typical)
18. Forward Envelope Fuel Tank
19. Pendant Retrieving Line
20. Mooring Pendant
21. Long-Lines

Figure III-3. Navy Airship Envelope General Arrangement.

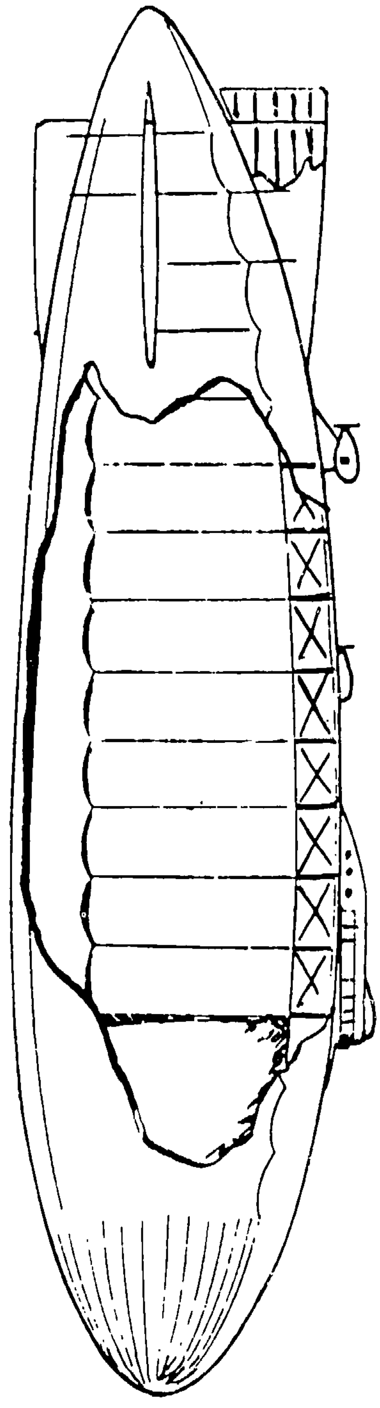


Figure III-4. Semi-Rigid Airship.

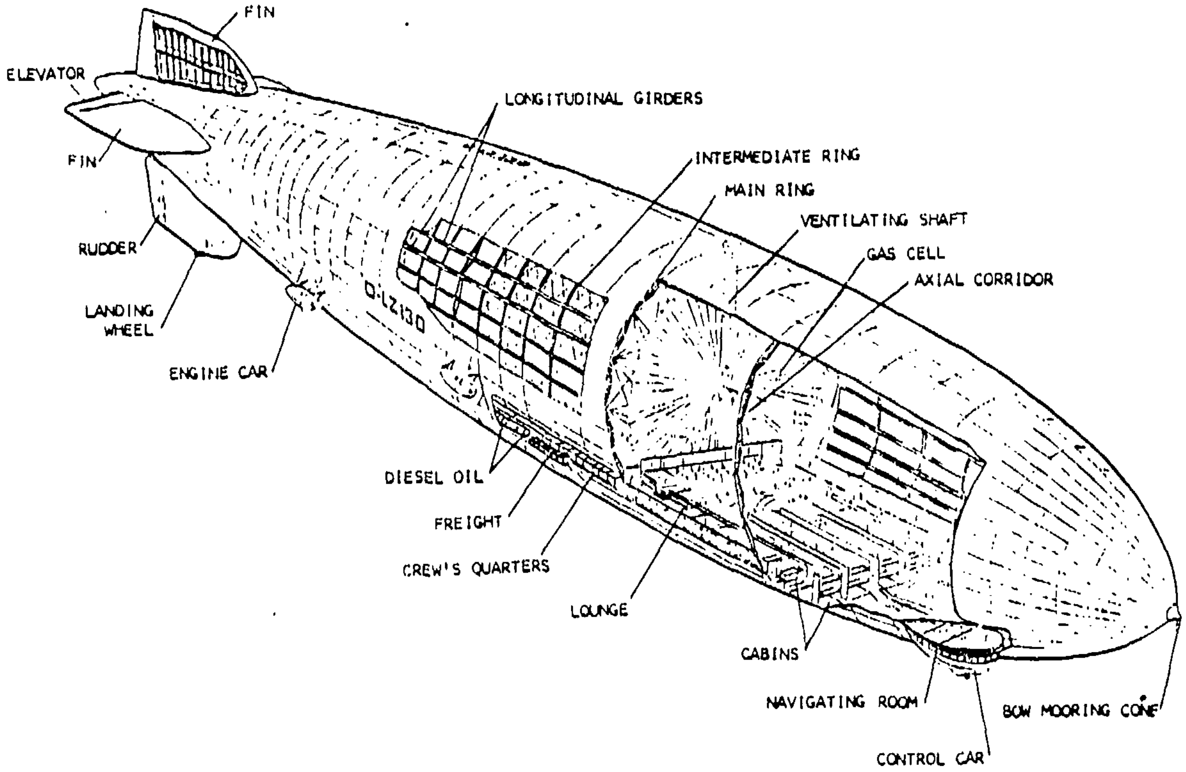


Figure III-5. Typical Rigid Airship.

their own compartments. Ballast recovery on the later U.S. Navy rigids was achieved by funneling the engine exhaust through condensers built into the hull structure to separate out the water.

The recent studies described in Table II-I provide additional detail in the historical technical nature of LTA vehicles.

The spectrum of past airship sizes is broad - varying in gross weight from less than 5,000 pounds to nearly 500,000 pounds. This results in a wide range of performance capabilities. The non-rigid vehicles, limited in maximum size usually by seaming technology (to about 2,000,000 cubic feet in volume according to recent estimates), are the least capable. On the other end of the spectrum, rigid airships suffer structural inefficiency in small sizes (less than about 3,000,000 cubic feet in volume). Predictions vary as to how large rigid airships might feasibly be today (history's largest was the German LZ-139 at 7,650,000 cubic feet).

For purposes of maritime patrol it was important to focus attention on realistic vehicle sizes. Figure III-6 presents the payload-times-endurance ability of past Navy non-rigid airships[48]. Also presented in this figure are the predicted performance increases documented in recent studies as a result of modern technology improvements[6, 7, 13]. Discussions with Coast Guard personnel determined that CG performance requirements would fall well within this expanded envelope of performance. In other words, the MPAS would focus on non-rigid airships.

Operationally, LTA vehicles have had a very diverse experience. The Germans established a commercial transport company with the early vehicles. During World War I (WWI) the German Zeppelins were used over London as strategic bombers (with little actual material effect) and the British operated non-rigids for submarine detection missions over the North Sea. American participation in LTA vehicle technology began in earnest in 1923 with the construction of a home-built rigid airship (a copy of a German Zeppelin captured intact in France during WWI). Based on fundamental LTA technology developed by the U.S. Army operating some semi- and non-rigid vehicles, the U.S. Navy initiated (with the construction of the Shenandoah) an airship organization which lasted almost 40 years[48]. The mission description of the Navy's rigid airships (four were operated between 1923 and 1935) is presented as published in 1940 in Figure III-7.

During World War II (WWII) the Navy established a global airship organization to deal with the very real menace of Axis submarines. Operations included convoy escort/ASW, search, observation/photography, mine laying/sweeping, and rescue/assistance missions[2, 3]. Between 1942 and the war's end (1945), fifteen squadrons (totaling 164 non-rigid airships) operated on three continents[3, 4]. A brief summary of their performance is shown in Figure III-8. Following WWII, airships were employed effectively in Airborne Early Warning (AEW) roles for continental defense along the east coast in concert with other vehicles. They were also used as stable platforms for the development of many present Anti-Submarine Warfare (ASW) sensor systems[5]. Figures III-9 and III-10 pictorially present the airship conducting a variety of operations.

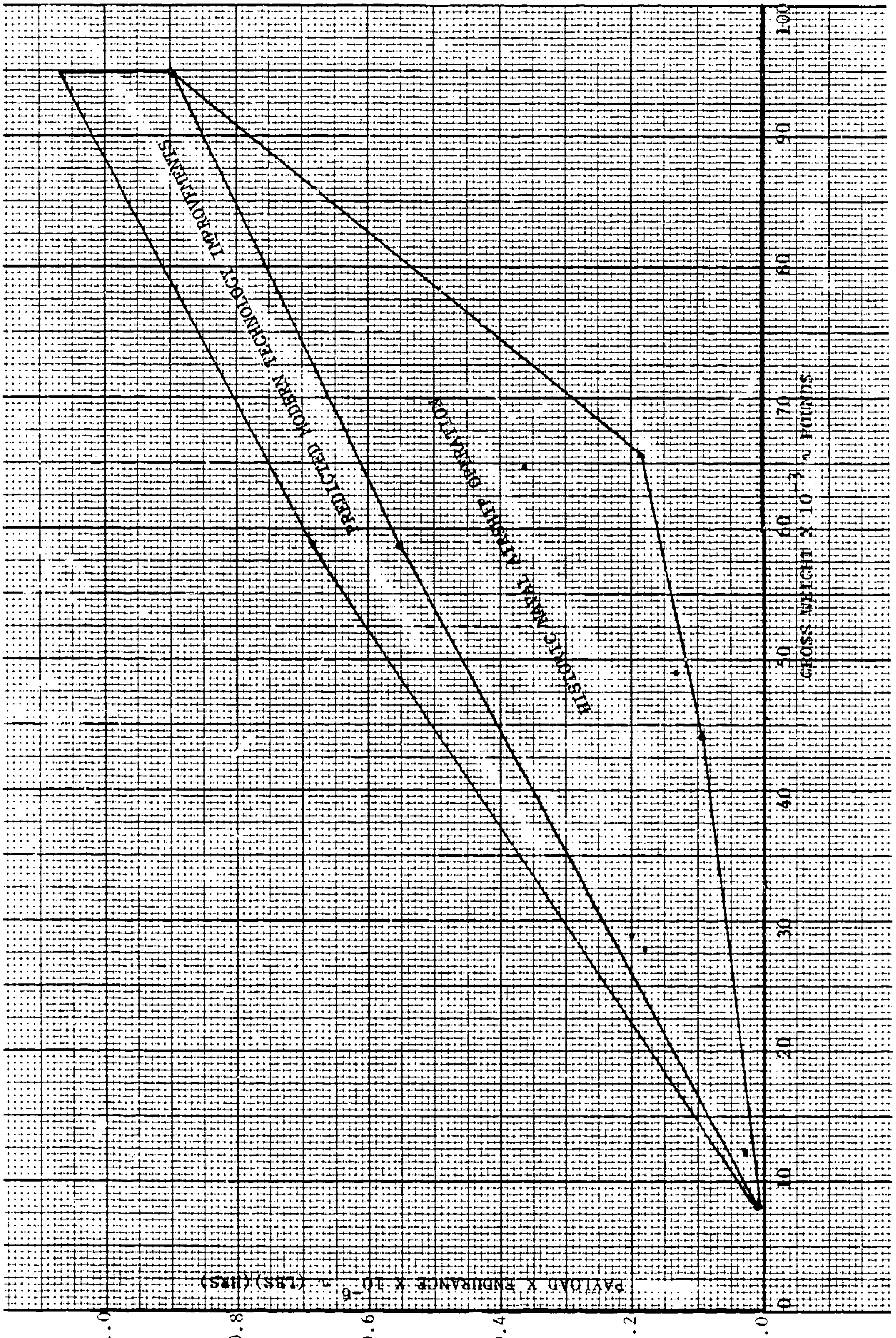


Figure III-6. Navy Non-Rigid Airship Payload-Endurance Performance.

SCOUTING:

- Search Operations at Long Ranges
- Contact Scouting (Strategic)
- Observation
- Reconnaissance

GENERAL:

- Neutral Patrols
- Locating Enemy Commerce Raiders
- Convoying Merchant Vessels
- Locating Mines and Submarines
- Bombing (by Planes) Under Certain Conditions

MISCELLANEOUS:

- Radio Station Calibration, Radio Relay, DF Special Communication Station
- Transport of Special Personnel (or Supplies) as "Assisted Takeoff" for Overloaded Airplanes
- Flight Research Laboratory

Figure III-7. Tactical Missions for Rigid Airships (1940).

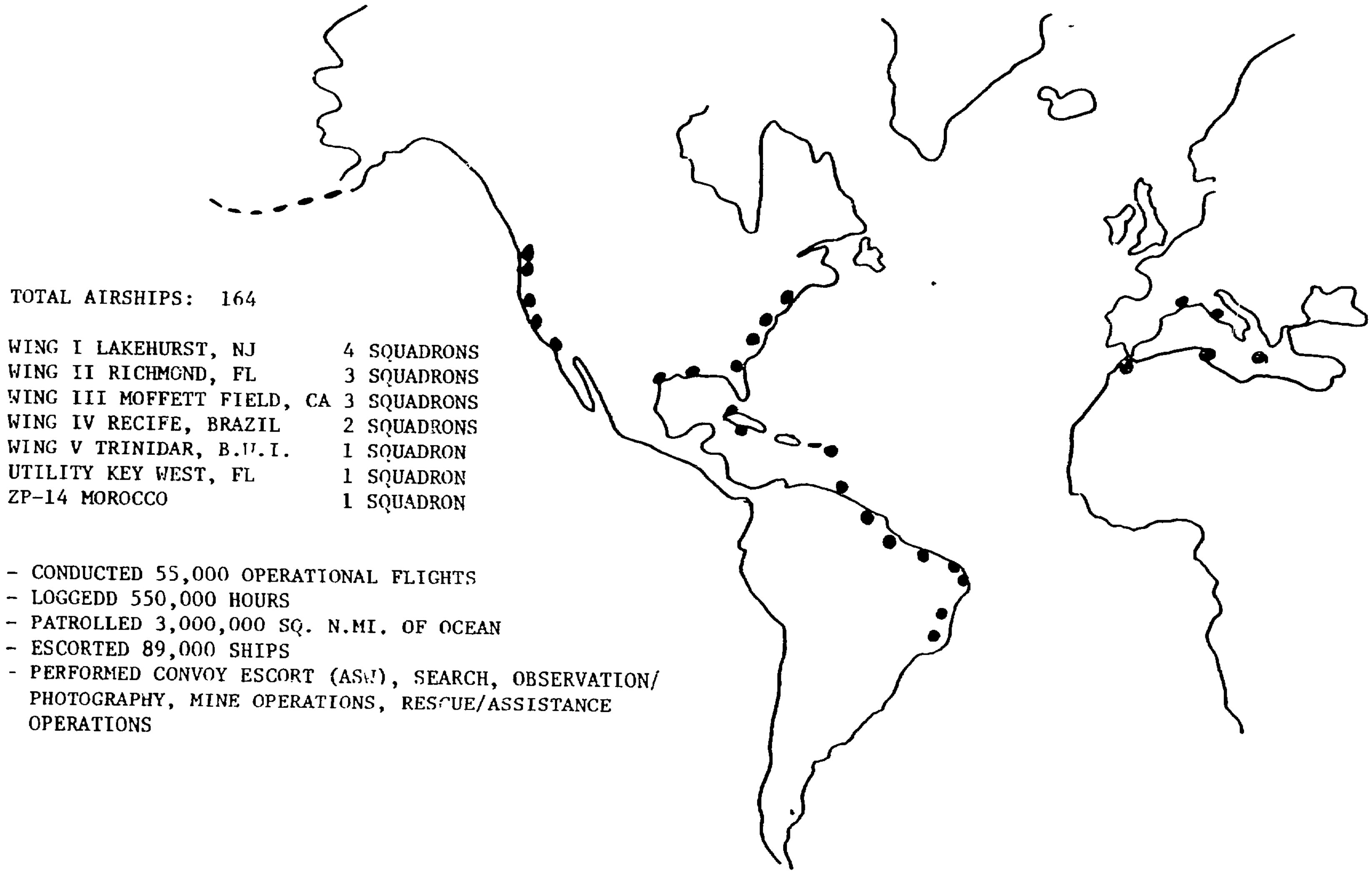


Figure III-8. World War II Airship Orgranization and Performance.

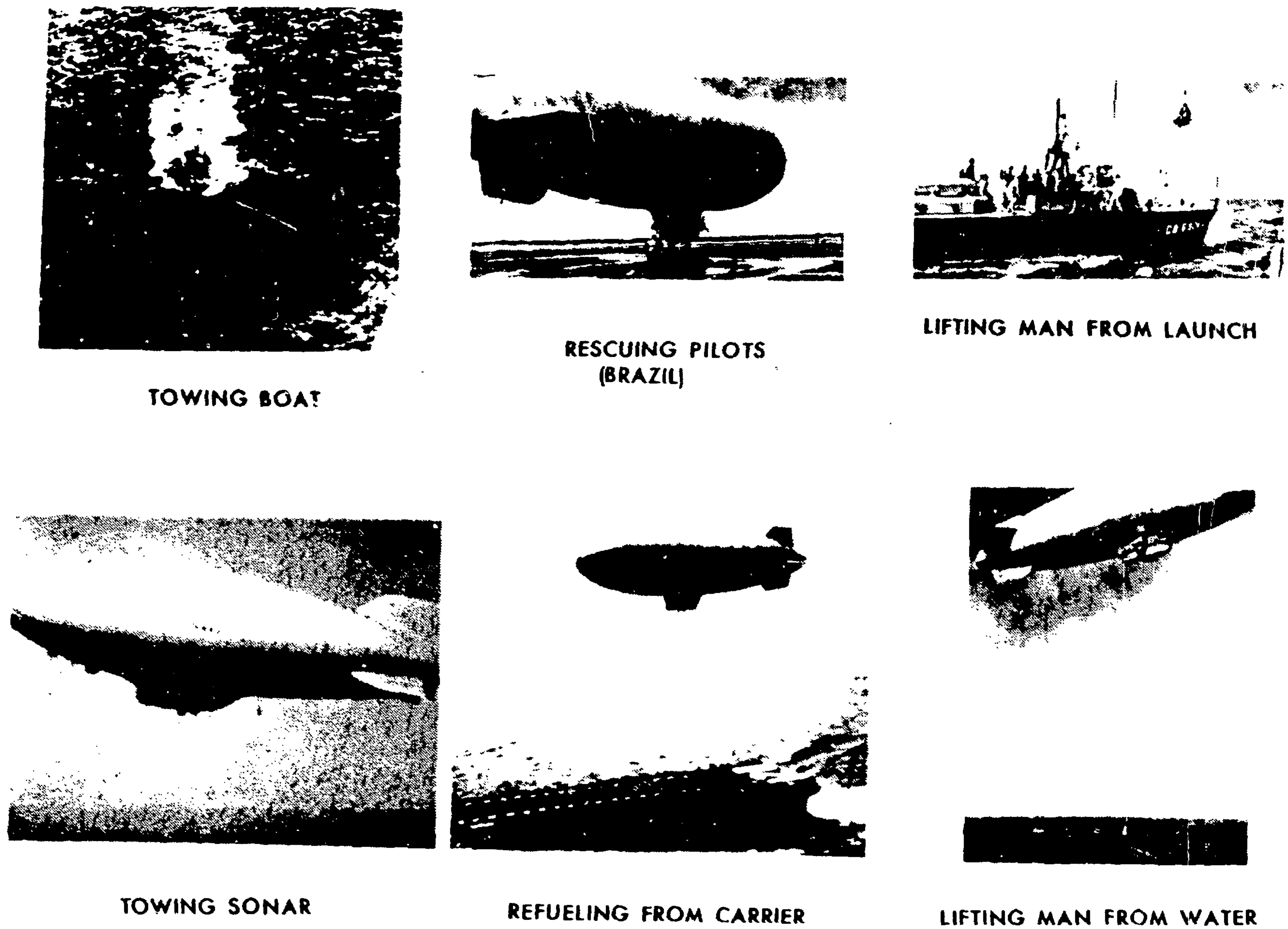
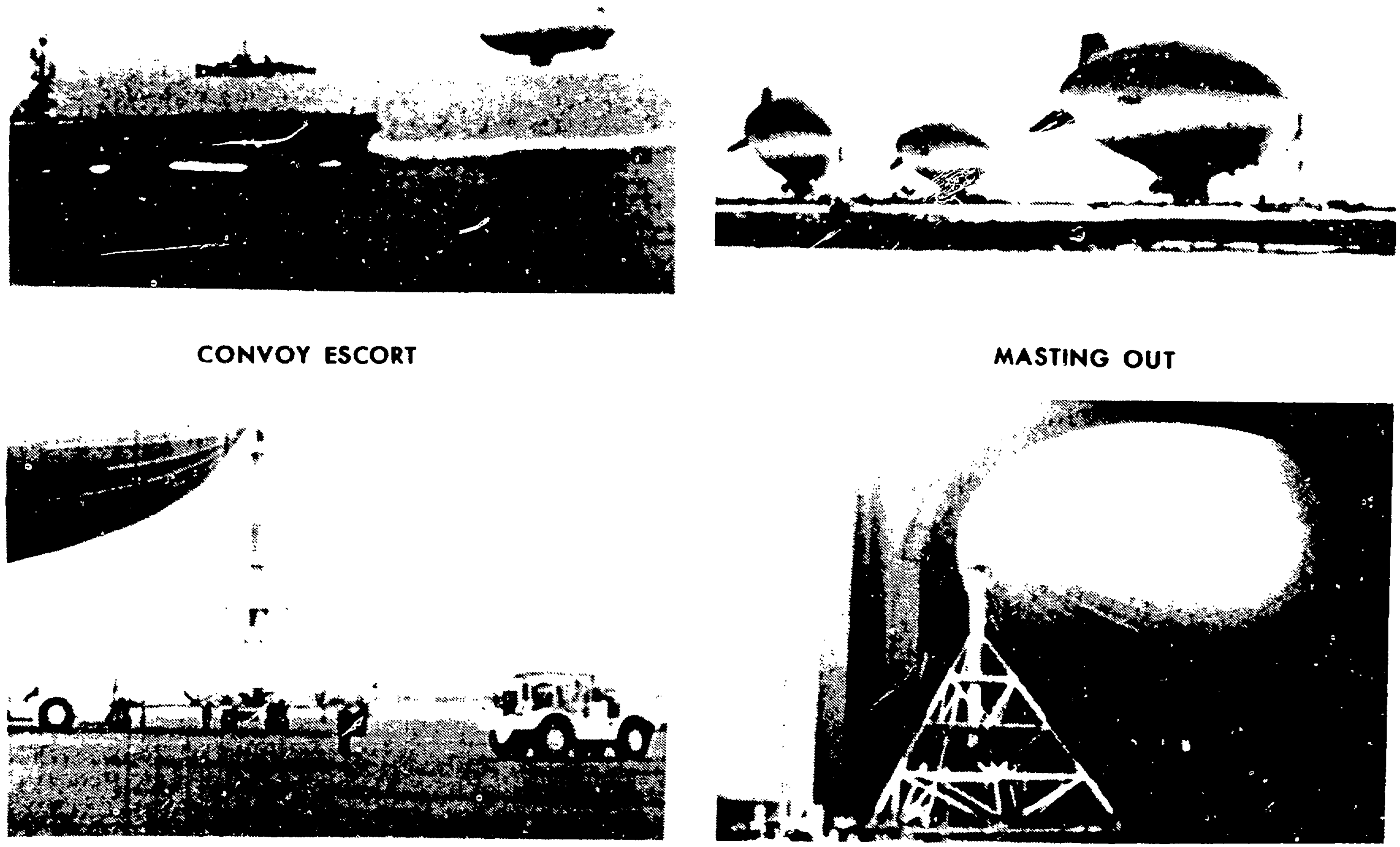


Figure III-9 WORLD WAR II AIRSHIP OPERATIONS.



CONVOY ESCORT

MASTING OUT

LANDING WITH MECHANICAL MULES

TOWED ON SHORT MAST

Figure III-10 PAST AIRSHIP OPERATIONS.

Throughout these years of Navy service, several distinctive features of LTA vehicles were made very apparent.

- Long endurance was a routine operation - the USS MACON in 1934-35 could operate unrefueled up to 160 hours[48]; the non-rigids of WWII operated for up to 85 hours unrefueled[7];

- Stable, low vibration platform has benefited both crew and sensors in past operations[7] - the flexible nature of the vehicle affords vibration damping, the inertia of such large vehicles results in platforms insensitive to short period gusts reducing accelerations for crew and equipment (one 300-plus hour flight program recorded the occurrence of normal accelerations (g's) which exceed ± 0.20 to less than once in 100 times[49]);

- Low installed power requirements result in attractively lower operational costs - since the major portion of airship lift is derived from buoyant means, power is necessary primarily for horizontal flight (smaller noise signature is by product);

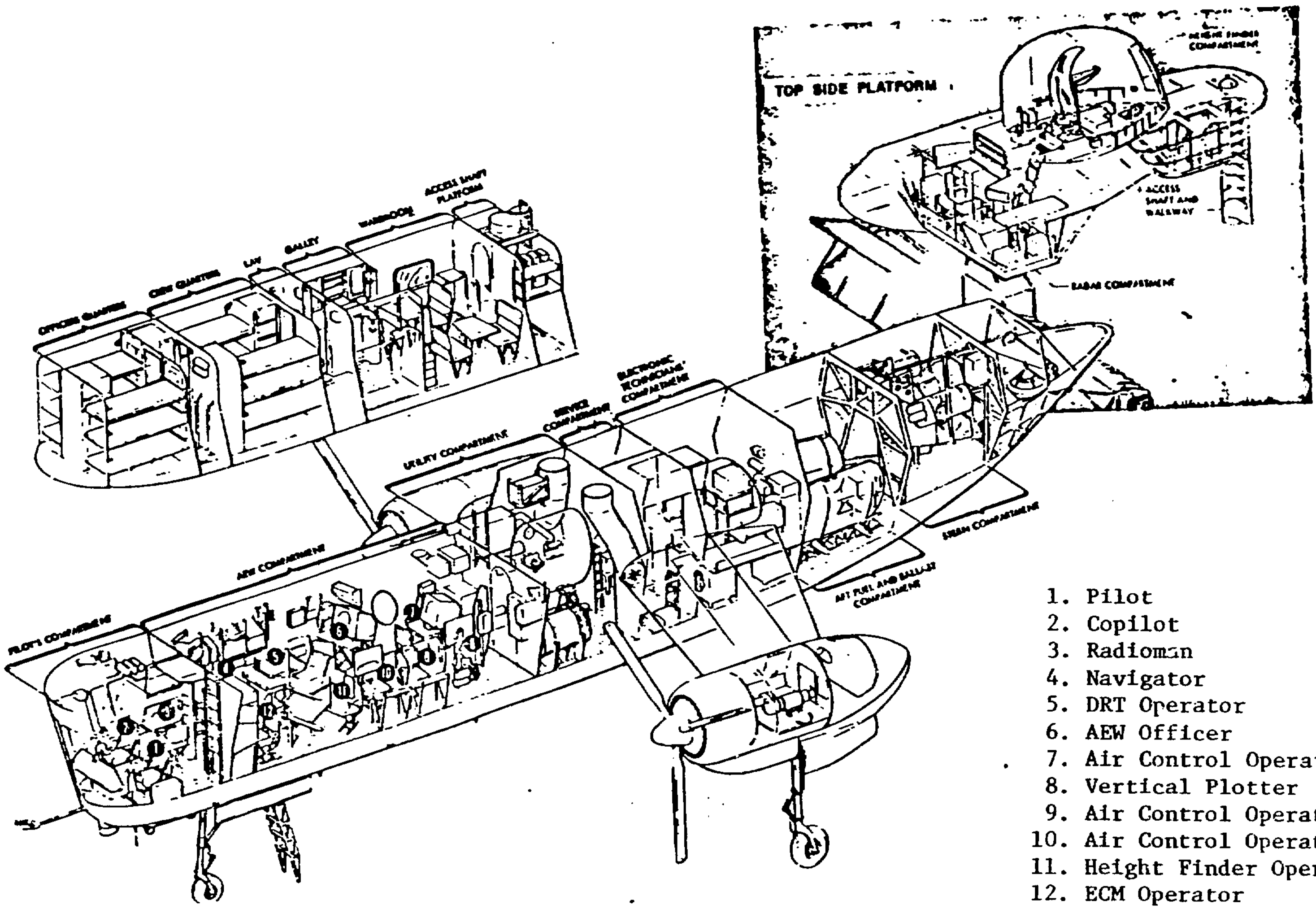
- No noise into the water is an important feature in ASW missions such as towing sonar from airships[50];

- Comfortable accommodations such as those shown in Figure III-11 for a non-rigid airship is essential in delaying crew fatigue in long endurance missions;

- High operational availability is the result of fundamental simplicity as demonstrated during WWII when availability was 87 percent[2, 3].

Historic criticism of LTA has included slow forward speed capability, inability to operate in adverse weather, poor low speed control, vulnerability to hostile action, difficult ground handling and large ground facilities requirements. Since these issues are crucial to an effective system, steps were taken during Navy airship operation to address them to some extent and the recent studies described in Chapter II have addressed the application of modern technology to the unresolved portions of these issues. It is informative to briefly recount progress in these areas as follows:

1. Vulnerability to Attack. Since the lift forces for an airship are not composed entirely of dynamic (forward flight) and/or powered (rotor lift, etc.) forces, should either or both of these components be eliminated the airship maintains its primary means of lift - static buoyancy. Airships when punctured will not flutter about the sky as would a toy balloon. The internal pressure of any airship remains only slightly above that of ambient air pressure (at most two to three inches of water) and, therefore, leaks (or holes) create a gradual seeping situation[7, 42, 51]. Secondly, the size of a hole necessary to "bring down" a non-rigid airship would be on the order of square yards and not square inches. In the worst situation (an immediate very large hole) the vehicle would descend gradually. This sort of graceful failure would undoubtably add to crew



1. Pilot
2. Copilot
3. Radioman
4. Navigator
5. DRT Operator
6. AEW Officer
7. Air Control Operator No. 2
8. Vertical Plotter
9. Air Control Operator No. 1
10. Air Control Operator No. 3
11. Height Finder Operator
12. ECM Operator

Figure III-11. Internal Arrangement of the ZPG-3W Airship Car.

safety and morale. Sophisticated weaponry would be necessary to produce large holes in such a low density vehicle (whose vital components are widely spaced).

2. Expensive Ground Facility Requirements. WWII deployment of airship squadrons to remote areas demonstrated that LTA vehicles could perform their duties entirely without aid of hangars except for depot-level overhaul maintenance[2]. Today's materials and weather forecasting make this even more feasible. Therefore, except when all exposed aviation assets evacuate the path of hurricanes, the LTA hangar facilities still in existence should prove adequate for erection of vehicles and depot level maintenance for initial deployments (from U.S.) and thereby maintain the objective of a "low cost" system by not requiring development of ground facilities[42].

3. Ground Handling Requirements. In the early 1900's, the airship was a not-fully understood and difficult-to-control vehicle. Through the 1930's a considerable demand for rope handlers was a necessity. Over these years, however, improvements were made such as gimbaling propellers on the U.S. Navy's AKRON and MACON. Non-rigid airships, derived from free balloons, were considered mainly rich men's toys until the military application of barrage balloons and non-rigids by the British before and during WWI. By the time non-rigids were put into service by the U.S. Navy in 1942, ground handling operations were standardized. During WWII the required size of ground handling parties had decreased from nearly 100 to half that size. The advent of mechanical ground handling equipment (mobile winches) in the early 50's further reduced the ground party to less than 30, while non-rigid airships had tripled in size (volumetrically). By the time LTA operations were terminated in the U.S. Navy in 1961, ground operations of 400+ foot airships had been developed to a science utilizing mobile and short-masts and required a ground crew of less than 20 under normal conditions[49]. The recent studies mentioned above indicate that by virtue of developments in related air vehicle technologies (especially rotary wing) hover, helicopter-style, is a practical objective.

4. Poor Airship Performance in Adverse Weather. To explore the weather vulnerability issue, the Navy conducted studies in the late 1950's[53].

Some findings are presented as an example:

"A barrier station over the Atlantic Ocean was maintained for a ten-day period embracing a cross section of all-weather operating conditions. A barrier station at 38°51'N, 70°13'W, was manned at 2100, 14 January 1957, and maintained until 0012 on 25 January 1957, by airships from the Naval Air Development Unit, South Weymouth, Massachusetts, and Airship Airborne Early Warning Squadron ONE, Lakehurst, New Jersey. A total of 415.7 flight hours were flown by all airships of both commands through weather conditions which included icing, snow, sleet, rain, fog, and winds as high as 60 knots. . . The average flight was 37.8 hours in duration of which the average time on station was 22.2 hours, the average time enroute to station was 5.8 hours, the average time returning to base was 6.3 hours, and an average of 3.5 hours was spent standing-by at home base awaiting landing crews or proper landing conditions."

"Ground handling operations were conducted during conditions of snow, low visibility, rain, high wind, and normal weather conditions. One airship was unmasted and launched with winds gusting to 35 knots and increasing to 50 knots ten minutes after launching. Another airship landed and masted with winds gusting to 39 knots. At least one airship was landed during a snowstorm. On one occasion an airship was unmasted and a take-off accomlished during a snowstorm which had lasted for eight hours, during which time the airship was on the mast. A GCA approach and landing was accomplished with 200 ft. ceiling and 3/16 mile visibility; a takeoff was made with a 100 ft. ceiling, in fog, with visibility less than 1/4 mile."

In light of these preceeding comments, one question remains to be answered: It is rightly asked if airships were so effective in service for the Navy, why were they decommissioned and why are they worth reconsideration today? A recent study has examined this question. Answering this question will serve to summarize this entire chapter. Reference [5] discloses that in the period immediately following WWII, airships were retained in the Navy for the missions that they had accomplished so well during the war in Anti-Submarine Warfare (ASW). These consisted primarily of coastal patrol and convoy escort in the offshore region (within about 300 miles). In the post-war period these missions were expanded to include operations with a hunter/killer group and extended capability for convoy escort with an ultimate goal of accompanying the complete ocean transit. In order to achieve these missions, a number of technological improvements were developed. For hunter/killer operations it was necessary to strengthen the structural members of the airship to permit landings on aircraft carriers. Rapid refueling systems were developed, and these were later followed by development of systems that would permit the airship to be refueled in the air and also to be rearmed and remanned from surface ships. Hydraulically assisted control systems were developed to permit better control during landing operations aboard carriers as well as better control during ASW operations. Reversible pitch propellers were designed to provide further controllability during these operations. ASW sensor development was centered about an innovative new towed acoustic system that could be operated either in an active or passive mode and towed continuously by the airship. Many other innovative ideas were tried but never became operational. These included an IR wake detection system, bow fins for improved controllability, boundary layer schemes, and many others. It should be noted that greatly improved ground handling equipment was developed that reduced ground personnel requirements significantly and improved safety.

Tactical development efforts included new procedures for conducting combined operations with both surface escorts and ASW aircraft operating from carriers or from short bases. In addition, tactics were developed for support of bottom mounted surveillance systems.

Many of the technological developments intended for application to the hunter/killer mission were also applicable to the extended convoy escort mission. However, in addition, great strides were taken in improving the habitability of the airships and providing means for accommodating increased crew sizes so that extended endurance could be maintained before it was necessary to relieve the airship crew. It was demonstrated that an airship could be flown across the Atlantic and back again without refueling, or any other surface support. Thus, the convoy escort goal seemed easily attainable.

In the early 1950's a new mission was perceived for the larger sized airships. This mission consisted of Airborne Early Warning (AEW) which was intended to provide a means of warning continental defense forces of impending enemy aircraft raids that might use the ocean routes to penetrate U.S. defenses.

AEW airships were developed and utilized for the continental air defense mission over a period of years. They provided an extremely efficient way of accomplishing this mission. While they were never procured in sufficient numbers to permit performance of the entire mission, the ZW airships were a very good complement to the fixed wing ASW aircraft that were used.

The principal advantage that the airship was able to provide in both the ASW and AEW missions was its long endurance and capability to remain on station for prolonged periods of time. For the ASW mission the use of an innovative new sensor, the towed sonar body, also provided an advantage over the fixed wing ASW aircraft against the submarine threat of that time period. In the AEW mission the additional advantage of the airship was its capability to employ a very powerful stabilized radar.

As time progressed the requirement for accomplishing the AEW mission became of reduced importance. This was a result of the shift in Soviet strategic forces from manned bombers to intercontinental ballistic missiles. This shift in weapon systems essentially cancelled the requirement for an early warning system that could provide surveillance in the seaward approaches to CONUS against an incoming low flying threat. Thus, the AEW mission requirement essentially disappeared in the early 1960 time period.

In the ASW mission new sonobuoys were being developed for fixed wing aircraft that permitted them to close the gap in performance that the airships had enjoyed. The increasing cost of operations and the requirements for the Navy to reduce their ASW force levels eventually led to the decision to also decommission the ASW LTA squadrons in the early 1960's.

There is little doubt that, with the developments that were made in the 1945-1960 time period, and with application of later technology developments in aerodynamics, structures, materials, propulsion, and avionics, modern airships could be built to provide an extremely flexible and useful platform in the current and future maritime patrol applications.

<u>MPAS Vehicle Assumptions</u>

Based on the past performance of airships (described above) and the infusion of modern technology the attributes of airships assumed for MPAS are shown in Table III-I. There are other assumptions for this study which are presented here. For Coast Guard operation the environmental picture is essential for proper vehicle design criteria. Appendix A explores this issue in some depth. A vehicle capable of a 90 knot speed was determined capable of operating in more than 95 percent of Coast Guard missions (occasional large headwinds being the primary limiting factor).

The lifting gas presumed for all vehicles is Helium. Current and future availability of this non-flammable resource appears readily assured[54].

Crew accommodations for the missions examined were estimated from past airship operation. For extended operations (and even for the MPAS profiles) a human factors analysis should be performed (such as Reference [55]).

In the interest of expediency, the avionics and sensor suites for the conceptual designs were assumed to be the same as those designed for the Coast Guard HU-25 fan jet aircraft intended for medium range search operations[56] (with one exception, a conceptual ASW towed array sonar system). These equipments are in a near operational status and while they are not tailored for airship use (airships could carry a much larger radar antenna for example) they are considered off-the-shelf technology. Note that for this particular radar (APS-127)[57] the performance envelope of the airship (primarily speed) effects the normal sweep rate. For this reason, an adjusted sweep rate was determined and is described in Appendix B. State-of-the-art technology levels (1980) have been assumed for materials, propulsion, and structures.

Current Coast Guard aircraft basing facilities for deployment and existing LTA hangars for erection, overhaul, and major repair have been postulated. The manning assumptions are discussed later in Chapter VII along with costing. Finally the payload items will be presented here as they were specified for vehicle designs. The fixed payload is defined as the equipment which remains aboard the airship for every mission. The variable payload is that equipment which changes with the mission. These items were defined after consultation with Coast Guard operational personnel and are presented in Table III-II.

TABLE III-I
AIRSHIP ATTRIBUTES

- HOVER
  - Logistics
  - Boarding
  - Rescue
  - Observation
  - Remanning/Refueling
- PRESENCE
- 0 - 90 KNOT CAPABLE
- VERTICAL DELIVERY
  - Logistics
  - Boarding
  - Rescue
- RAPID ASCENT/DESCENT
  - Observation
- COMMUNICATIONS
- TOW
  - Sensors
  - Vessels
- MINIMAL WEATHER LIMITATION
- LOW INSTALLED POWER

NOTE: All attributes except hover were demonstrated by 1940-60 vintage airships - "hover" tasks were all achieved by "flying station" with surface vessels.

TABLE III-II
MARITIME PATROL AIRSHIP STUDY PAYLOAD COMPOSITION

FIXED PAYLOAD*

ITEM	WEIGHT (LBS)
1. MRS Sensor Suite	1,600
2. MRS Avionics Suite	2,000
3. Winch and Service Module	700
4. 50 Caliber Machine Gun, Mount, and Ammo	120
TOTAL	4,420

VARIABLE PAYLOAD**

ITEM	
1. Crew (including furnishings and equipment)	200/man
2. Provisions; General Stores, and Potable Water	25/man/day
3. Mark III Zodiac Inflated Boat (15'6" in length)	211
4. HH-3F Rescue Kit	81
5. 40 Horsepower Outboard Motor, Tank, Fuel	200
6. HH-3F Dewatering Pump	110
7. HH-3F Firefighter Equipment	90
8. HH-3F Smoke Floats and Light Floats (six each)	42
9. ADAPTS Pollution Kit (Pumps, Hoses, Bags, Skimmer)	17,000
10. Harbor Oil Boom	220
11. Coastal Oil Boom	720

*Carried by all airships on all missions
**See Appendix D for specific variable payload carried for each mission

CHAPTER IV
MISSION DEFINITION AND ANALYSIS

MISSION DEFINITION

INTRODUCTION

The emphasis of this study has been on the determination of the suitability of LTA platforms in current Coast Guard operations. Consideration has been given only to operations as they are currently being performed in a manner consistent with the utilization of available Coast Guard air and sea assets. It is the purpose of this analysis to determine if airships can be used to supplement Coast Guard aircraft and ships in their operations.

MISSION IDENTIFICATION

To approach this effort a review of existing Coast Guard operations was undertaken. The Coast Guard operations are organized by program. Table IV-I lists the thirteen Coast Guard programs. Of these, eight programs listed in Table IV-II were identified for a more detailed investigation for possible airship participation. The choice of these eight programs is based upon the analysis of the attributes of a Lighter-Than-Air (LTA) platform and consideration of the program requirements.

Review of each of these eight programs resulted in the identification of particular missions that could be performed by an airship. In approaching this analysis, a concept of a nominal airship was used to assist in the selection of these potential missions. A candidate airship of the approximate size and operating characteristics given in Table IV-III was assumed for the purpose of screening the Coast Guard missions. Missions with requirements significantly exceeding these capabilities and which could be accomplished effectively using existing Coast Guard assets, were not considered.

At the completion of the mission definition task of this study, more detailed operating requirements were specified from which an exact point design was determined. Just as the Coast Guard has a variety of ship types and aircraft types, it may be reasonable to assume, in the future, the Coast Guard would have more than one type of airship. This would widen the range of missions that could be performed by airships and improve on the expected efficiency of each type of airship that would operate on missions within a specified portion of the total mission spectrum. To limit the scope of this study, a single point design airship was considered. The effectiveness of airships in Coast Guard operations was determined on the basis of this airship.

Also relevant to the selection of potential airship missions are the capabilities and attributes of a modern airship consistent with traditional operations and advances in modern technology. It is of interest to review how these attributes impact on the ability of the airship to perform Coast Guard missions.

TABLE IV-I
COAST GUARD PROGRAMS

Short Range Aids to Navigation

Bridge Administration

Commercial Vessel Safety

Enforcement of Laws and Treaties

Ice Operations

Marine Environmental Protection

Military Operations and Preparedness

Marine Operations and Preparedness

Marine Science Activities

Port Safety and Security

Radio-Navigation Aids

Boarding Safety

Reserve Forces

Search and Rescue

TABLE IV-II
POTENTIAL AIRSHIP UTILIZATION IN COAST GUARD PROGRAMS

ENFORCEMENT OF LAWS AND TREATIES (ELT)

- Surveillance, Interdiction, and Seizure of Illicit Fishing and Drug Traffic

SEARCH AND RESCUE (SAR)

- Search, Logistics, and Aid

MARINE ENVIRONMENTAL PROTECTION (MEP)

- Search and Surveillance of the Marine Environment
- Assist in the Logistics and Command, Communication, and Control of Clean Up Operations

PORT SAFETY AND SECURITY (PSS)

- Hazardous Cargo Traffic Control
- Command, Control, and Communications

MARINE SCIENCE ACTIVITIES (MSA)

- Ice Patrol
- Oceanographic Survey
- Locating Buoys

ICE OPERATIONS (IO)

- Surveillance of Ice Conditions

SHORT RANGE AIDS TO NAVIGATION (A/N)

- Monitor Buoys

MILITARY OPERATION/PREPAREDNESS (MO/MP)

- Surveillance for Enemy Forces
- Antisubmarine Wareface (ASW)
- Protection of Offshore Installations
- Convoy Ships
- Logistics Support
- Inshore Undersea Warfare

TABLE IV-III
APPROXIMATE CHARACTERISTICS OF A PATROL AIRSHIP

Volume	500,000 ft^3 - 1,000,000 ft^3
Endurance	20 - 50 hrs
Maximum Speed	90 kts
Cruise Speed	40 - 50 kts
Payload	10,000 lbs - 20,000 lbs
Maximum Altitude	5,000 ft - 10,000 ft

The ability to hover for extended periods has been assumed technically feasible throughout this study although it remains to be demonstrated. Historically, airships were capable of "flying station" by flying into the wind. By using vectored thrust and other techniques, a multiple engine, modern technology airship should be able to maintain rotary wing-style hover in most nominal weather conditions. The ability to hover is considered the most essential attribute for missions requiring logistic support, boarding of ships or platforms, and rescue of personnel.

The large volume of the envelope, makes an airship a highly visible platform. This is particularly useful in search and rescue operations, and for coordinating multiple platform operations. Presence is considered the most significant deterrent in law enforcement operations.

An on-board winch is considered an essential piece of equipment if the airship is to be utilized in logistics, boarding, or rescue operations. A high powered, constant tension winch in conjunction with a hover capability makes an airship an ideal platform for ferrying and transferring equipment or personnel to or from the sea surface.

The natural buoyancy characteristics of an airship allows it to ascend or descend rapidly with little maneuvering and moderate power requirements. This capability is valuable in search and surveillance missions. After searching from an altitude of 5,000 feet an airship can rapidly descent for close-in observation and then rapidly return to search altitude, if desired.

Because of its size and payload capability, large antennas can be mounted on an airship. These antennas can be either for communication relay, or special, high resolution sensors. An airship's ability to remain relatively stationary makes it suitable as a command and communication platform for control of multiple platform operations.

Historically, airships have been used to tow both small boats and sonar arrays. The controllability of an airship allows it to operate close enough to the water to make these operations feasible, while the payload capability assures enough power to handle most towing loads. With the use of the constant tension winch the airship could be used to tow ships in rescue operations, very heavy equipment on sleds for environmental cleanup operations, or sensor systems for search and surveillance operations.

These attributes and the range of characteristics given in Table IV-III were used as a basis for determining Coast Guard missions in which there was potential for airship participation. After discussions with cognizant Coast Guard personnel in each of the eight program offices of interest, specific missions were identified.

MISSION ANALYSIS

After reviewing the mission requirements of each of the eight Coast Guard programs and determining the type and extent of operations in which airship participation was feasible, it was necessary to devise a method to determine the efficiency of airships in these missions. Because of the wide span of missions the procedure had to be general enough to be applicable across the spectrum of operations.

The approach used is based upon a generalized partitioning of a mission into distinct tasks. The seven specific tasks listed in Table IV-IV were for the analysis of the missions. This set of tasks was chosen in an attempt to categorize the major operations contributing to the success of a mission in the most general manner and, yet, distinguish between measures of effectiveness (MOE's) and required capabilities.

On the basis of these tasks, a set of composite profiles can be created for each mission. As an example of this approach consider a search and rescue mission in which a boat is reported missing 70 miles offshore; its position is known to within 20 miles; upon finding the boat a dewatering pump will be required, as well as an escort back to shore. This can be translated into a mission that requires: a 50 mile transit to the beginning of the search area; a radar and visual search of approximately 1,000 n mi^2; the delivery of a dewatering pump (logistics requirement of 110 lbs.); and an escort back to a dock (station keeping/trail for 15 hours).

Obviously, every mission will differ from all of the others. However, by using these seven basic tasks many different operational profiles can be created. Table IV-V provides an example of the standard form used to specify the profiles for each mission under each program. The program and mission is given at the top of the form. There is one profile sheet for each mission. There is a profile designator associated with each profile, consisting of three numbers separated by periods (i.e., a.b.c.). The first number, a, corresponds to the program designation; the second number, b, is a mission identified; and the last number, c, is a profile designator.

The next ten columns of the form are used to specify the operational requirements of the mission profile. Not all tasks need be specified for every profile. The transit distance is given in nautical miles and is the distance to and/or from the scene of operation. This will be assumed to be performed at cruise speed. Not every profile will require transit. Some operations may start right at or near the airbase. Other operations may require transit to the scene of an operation but perform another task in returning to the base (e.g., in the SAR profile just described, the airship escorts the boat back to port).

Patrol tasks are also specified on the basis of the required distance traveled. Patrol tasks directly contribute to the mission operations. Patrol tasks are included in logistics operations, ELT missions requiring patrol from fishing ship to fishing ship, patrol from offshore industry site to offshore industry site, etc. patrol is assumed to be performed at cruise speed.

Station keeping/trail tasks are low speed operations, but not hover, assumed to be performed at the most fuel efficient speed. Typical operations associated with the station keeping/trail task are ship escort, ELT surveillance, MEP command and control. The task requirement is measured by the number of hours the airship remains in station keeping/trail operation.

TABLE IV-IV
AIRSHIP TASKS

Transit	- The flight to or from a port or base to the area of operations.
Patrol	- Transit from one defined location to another at a moderate speed; such as transit from buoy to buoy or from ship to ship in a Fleet (does not include transit from base or port to operating area).
Station Keeping/Trail	- Slow speed operation while monitoring an identified object.
Search	- Search operations performed in an area in order to find and identify objects of interest. These objects may be boats, pollutants, or enemy forces.
Visual Search	- Eye search for objects on or in the water.
Instrument Search	- The use of radar, AGTV, IR/UV, or cameras and possibly passive electromagnetic radiation detection in search of vessels or people in the water.
Pollution Search	- The search for pollutants in the water.
ASW Search	- The search for submarines using listening devices in the water, i.e., sonobuoys or towed arrays.
Board	- The placing of a man on a boat or platform in the water either by direct transfer or by lowering a small boat and man.
Logistics	- The transport and transfer of objects and supplies to a boat or platform in the water (includes the transport of equipment for the containment, transfer, or dispersal of oil on the water).
Tow	- Towing a boat or other objects in water from the airship.

TABLE IV-V

STANDARD MISSION PROFILE LIST

Mission:

Profile Designator	TASKS											
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence

Four types of search can be specified. These are: visual, instrument, pollution, and ASW. Each type of search is associated with the use of a different type of device and, therefore, the rate at which an area can be searched depends upon the type of search and the device used. The search effectiveness is measured on the basis of area covered. This, in turn, is determined by the sweep rate of the airship. Random search has been assumed[55]. The probability of detection as a function of time for random search is given by:

$$P(t) = 1 - e^{-\frac{st}{A}}$$

where

P(t) is the probability of detection as a function of time
s is the sweeprate
A is the area of search
t is the time

The sweeprate s is frequently approximated by taking the .5 point from the single look probability of detection curve associated with the search device and multiplying by the speed of the platform. As discussed in Appendix B the following is used in this analysis:

Target	Sweep Width	Sweep Rate	Target Reflectivity
Large Target	60 nmi	3,000 nmi^2/hr	150 M^2
Oil Slick	30 nmi	1,500 nmi^2/hr	20 M^2 (Sea State 3 limit)

These numbers assume that the APS-127 Forward-Looking Radar is the primary detection device when looking for vessels on the water (instrument search) and that the equivalent to the APS-94 Side-Looking-Radar is used for pollution search. The sweep widths are enhanced over the equivalent performance when the equipment is on board an airship. This is because studies[59] have shown that there is an improvement in the ability to detect a target in the slower speed airship. The slower speed of the airship does result in a lower sweep rate, however.

For visual search, a sweep width of 20 miles is assumed[56]. This is based upon two visual observers using field glasses and the airship operating at an altitude of from 3,000 to 5,000 feet.

For ASW search, either using sonobuoy or towed arrays, a sweep rate of 2,500 nmi^2/hr has been assumed. This would be associated with a moderate to good convergence zone environment. For a sonobuoy search a moving barrier monitoring sixteen sonobuoys is the assumed tactic. A sprint and drift operation is assumed for utilizing the towed array. For this tactic, during the monitoring phase, the array is towed at a low speed (approximately 10 knots) and then transported at higher speed (30 knots or more). The array can be transported through the air or in the water depending on the design of the array and requirements of the operation.

All of the search capabilities that have been specified are dependent on many factors. The target and the environment are probably the most significant factors. The detectability varies with the target size and type. Sea state, visibility, and whether there is precipitation or not will effect the performance of the sensors. The values for search rate that have been used are considered realistic and adequate for the general level of this study.

Boarding operations require the airship to hover. In the hover mode the airship will lower a man (or men) and a small boat into the water. Boarding will then occur from the boat. If the technology and operations can be developed it may be possible to lower a boarding party directly on to the deck of a moderate to large vessel. The boarding requirement is specified by the duration of the operation. While the boarding party is on board the vessel of interest, the airship will operate at low speed in the vicinity of the vessel. This time spent in the vicinity of the vessel is accounted for under the station keeping/trail task.

Logistics operations also require the airship to hover as well as having the capability of raising and lowering large loads. The lift capability will be provided by a constant tension winch. Except for the determination of the payload capability of the point design airship, detailed analysis of the handling equipment and design of the airship car, for storage of large payloads, has not been undertaken.

The measurement of a logistics task is the weight of the payload delivered. Obviously, the maximum size of the payload in support operations will be the maximum capability of the airship. There are, however, identifiable payload packages for particular missions. For clean up missions of the MEP program, the Air Deliverable Antipollution Transfer System (ADAPTS) package has been identified as a deliverable.

The payload associated with logistics tasks differ from mission payload in that logistics tasks assume the payload is delivered, and therefore, hover capability is required. After the logistics payload is delivered the airship weight and its buoyancy will usually be affected and must be compensated by ballast recovery.

Towing operations are associated with towing a vessel or a sensor through the water. Due to the increased drag on the airship there is a greater power requirement and increased fuel consumption during towing operations. Towing usually occurs in MO/MP ASW operations, towing of distressed vessels in SAR operations, and occasionally in the event of seizure in ELT operations. It may be possible to use the airship in MEP operations to place booms and tow skimmers, but these have not been considered in this analysis. It is expected that the point design airship should be able to tow boats of up to at least 150 feet at speeds up to 10 knots.

The last column of each of the profile forms lists the annual occurrences of each profile. The profiles that are provided for each mission are estimates of actual Coast Guard operations. A sufficient number of profiles are provided for each mission to span the spectrum of Coast Guard operations. The occurrence numbers helps provide an estimate of the frequency of each type of profile for each type of mission. As is discussed in Chapter IX, Mission Effectiveness, from the mission profiles and their occurrences, a snap shot of the potential utilization of a maritime patrol airship in Coast Guard missions can be obtained.

Since the scope of this study has been very broad, spanning a majority of Coast Guard operations, and due to the limited nature of the effort, most of the entries in the profile tables are rough estimates. The accuracy of the entries is approximately an order of magnitude. In that the purpose of this study is to determine if an airship can fill a Coast Guard role in a cost effective manner, these "ball park" numbers are considered more than adequate. In that actual operations should be based on the available resources and their capabilities, it would be unrealistic to attempt to define more precise numbers at this time.

In the next eight sections a broad overview of each of the Coast Guard programs of interest is presented, followed by a discussion of the particular missions in which an airship could participate and a profile list for each of the missions.

Based upon this approach a total of 264 profiles were created for the missions specified for the eight Coast Guard programs of interest. A summary of the number of profiles by program is given in Table IV-VI.

SHORT RANGE AIDS TO NAVIGATION PROGRAM

Objective

The objective of the Short Range Aids to Navigation (A/N) Program is to assist the mariner in determining his position and to warn him of dangers and obstructions so that he may follow a safe course. This is accomplished by providing navigational references such as audio, visual, or electronic signals, using buoys and lights.

Program Description

The A/N program has broad geographic scope in that aids to navigation are established and maintained in or near U.S. navigable waters, territories, and possessions of the United States, the Trust Territory of the Pacific Islands, and where required to support the Department of Defense. Users range from the sophisticated professional navigator to the relatively untrained and unskilled recreational boater. The differing level of these abilities means that the Coast Guard must satisfy a broad spectrum of user needs.

Of the roughly 78,000 short range aids to navigation in use, nearly 60 percent are aids for which the Coast Guard is wholly responsible. The remainder are privately owned aids for which the Coast Guard has a management responsibility. The main areas of Coast Guard involvement are the monitor, repair, and replacement of navigational buoys.

Potential Airship Missions

As originally proposed there was a single A/N mission:

TABLE IV-VI

NUMBER OF PROFILES

Program	A/N	ELT	MEP	MO/MP	MSA	PSS	SAR	IO	TOTAL
Number of Missions	1	3	3	10	3	3	6	1	30
Number of Profiles	5	41	23	109	11	18	49	8	264

- A/N Repair and Replace Buoy

Current operating practice requires the lifting of the buoys in exposed areas on to the deck of a tender for routine maintenance. Because of the large weights of these buoys, it is not practical to bring them aboard the airship. The weight of the buoy plus the payload weight of spare parts and tools would exceed the payload capability of an airship of the size envisioned for this study. Coast Guard personnel consider it impractical and unsafe to handle large buoys directly in the water.

Smaller buoys are generally serviced by smaller boats, buoy tenders (65' - 110'), and buoy boats (45'). In many areas where there are smaller buoys such as rivers or inlets there are too many obstacles to be able to have access to all of the aids from an airship.

While it does not appear to be feasible to handle routine maintenance of buoys without extensive modification of current operating procedures, there are roles that airships can provide in the A/N program.

After severe weather conditions, it is desirable to determine any discrepancies (buoys lost, displaced, or not operating). An airship is ideally suited for these operations because of its speed, surveillance capability, and its potential ability to hover near the surface. Emergency repairs could be performed by lowering a man and boat into the water.

Another major need of the A/N program is placement of buoys. Current procedure uses a horizontal sextant to triangulate on three or more points of observation. Because of the limited horizon of a tender it sometimes is difficult to identify a sufficient number of landmarks to sight on. An airship, with an ability to hover and providing a stable platform and a greater horizon due to altitude, could survey an area and place marker buoys at the precise location. A tender could later place the buoys at the marked location.

Another requirement for both the short range aids to navigation and radio aids to navigation programs is logistic support. Light Stations and Light Ships, as well as LORAN stations, need logistics support. In addition, as part of the Lighthouse Automation and Modernization Project (LAMP) a number of Light Stations have been automated. These stations need routine maintenance as well as emergency service which could be performed by a crew transported by airship.

Mission Profiles

Based upon the above discussions only two missions have been analyzed for the A/N program. These are the discrepancy reporting and buoy placement operations. General maintenance and repair of buoys have not been included because of the operational difficulties associated with that mission. The logistics support mission also has not been analyzed as part of the A/N program because the frequency of occurrence is not known and the mission is similar to logistics operations of other programs.

Only one mission profile table, Table IV-VII, is included in this analysis. It is associated with both the discrepancy reporting and buoy placement operations. The profiles given are based upon general consideration of the nature of the operations. In that these missions are not separated from the normal duties of platforms performing A/N operations, exact profiles cannot be determined.

Summary of Potential Airship Participation in the A/N Program

Airships can be useful for:

1. Descrepancy Reporting

   - after severe weather, survey for lost, disabled, and displaced buoys

2. Buoy Placement

   - through precise navigation techniques, mark placement of buoys

3. Logistics support

4. Inadequate for Routine A/N Maintenance

ENFORCEMENT OF LAWS AND TREATIES

Objective

The objective of the Enforcement of Laws and Treaties (ELT) Program is to enforce all Federal laws in the marine environment, except those specifically assigned to other Coast Guard programs - i.e., vessel safety, marine pollution, vessel traffic control, and port safety and security. In recent years ELT enforcement efforts have focused particularly on laws relating to fisheries protection, immigration, and drug smuggling.

Program Description

ELT can claim to be the oldest Coast Guard program since the Revenue Marine - the ancestor of the modern Coast Guard - was established in 1790 to suppress smuggling. Today, as the Federal maritime enforcement agency, the Coast Guard is responsible for enforcing all Federal laws on the navigable waters of the United States and its possessions and on the high seas. The laws to be enforced fall into two categories: laws relating to marine safety for which the Coast Guard has sole responsibility; and laws relating to customs and revenue, immigration, quarantine, neutrality, protection of fish and game, marine environmental protection, and other matters that fall within the jurisdiction of other Federal agencies for which:

- the Coast Guard shares enforcement responsibility, and

- the Coast Guard's unique facilities are required to accomplish maritime law enforcement.

TABLE IV-VII
PROFILE LIST

Mission: A/N DISCREPANCY REPORTING, BUOY PLACEMENT

Profile Designator	TASKS											
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search ($1,000\ n^2mi$) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
1.1.1	50	150	1						2,000		10
1.1.2	50	300	2						2,000		10
1.1.3	100	200	2						5,000		10
1.1.4	100	300	2						5,000		10
1.1.5	200	200	4						5,000		10

The ELT program encompasses a wide variety of duties covering a broad geographic area. Included are:

- enforcing laws and regulations governing the fishery conservation zone extending 200 nautical miles off the U.S. coasts;

- interdicting drug and alien smuggling in areas such as the Caribbean;

- ensuring that U.S. tuna boats off the shores of South America comply with the Inter-American Tropical Tuna Convention;

- minimizing damage and loss of fishing gear caused by conflicting deployment of mobile and fixed equipment, such as the simultaneous use of lobster pots and bottom trawlers off the New England coast.

The functional elements of an enforcement system are detection, surveillance, and apprehension.

Potential Airship Missions

As a result of discussions with the ELT program office and review of references [60] and [61] three types of missions were identified for airship utilization. These are:

- ELT Surveillance
- ELT Search and Board
- ELT Search, Board, and Seizure

The missions are differentiated on the basis of operations. Both fishery enforcement and drug enforcement missions are included in each.

The location of operations, proposed airship basing, and current platforms performing the operation are identified in Table IV-VIII.

It will be noticed from Table IV-VIII that the airship is expected to fulfill missions of both aircraft (MRS, LRS) and cutters (WHEC, WMEC). This is a realistic assumption in that the airship can provide high sweep rates similar to the aircraft and the endurance, presence, and sighting capability of the ships. Because of the capabilities of the modern airship, it is expected that boarding of vessels of interest is feasible.

Compared to existing Coast Guard platforms, the airship is a unique platform in that it combines characteristics of both sea platforms and air platforms. It has the ability to travel at higher speed than ships, is not affected by high sea state and has the ability to survey the sea from high above it. At the same time it has the ship-like characteristics of long endurance, the ability to travel at low speed or hover, and can deliver a substantial payload.

In reference [60] the comparison of aircraft and ships in various aspects of the fisheries patrol missions is made. These comparisons are reproduced here. In all cases, the airship has the capabilities to satisfy the Pro arguments for both the aircraft and ships. At the same time, the limitations listed

TABLE IV-VIII
POTENTIAL ELT MISSIONS

AREA	PROPOSED AIRSHIP BASE	CURRENT PLATFORM
Southern New England	Cape Cod	MRS
New England	Cape Cod	MRS
Southern New England	Cape Cod	MEC/HEC
New England	Cape Cod	MEC/HEC
Chesapeake Bay	Elizabeth City	MRS
Texas	Corpus Christi	MRS/MEC
Middle Atlantic	New York City Elizabeth City	MRS
Middle Atlantic	New York City Elizabeth City	MEC
West Florida	St. Petersburg	MRS
West Florida	St. Petersburg	MEC
S.E. Alaska	Kodiak	MRS/MEC/HEC
Louisiana	New Orleans	MRS/MEC
West Coast	Port Angeles	MRS/MEC
Summer Herring	Kodiak	LRS/HEC
Ground Fish	Kodiak	LRS/HEC
Ground Fish	Kodiak	LRS/HEC
Far Aleutians	Kodiak	LRS/HEC
Guam/Marianas	Hawaii	LRS/HEC
Summer Salmon	Kodiak	LRS/HEC
Summer Salmon	Kodiak	LRS/HEC
Hawaii	Oahu	LRS/HEC
Straight of Yucatan	Miami	Drug Enforcement
Windward Passage	Mobile	Drug Enforcement

under Con are not applicable to the airship. An airship should be able to perform these functions at a reasonable cost of operation.

From reference [60]:

"C. DETECTION ALTERNATIVES ANALYSIS

.
.
.

e. Aircraft:

Pro (1) Can establish presence, level, and type of activity, and, in most cases, identify vessels.

(2) Provides, through visible presence, an expression of active interest and control by the coastal state.

(3) Presence serves as a greater deterrent to potential violators than most other alternatives.

(4) Provides some verification of compliance with regulations.

Con (1) Costs.

f. Ships:

Pro (1) Can establish presence, level, and type of activity, and vessel identity.

(2) Ship presence exerts maximum deterrence in area where it operates.

(3) Provides, through visible presence, an expression of active interest and control by the coastal state.

(4) Provides verification of compliance with certain regulations.

Con (1) Limited speed results in a limited area of coverage. (This is somewhat mitigated when helicopters are carried.)

(2) Costs.

.
.
.

"D. SURVEILLANCE ALTERNATIVES ANALYSIS

.
.
.

c. Aircraft:

Pro (1) Can observe certain aspects of fishing operation - type of gear in use/fishing activity.

(2) Can conduct localized activity external to vessels under surveillance.

(3) Relative large area, all-weather coverage.

Con (1) Cannot provide internal inspection of vessel.

(2) Confirmation of observations is often difficult.

(3) Does not provide the level of detailed information required.

d. Ships:

Pro (1) Combination of close observation and detailed on-board examination or inspections permits positive:

(a) Determination of whether or not vessel is fishing.

(b) Determination of type of fishing gear being employed.

(c) Determination of whether or not vessel is bottom fishing.

(d) Determination of kind of fish being taken.

(e) Determination of size of the catch.

(f) Determination if the vessel is in violation of established laws, regulations, or treaties.

(g) Determination of other information concerning administration of regulations, and management of the fishery.

(2) Large deterrent effect provided by the capability to conduct a boarding.

(3) Ships are the only practicable platform from which to dispatch/disembark boarding parties.

Con (1) Cost.

"E. APPREHENSIVE ALTERNATIVES ANALYSIS

1. Analysis

a. Aircraft:

Pro (1) Can signal a violator and continue tracking to satisfy the requirements of "Hot Pursuit."

Con (1) Limited endurance often necessitates sequential relief by several other aircraft until an enforcement vessel arrives on scene.

(2) Boarding party, which is necessary to effect apprehension or detention/seizure, arrest, cannot be safely disembarked from an aircraft.

b. Ships:

Pro (1) Can signal a violator and establish and maintain "Hot Pursuit."

(2) Can be used to disembark a boarding party to effect apprehension.

(3) Capable of providing protection and ready support for boarding party personnel on board another ship for the purpose of effecting a seizure.

Con (1) Lacks the speed of an aircraft for quickly arriving on scene to initiate "Hot Pursuit" on a violator.

(2) Cost.

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5. Ships, and Aircraft, in combination, perform all of the functional elements of the fisheries enforcement system effectively. The wide area coverable capability of aircraft coupled with the ability to notify a violator and initiate "hot pursuit" supports the limited area coverage capability of ships. Ships, on the other hand, provide the best alternative, external to the fishing vessels, to monitor operations through boardings, and to complete the apprehension act when it is required. The unique ability of ships to satisfactorily

execute the apprehension act, in addition to performing detailed surveillance/monitoring, support and other enforcement-related operations makes them directly applicable to an effective enforcement program.

Mission Profiles

The total of 41 different profiles were generated for the three specified ELT missions. The profile tables for ELT missions are given in Tables IV-IX through IV-XI. These profiles correspond to existing operations as given in Table IV-XII. The proposed basing and current platform used in these missions has been given previously in Table IV-VII. It should be noted that some profiles are associated with more than one operation, e.g., 2.1.18 reflects both Gaum/Marianas operations and Summer Salmon operations, and some operations are described by more than one profiles, e.g., Southern New England search operations 2.1.1 and 2.1.3. When operations require similar airship operations they can be grouped under the same profile. Similarly, an operation may at times be described by different profiles.

Summary of Potential Airship Participation in the ELT Program

Airships can be used for:

a. Drug Enforcement

b. Fisheries Enforcement

Airships provide:

a. Combine Characteristics of Ships and Aircraft

- higher speed than ships
- not affected by sea state
- high sweep rate due to speed and altitude
- slow speed and hover capability
- ability to board;

b. Presence

c. "Hot Pursuit" Capability

MARINE ENVIRONMENTAL PROTECTION PROGRAM

Objective

The primary objective of the Marine Environmental Protection Program (MEP) is to maintain or improve the quality of the marine environment through preventive measures. The secondary objective is to minimize the damage caused by pollutants discharged into the marine environment by providing coordinated and effective response to remove discharges of oil or hazardous substances.

TABLE IV-IX
PROFILE LIST

Mission: ELT SEARCH

Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n²mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
2.1.1	0	0	0	0	20						10
2.1.2	0	0	0	35	35						75
2.1.3	0	100	4	20	20						25
2.1.4	0	100	6	35	35						100
2.1.5	50	0	0	3	3						10
2.1.6	50	50	4	10	10						50
2.1.7	50	0	0	15	15						50
2.1.8	50	50	2	15	15						100
2.1.9	50	0	0	20	20						25
2.1.10	50	100	4	20	20						100
2.1.11	50	200	10	35	70						200
2.1.12	150	50	2	5	5						50
2.1.13	150	100	4	20	20						100
2.1.14	500	50	2	25	25						50
2.1.15	500	100	4	25	50						200
2.1.16	500	200	8	50	100						100
2.1.17	2,000	100	4	25	25						50
2.1.18	2,000	150	6	50	50						25
2.1.19	2,000	200	8	75	100						50
2.1.20	1,000	0	8	15	15						300

TABLE IV-X
PROFILE LIST

Mission: ELT SEARCH AND BOARD

Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
2.2.1	0	100	4	20	20			2			25
2.2.2	0	100	6	35	35			2			100
2.2.3	50	50	2	10	10			2			10
2.2.4	50	50	2	15	15			2			50
2.2.5	50	100	4	20	20			2			10
2.2.6	50	200	10	35	70			4			100
2.2.7	150	50	2	2	5			2			10
2.2.8	150	100	4	20	20			2			100
2.2.9	500	50	2	25	25			4			25
2.2.10	500	100	4	25	50			4			100
2.2.11	500	200	8	50	100			2			200
2.2.12	2,000	100	4	25	25			4			50
2.2.13	2,000	150	6	50	50			2			25
2.2.14	2,000	200	8	75	100			2			50
2.2.15	1,000	8	8	15	15			2			50

TABLE IV-XI
PROFILE LIST

Mission: ELT SEARCH, BOARD, AND SEIZURE

Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
2.3.1	25	50	15	15	15			2		0	2
2.3.2	25	50	2	15	15			2		100	1
2.3.3	50	100	20	20	20			2		0	2
2.3.4	100	100	20	50	50			2		0	1
2.3.5	1,000	200	50	50	50			2		0	2
2.3.6	500	0	50	15	15			2		0	2

TABLE IV-XII
PROFILE CORRESPONDENCE TO ELT MISSIONS

AREA	DESIGNATOR		
	Search	Search and Board	Search, Board and Seizure
Southern New England	2.1.1		
New England	2.1.2		
Southern New England	2.1.3	2.2.1	2.3.1/2.3.2
New England	2.1.4	2.2.2	2.3.1/2.3.2
Cheaspeake Bay	2.1.5		2.3.2
Texas	2.1.6	2.2.3	2.3.1
Middle Atlantic	2.1.7		
Middle Atlantic	2.1.8	2.2.4	2.3.1/2.3.2
West Florida	2.1.9		
West Florida	2.1.10	2.2.5	2.3.3
S.E. Alaska	2.1.11	2.2.6	2.3.4
Louisiana	2.1.12	2.2.7	2.3.3
West Coast	2.1.13	2.2.8	2.3.3.
Summer Herring	2.1.14	2.2.9	2.3.4
Ground Fish	2.1.15	2.2.10	2.3.4
Ground Fish	2.1.16	2.2.11	2.3.4
Far Aleutians	2.1.17	2.2.12	2.3.5
Gaum/Marianas	2.2.18	2.2.13	2.3.5
Summer Salmon	2.1.18	2.2.13	2.3.5
Summer Salmon	2.1.19	2.2.14	2.3.5
Straight of Yucatan	2.1.20	2.2.15	2.3.6
Windward Passage	2.2.20	2.2.15	2.3.6
Hawaii	2.2.10	2.2.15	2.3.6

Program Description

Congress has established the restoration and maintenance of the chemical, physical, and biological integrity of the nation's waters as a national objective. The Coast Guard is the primary maritime agency empowered to meet this national objective.

The role for the Coast Guard in marine environmental protection is a logical extension of its traditional missions in marine and port safety and law enforcement.

The MEP Program is divided into six major operational components: response, enforcement, prevention, monitoring and surveillance, impact assessment, and in-house abatement.

Initial efforts were designed to solve the immediate problem of minimizing the effects of pollution. More recent actions have concentrated on developing an adequate cleanup (response) capability to effectively remove most oil discharges. Current efforts in this area are concentrating on special technical problems for oil removal, removal of hazardous substances, and the removal of pollutants in the arctic environment.

In addition to attempting to resolve the immediate problems of cleanup, a second phase has been initiated to eliminate all types of discharges. Efforts are being directed at establishing an effective enforcement program, coupled with public awareness and education campaigns. Future efforts in this area will attempt to improve the level of enforcement in the coastal areas and to provide limited coverage in those outlying areas where little or no enforcement activity is presently conducted.

The U. S. Coast Guard Pollution Prevention Regulations for vessels and oil transfer facilities, which went into effect on 1 July 1974, signified the beginning of the third phase of the Program - prevention. Additional regulations, such as those dealing with hazardous substances, will be developed as necessary in conjunction with public education efforts, in a unified enforcement approach.

Several other initiatives support the response, enforcement, and prevention phases of the MEP Program. Monitoring and surveillance serve to meet program objectives in two ways. First, adequate detection enhances enforcement capabilities as well as being a deterrent which aids in preventing discharges. Second, this activity provides the Coast Guard with an impact assessment capability which can be used to judge the damage or the impact of pollutants on the marine environment. This information is required to ensure effective cleanup and to establish effective prevention policies. Initial steps to accomplish this are taken by providing surface and air surveillance in coastal and port areas.

To complement the aircraft, cutters, and boats that conduct the bulk of the MEP Program, three major items of response or cleanup equipment are in use. These are (1) the Air-Deliverable-Antipollution Transfer System (ADAPTS), (2) a high seas oil containment device, and (3) two types of oil recovery devices.

Potential Airship Missions

After discussions with cognizant personnel in the MEP Program Office, three MEP missions were selected for further evaluation. These are:

- MEP Surveillance, Detection, and Identification (Sample)

- MEP Logistics Support

- MEP Command and Control

The Surveillance and Identification mission is associated with three distinct operations:

- Aerial surveillance of ports handling ten million tons or more of petroleum per year,

- Coastal surveillance

- Ocean dumping operations

Airships are suited for MEP surveillance operations because of their speed, station keeping, and altitude characteristics. The airships considered for this study should be capable of hovering or traveling at speeds of up to 90 knots.

Operating at an altitude of 5,000 feet at a cruise speed of 60 knots or more, airships have a sweep rate almost comparable to airplanes and significantly greater than ships. The speed range of an airship allows it a quick response capability in emergencies, and yet it can also perform close-in surveillance at low speed.

Hovering is required for boarding operations. Sampling of detected pollutants can be handled at low speeds or in hover. The airship can operate close to the surface or at altitude up to 5,000 feet. The low altitude capability would be used for boarding, sampling, or close-in surveillance and the higher altitudes can be used for large area surveillance. Another significant attribute of the airship is its high visibility. The presence of a Coast Guard airship could be a strong deterrent to intentional dumping. For pollution detection operations it is assumed that an airship will be equipped with the MRS Aireye sensor package[56].

The combination of relatively high payload, compared to helicopters or an MRS, high speed and hover capability makes an airship a useful vehicle for logistics support in cleanup operations. It is not restricted by high sea state or shallow water, which are frequently the type of conditions in which large tanker accidents occur. The airship, as designed for Coast Guard missions, would be able to carry and deliver to the scene the ADAPTS package. For these missions the airship is assumed to be able to carry the ADAPTS system, repeating this ferrying operation three or four times before refueling. In the Torey Canyon spill of 1976, although the ship was only 26 miles offshore, a trip of over one hundred miles by sea was required due to shoals. In order to deliver the equipment it was necessary to use a U.S. Army Skycrane. Currently large clean-up equipment such as ADAPTS is stored at central locations throughout the country. This equipment must be transported to a staging area and then delivered to the incident. HC-130 aircraft are used to fly the equipment long distances. Airships could be used to deliver the equipment directly to the scene.

Additional missions under the MEP Logistics Support are associated with carrying and deploying booms, herders, burning agents, dispersants, sinking agents, etc. While the number of occurrences of these incidents may not be large, the importance of having the capabilities of the airship at these times is great.

For command and control functions at the cleanup scene, an airship provides an ideal platform for coordinating operations. Its ability to operate at low speed above, but close to, the incident is useful in obtaining information, determining the status, and giving commands. Its high-speed capability provides a quick response and allows surveillance of the entire scene in short periods of time. Its high endurance allows control to be maintained from a single platform for the duration of most operations. It can also be used to ferry personnel and as an illuminating platform for night-time operations.

Mission Profiles

For the MEP program there are 23 profiles for the three mission types. The profiles and occurrences listed for the surveillance and sample mission reflect the requirements specified in the MEP Program Standard[62] provided here in Table IV-XIII. The correspondence of the profiles in Table IV-XIV with the operations is as follows:

- Port Surveillance	Profiles 3.1.1 - 3.1.4
- Coastal Surveillance	Profiles 3.1.3 - 3.1.7
- Ocean Dumping	Profiles 3.1.8 - 3.1.11

Profiles 3.1.10 and 3.1.11 are associated with the criterion of boarding 15 percent of all "A" vessels and a spot check boarding of "B" vessels.

The logistic support mission is associated with delivering of clean-up equipment. The profiles are given in Table IV-XV. Profiles 3.2.1 and 3.3.3 are associated with an operation in which the airship is assumed to be able to carry the ADAPTS system, repeating a ferrying operation three or four times before refueling. The remaining profiles listed under the MEP Logistics Support mission are associated with carrying and deploying booms, herders, burning agents, dispersants, sinking agents, etc. While the number of occurrences of these incidents may not be large, it is of great importance to have the capabilities of the airship at these times.

The remaining profiles, Table IV-XVI, are associated with command and control functions at the cleanup scene. These operations are treated in Profiles 3.3.1 - 3.3.5.

TABLE IV-XIII
PROGRAM STANDARDS

PROGRAM: MEP

	ELEMENT	RELATED CRITERIA
1.	Monitor liquid bulk transfer operations of oil or hazardous substances.	20%-30% of vessels with a tank capability of over 250 BBLS. 50% of tankers arriving at deepwater ports.*
2.	Board tanker vessels to ensure compliance with pollution laws.	10% - 15%
3.	Conduct patrols of the essential harbor areas.	1/day daylight hours 1/week nighttime
4.	Conduct patrols of remote harbor areas.	Once/week
5.	Spot-check liquid bulk waterfront facilities.	Once/month
6.	Inspect liquid bulk waterfront facilities.	Twice/year
7.	Survey liquid bulk waterfront facilities.	Bi-annually
8.	Send monitor to scene of discharge.	All discharges where Coast Guard is predesignated on-scene coordinator including deepwater ports.*
9.	Remove polluting discharges where not done or inadequate by responsible party.	All discharges when required and removal is feasible.
10.	Conduct aerial surveillance flights in port areas handling 10 million tons or more of petroleum per year, including deepwater ports and their approach channels.	Twice a week for deepwater ports.* Frequency of flights for port areas based on actual amount of petroleum handled. Varies on a sliding scale from 1 patrol/week for 10 million tons to 6 patrols/week for 250 million tons.

*Deepwater port criteria effective pending operation of LOOP (FY-80).

TABLE IV-XIII
PROGRAM STANDARDS
(Continued)

PROGRAM: MEP

ELEMENT	RELATED CRITERIA
11. Conduct coastal surveillance flights over territorial waters, contiguous zone, prohibited zone, and expanded jurisdiction zone mandated by FWPCA amendments of 1977.	See Marine Safety Manual, CG-495, Volume VI. Frequency of patrols for 1977 amendments to FWPCA expanded zone to be determined.
12. Send Coast Guard representative to scene and investigate discharges.	All discharges (adequate investigators by other agencies may be used).
13. Conduct surveillance of ocean dumping operations authorized by permit.	75% of Category "A" dump operations, 10% of Category "B" operations, 15% boarding of "A" vessels, spotcheck boardings on "B" vessels.
14. Inspect records and logs required at deepwater ports.	Quarterly*
15. Inspect oil transfer controls and procedures at deepwater port terminals.	Quarterly*

*Deepwater port criteria effective pending operation of LOOP (FY-80).

TABLE IV-XIV
PROFILE LIST

Mission: MEP SEARCH AND SAMPLE

	TASKS										
				Search (1,000 n^2mi)							
Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
3.1.1	50	10	.5	10		10					100
3.1.2	50	10	.5	20		20					50
3.1.3	100	10	.5	10		10					100
3.1.4	100	10	.5	20		20					100
3.1.5	100	10	.5	25		50					100
3.1.6	500	10	.5	25		50					50
3.1.7	1,000	10	.5	25		50					25
3.1.8	200	0	4								100
3.1.9	500	0	4								100
3.1.10	200	0	4					1			10
3.1.11	500	0	4					1			

TABLE IV-XV
PROFILE LIST

Mission: MEP LOGISTICS SUPPORT

Profile Designator	TASKS										
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
3.2.1	200	10	8						17,000		1
3.2.2	50	10	2						17,000		1
3.2.3	50	10	4						500		10
3.2.4	50	10	4						1,000		10
3.2.5	100	10	4						500		10
3.2.6	100	10	4						1,000		10
3.2.7	100	10	8						3,000		5

TABLE IV-XVI
PROFILE LIST

Mission: MEP COMMAND AND CONTROL

	TASKS										
				Search ($1,000\ n^2mi$)							
Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
3.3.1	50		4								25
3.3.2	50		12								10
3.3.3	50		24								10
3.3.4	100		8								.5
3.3.5	100		36								5

For the purpose of generating profiles for the logistics and command and control missions, the data on the number of pollution incidents and Coast Guard participation in cleanup operations was obtained from the Coast Guard's Pollution Incident Reporting System (PIRS). It was assumed the airship participation in these cleanup operations would be predominantly limited to spills of greater than 10,000 gallons. It is expected that for smaller spills, other platforms would be utilized.

Summary of Potential Airship Participation in the MEP Program

Airship participation in MEP operations can include:

a. Surveillance

- including sampling capability

b. Logistics Supply

- capable of delivering skimmers and large pumps

c. Command, Control, and Communications Platform for Large Clean-up Operations

- provide illumination for night time operations

MILITARY OPERATIONS/PREPAREDNESS PROGRAM

Objective

The objective of the Military Operations/Preparedness (MO/MP) Program is to maintain the Coast Guard as an effective and ready armed force prepared for and immediately responsive to assigned tasks in time of war or national emergency. This includes readiness to function as a specialized service in the Navy in time of war, responding to national disasters and domestic emergencies, and the efficient conduct of peacetime missions. The program unifies both preparedness and operations.

Program Description

In order to maintain the Coast Guard as an effective and ready armed force, MO/MP combines training with the preparation of contingency plans based on realistic assessments of Coast Guard capabilities. Joint command post, joint operational, multi-unit, and individual exercises, are scheduled periodically to promote military preparedness. The Coast Guard participates in DOD's World-wide Military Command and Control System (WWMCCS). Participation in Fleet and inter-service exercises is geared to ensure that personnel and material performance are equal to Navy standards.

Typical tasks which may be required of the Coast Guard in wartime are: surveillance for enemy forces, antisubmarine warfare (ASW), protection of off-shore installations, convoy escort, and logistics supply.

Potential Airship (MO/MP) Missions

The MO/MP program is unique among the eight programs identified in this study for potential airship utilization. It is a support program set up to respond to contingencies. In this role it is not utilizing assets on a daily basis. In fact, the program does not have assigned assets. However, when the Coast Guard purchases a platform, it does consider the military capability. The airship is analyzed within this context.

Consistant with the historical use of Navy airships and the roles identified in the MO/MP program, ten missions were specified as follows:

- MO/MP Patrol
- MO/MP ASW Sonobuoy Surveillance
- MO/MP ASW Towed Array Surveillance
- MO/MP ASW Sonobuoy Surveillance and Attack
- MO/MP ASW Towed Array Surveillance and Attack
- MO/MP Ocean Industry Protection (OIP), Surveillance
- MO/MP Ocean Industry Protection, Surveillance, and Inspection
- MO/MP Convoy Ships
- MO/MP Logistics and Supply
- MO/MP Inshore Underwater Warfare

Three types of search and surveillance operations are identified; patrol, sonobuoy search, and towed array search. These differ in the type of sensors used. Patrol would rely on radar and visual search looking for aircraft or objects on the ocean surface. Sonobuoys and towed arrays would be used predominantly for ASW operations. Airships would utilize sonobuoys in a manner similar to aircraft. A sonobuoy field would be laid and then monitored by the airship. Additional sonobuoys could be deployed as operations require. Because of the airship's long endurance a field could be monitored for much longer periods of time than is currently accomplished by patrol aircraft.

A specially designed towed array, for air operations, could be deployed by an airship operating at low altitude and slow speed. Because an airship is not in direct contact with the water its radiated noise greatly minimizes interference with the performance of the sensor. The higher speed capabilities of an airship, as compared to a ship, enhances its operational effectiveness. A standard tactic in the employment of towed arrays is "sprint and drift" in which the array is towed at low speed (drift), to search an area, and then towed to a new area at higher speed (sprint). The higher the speed of the sprint cycle the more effective the operation.

Upon detection of a submarine an airship may either maintain surveillance or initiate an attack. The attack may be made by another platform in the area, e.g. surface ship or submarine, or carried out by the airship. For attack, the airship would be equipped with torpedoes.

Ocean Industry Protection (OIP) is a mission the Coast Guard may be required to perform in peace time as well as in war time. Oil platforms, deep sea ports, etc., are susceptible to terrorist attacks as well as military action. The speed and endurance of an airship allow for surveillance of a number of platforms during a single flight. At an offshore site an airship can either perform low speed visual inspection or allow direct inspection by a boarding party.

The range, speed and payload capability makes an airship an ideal platform for logistics and supply of moderate size payloads. This is true for non-military programs, i.e., MEP, A/N, etc., as well as for the MO/MP program. Because of its ability to hover, an airship could supply remote areas where basing or port facilities are minimal or non-existent.

The protection of coastal and adjacent waterways from penetration by hostile forces is an area of increasing concern to the Coast Guard. The airship's ability to do large area search from high altitude as well as close in search from near the surface can be well utilized in Inshore Undersea Warfare. Swimmer teams, for investigation or attack, can be transported and deployed and recovered by hovering airships. The speed and endurance of the airship allow for a range of operations.

Mission Profiles

Mission profiles for the MO/MP missions are given in Tables IV-XVII - IV-XXVI. There are a total of 109 profiles specified for the ten different missions. MO/MP operations are not performed on a daily basis, rather they are formulated to meet emergency situations that arise. Therefore, the exact nature of. and the need for a mission is dependent on the type and severity of the contingency. The measures for each task are varied to assure spanning the operational requirement of the potential missions and to show the potential and diversity of the airship contribution to MO/MP operations.

Occurrences are not given for these profiles. Therefore, the MO/MP missions are not accounted for in the determination of the total airship requirement.

Summary of Potential Airship Participation in the MO/MP Program

Potential mission areas for airship participation in MO/MP operations are:

- patrol
- ASW sonar surveillance/attack
- OIP surveillance/inspection
- escort of convoys or independent ships
- logistics and supply
- inshore undersea warfare

NOTE: While the MO/MP Program does not have dedicated assets, operations would typify part airship military roles.

TABLE IV-XVII
PROFILE LIST

Mission: MO/MP PATROL

Profile Designator	TASKS											
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
4.1.1	25	25		10	10						0
4.1.2	25	25		100	200						0
4.1.3	100	25		10	10						0
4.1.4	100	25		50	100						.0
4.1.5	500	25		25	50						0
4.1.6	500	25		100	200						0
4.1.7	1,000	25		25	50						0
4.1.8	1,000	25		100	200						0
4.1.9	3,000	25		25	50						0
4.1.10	3,000	25		100	200						0

TABLE IV-XVIII
PROFILE LIST

Mission: MO/MP ASW SONOBUOY SURVEILLANCE

Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Search Instrument	Search Pollution	Search ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
4.2.1	50						10				0
4.2.2	50						50				0
4.2.3	100						50				0
4.2.4	100						100				0
4.2.5	500						10				0
4.2.6	500						50				0
4.2.7	500						100				0
4.2.8	1,000						10				0
4.2.9	1,000						100				0
4.2.10	1,000						500				0
4.2.11	2,000						10				0
4.2.12	2,000						100				0
4.2.13	2,000						500				0

TABLE IV-XIX
PROFILE LIST

Mission: MO/MP ASW TOWED ARRAY SEARCH

	TASKS										
				Search (1,000 n^2mi)							
Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Visual	Instrument	Pollution	ASW *	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
4.3.1	50						10				0
4.3.2	50						50				0
4.3.3	100						50				0
4.3.4	100						100				0
4.3.5	500						10				0
4.3.6	500						50				0
4.3.7	500						100				0
4.3.8	1,000						10				0
4.3.9	1,000						100				0
4.3.10	1,000						500				0
4.3.11	2,000						10				0
4.3.12	2,000						100				0
4.3.13	2,000						500				0

*Equivalent to tow task for towed array.

TABLE IV-XX
PROFILE LIST

Mission: MO/MP ASW SONOBUOY SEARCH AND ATTACK

	TASKS										
				Search (1,000 n^2mi)							
Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
4.4.1	50	50	1				10				0
4.4.2	50	10	1				50				0
4.4.3	50	50	1				50				0
4.4.4	100	10	1				10				0
4.4.5	100	50	1				10				0
4.4.6	100	50	1				50				0
4.4.7	500	10	1				10				0
4.4.8	500	50	1				50				0
4.4.9	500	10	1				100				0
4.4.10	500	50	1				100				0
4.4.11	1,000	10	1				10				0
4.4.12	1,000	50	1				100				0
4.4.13	1,000	50	1				500				0
4.4.14	1,000	10	1				100				0
4.4.15	2,000	50	1				10				0
4.4.16	2,000	50	1				100				0
4.4.17	2,000	50	1				500				0

TABLE IV-XXI
PROFILE LIST

Mission: MO/MP ASW TOWED ARRAY SEARCH AND ATTACK

Profile Designator	TASKS: Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi): Visual	Instrument	Pollution	ASW *	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
4.5.1	50	50	1				10			200	0
4.5.2	50	10	1				50			1,000	0
4.5.3	50	50	1				50			1,000	0
4.5.4	100	10	1				10			200	0
4.5.5	100	50	1				10			200	0
4.5.6	100	50	1				50			1,000	0
4.5.7	500	10	1				10			200	0
4.5.8	500	50	1				50			1,000	0
4.5.9	500	10	1				100			2,000	0
4.5.10	500	50	1				100			2,000	0
4.5.11	1,000	10	1				10			200	0
4.5.12	1,000	50	1				100			2,000	0

*Equivalent to tow tasked for towed array.

TABLE IV-XXII
PROFILE LIST

Mission: MO/MP OIP SURVEILLANCE

Profile Designator	TASKS										Occurrence
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	
4.6.1	50	100	1	1	1						0
4.6.2	50	200	3	1	1						0
4.6.3	50	200	2	5	5						0
4.6.4	200	100	2	1	1						0
4.6.5	200	200	2	5	5						0
4.6.6	400	100	5	5	5						0
4.6.7	400	500	10	5	5						0
4.6.8	400	1000	10	5	5						0
4.6.9	400	1000	20	10	10						0
4.6.10	400	2000	10	10	10						0

TABLE IV-XXIII
PROFILE LIST

Mission: MO/MP OIP SURVEILLANCE AND INSPECTION

Profile Designator	TASKS										
				Search (1,000 n^2mi)							
	Transit (nmi)	Patrol (nmi)	Station Keeping/Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lh)	Tow (hr)	Occurrence
4.7.1	50	100	2	1	1			5			0
4.7.2	50	200	3	1	1			10			0
4.7.3	50	200	2	5	5			10			0
4.7.4	200	100	2	1	1			5			0
4.7.5	200	200	2	5	5			10			0
4.7.6	400	100	5	5	5			5			0
4.7.7	400	500	10	5	5			25			0
4.7.8	400	1000	10	5	5			50			0
4.7.9	400	1000	20	10	10			50			0
4.7.10	400	1000	10	10	10			20			0

TABLE IV-XXIV
PROFILE LIST

Mission: MO/MP CONVOY SHIPS

Profile Designator	TASKS											
				Search (1,000 n^2mi)								
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
4.8.1		500	5	10			10				0
4.8.2		100	10	10			10				0
4.8.3		200	10	25			50				0
4.8.4		500	20	25			50				0
4.8.5		200	20	50			100				0
4.8.6		500	40	50			100				0

TABLE IV-XXV
PROFILE LIST

Mission: MO/MP LOGISTICS AND SUPPLY

	TASKS										
				Search (1,000 n^2mi)							
Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
4.9.1	50								500		0
4.9.2	50								2,500		0
4.9.3	50								5,000		
4.9.4	500								500		0
4.9.5	500								2,500		0
4.9.6	500								5,000		0
4.9.7	2,000								500		0
4.9.8	2,000								2,500		0
4.9.9	2,000								5,000		0
4.9.10	5,000								5,000		0

TABLE IV-XXVI
PROFILE LIST

Mission: MO/MP INSHORE UNDERSEA WARFARE

Profile Designator	TASKS										
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi)				Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
				Visual	Instrument	Pollution	ASW				
4.10.1	10	100	2	1	1			1	500		0
4.10.2	100	10	2	.5	.5			0	500		0
4.10.3	200	200	2	.5	.5			1	500		0

MARINE SCIENCE ACTIVITIES PROGRAM

Objective

The objectives of the Marine Science Activities (MSA) Program are to provide marine science support to all Coast Guard programs and to support national economic, scientific, defense, and social needs.

Program Description

The Coast Guard marine science effort emphasizes applied oceanography in support of Coast Guard programs and missions. Coast Guard activities in Search and Rescue, Marine Environmental Protection, and Ice Operations rely heavily on the oceanographic and meterological information obtained through MSA operations.

The Coast Guard has the greatest federal presence in the coastal zone and has the sole U.S. capability for surface transit of ice-covered waters.

The Coast Guard has a long history of cooperation with the National Oceanic and Atmospheric Administration (NOAA) through projects with the National Weather Service (NWS), National Marine Fisheries Services (NMFS), and National Ocean Survey (NOS). Additionally, mutual interests have stimulated exchanges of services between the Coast Guard and the Department of Defense.

The following brief summary highlights some of the most signficant activities carried out by the Coast Guard through MSA:

a. International Ice Patrol - Commenced in 1914 after the sinking of the TITANIC, now conducted under international agreement. Aircraft and ships are deployed each year from February to August to detect icebergs near the North Atlantic shipping lanes and to study ice and current conditions;

b. Oceanographic Services - Applied oceanography to support Coast Guard operations. Sea surface current studies are conducted to assist in computerized Search and Rescue planning. Computerized models of sea currents for the entire U.S. coastline are being developed. In addition to SAR operations, these models have application in pollutant drift prediction and the planning of deep water ports. Other coastal projects being conducted include estuarine pollution studies, time dependent current modelings, and bays and sounds modeling;

c. Data Buoy Project - This project is administered by the National Oceanic and Atmospheric Administration with Coast Guard providing operational support for deployment and servicing of buoys, a technical staff, and a communications system to relay buoy data. An extensive network of buoys provides marine environmental data over the coastal U.S. from the Gulf of Maine to the Gulf of Alaska and the Great Lakes;

d. Marine and Coastal Weather Observation and Reporting - This project is conducted as a cooperative effort with the National Weather Service and the Naval Weather Service Command for use in preparation of marine weather forecasts. Approximately 170 shore stations and 50 cutters report weather data several times daily. National Weather Service prepared weather forecasts are broadcast to local marine users over Coast Guard communications facilities;

e. Cooperative Projects - The Coast Guard engages in cooperative projects with various federal agencies and provides marine science expertise and resources to further national goals in open ocean and coastal programs. Many of these projects represent unique efforts, where the Coast Guard contributes most or all of the data and services:

- Airborne Radiation Thermometer Surveys - Charts of sea surface temperatures in continental shelf regions are compiled from data acquired monthly by Coast Guard aircraft using infrared radiation thermometers. These charts of both the east and west coasts are provided to U.S. Government agencies and the civilian maritime community for use in search and rescue, marine environmental protection, and fisheries related problems.

- Ocean Sounding Program - Bathymetric data are routinely supplied to the Defense Mapping Agency Hydrographic Office by cutters engaged in regular Coast Guard functions. These data become an input to charts used by all members of the maritime community.

Potential Airship Missions

After discussions with cognizant personnel in the MSA Program Office and review of pertinent literature four missions were considered for airship operations. These are:

- MSA International Ice Patrol (IIP)
- MSA Airborne Radiation Thermometer (ART)
- NOAA Data Buoy Office Support (NDMO)
- Miscellaneous

A succinct description of the nature and requirements of these missions is given in reference (60) as follows:

"IIP - Aircraft are used as the primary method of tracking icebergs in the North Atlantic Ocean. Occasionally, Coast Guard vessels are used to track and mark the southern most icebergs and act as an aid to navigation . . . This normally required three or more flights per week averaging 1,200 miles . . . The length of the iceberg seasons is variable but an average season of 123 days occurs between March and July . . .

"ART - The Coast Guard has been monitoring sea temperatures from aircraft since 1962 . . . Selected air stations are responsible for two or three eight hour flights during the one week of each month. A typical flight carries two or three technicians as observers and 50 to 100 pounds of equipment. Monthly surveys are flown at a nominal altitude of 500 feet . . . The infrared radiometer is sensitive to vibration and the heat effects from turbine exhaust . . .

"NDBO - The Coast Guard is tasked with providing operational services for the NOAA Data Buoy Office in support of a network of deep ocean moored environmental buoys. A recurring requirement exists for aircraft to investigate disabled buoys and search for buoys which drift from station . . . The operational buoys are widely distributed along the United States coast including the Gulf of Alaska at ranges between 50 and 800 miles from the closest air station.

"Miscellaneous - Examples of the types of services provided are: ferrying scientific personnel and cargo, conducting aerial photography, monitoring currents and sediment patterns to determine pollution dispersal, providing non-search logistics support for IIP, airborne equipment test flights and flights in support of other agencies such as NOAA, USGS, and EPA."

The IIP missions require that a specified area be totally searched on a routine basis. While the length of the ice patrol season varies from year to year, the requirements of each patrol remains fairly constant. How the search is conducted is dependent on the type of platform used for the search. If long endurance platforms are available, long missions would be advisable. If a platform can only operate eight hours a day, missions should be shortened. There is a requirement of searching the entire area of interest (approximately 100,000 n^2mi) once a week for 20 weeks a year.

Typical search patterns, for current operations using the HC-130 are given in Figures IV-1 and IV-2.

IIP operations are frequency hampered by weather conditions. In the period from early spring through early summer the poor visibility and ceiling conditions off the Newfoundland coast interfere with IIP operations. The airship, because of its ability to operate at very low speeds and its greater maneuverability should be able to operate in many situations in which the HC-130, which currently performs the mission, cannot. As discussed in Chapter III, airships can operate under conditions of lower ceiling or lower visibility than fixed wing aircraft. Table IV-XXVII, which comes from Appendix A, specifies the expected occurrence of weather conditions for the Argentia area off the Newfoundland coast. In the late spring and early summer the visibility/ceiling is poorest and the wind conditions are least severe.

An airship also offers operational advantages in the ART mission. The low level of vibration and the ability to isolate instruments from high temperature sources or metallic parts make an airship an ideal platform for carrying the sensitive scientific instruments associated with this mission.

Mission Profiles

For the three MSA missions identified, there are a total of 11 profiles given. For International Ice Patrol (IIP) there are four profiles given in Table IV-XXVIII. These profiles are actually alternate sets of two profiles. Depending upon the capabilities of the airship either the combination of 5.1.1 and 5.1.3 or the combination of 5.1.2 and 5.1.4 should satisfy the mission requirement. The pair of profiles that can be most efficiently handled by the point design airship should be the profiles chosen for this mission. The profile configurations of IIP operations are based upon Figures IV-1 and IV-2.

Similar considerations should be given for ART and NDBO missions. The profiles given in Tables IV-XXIX and IV-XXX are based on the number of flight hours required as specified in reference [63]. The profiles can be modified to efficiently utilize the point design airship as long as the requirements of area surveillance are satisfied.

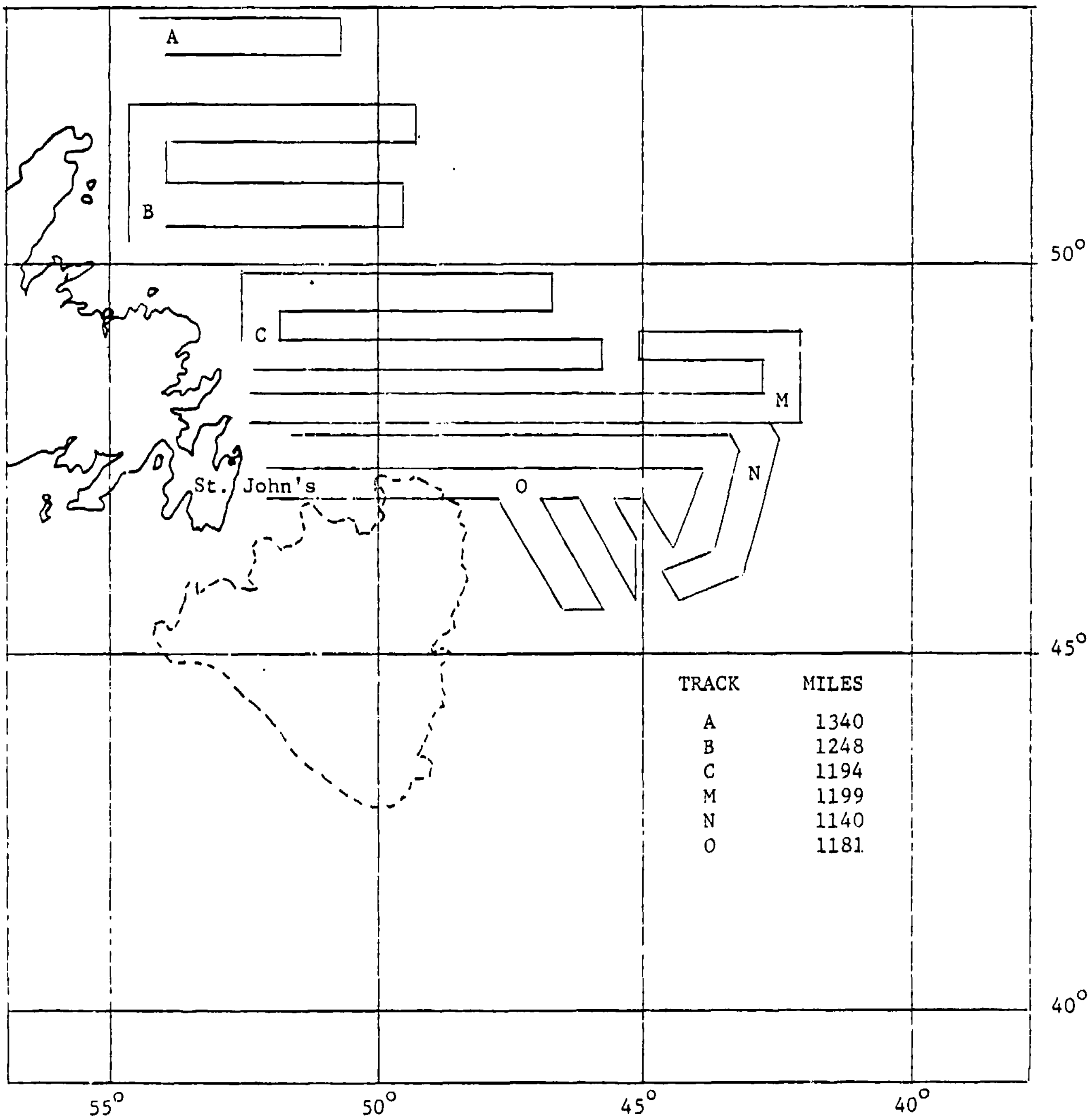

Figure IV-1. International Ice Patrol Standard Flight Plans.

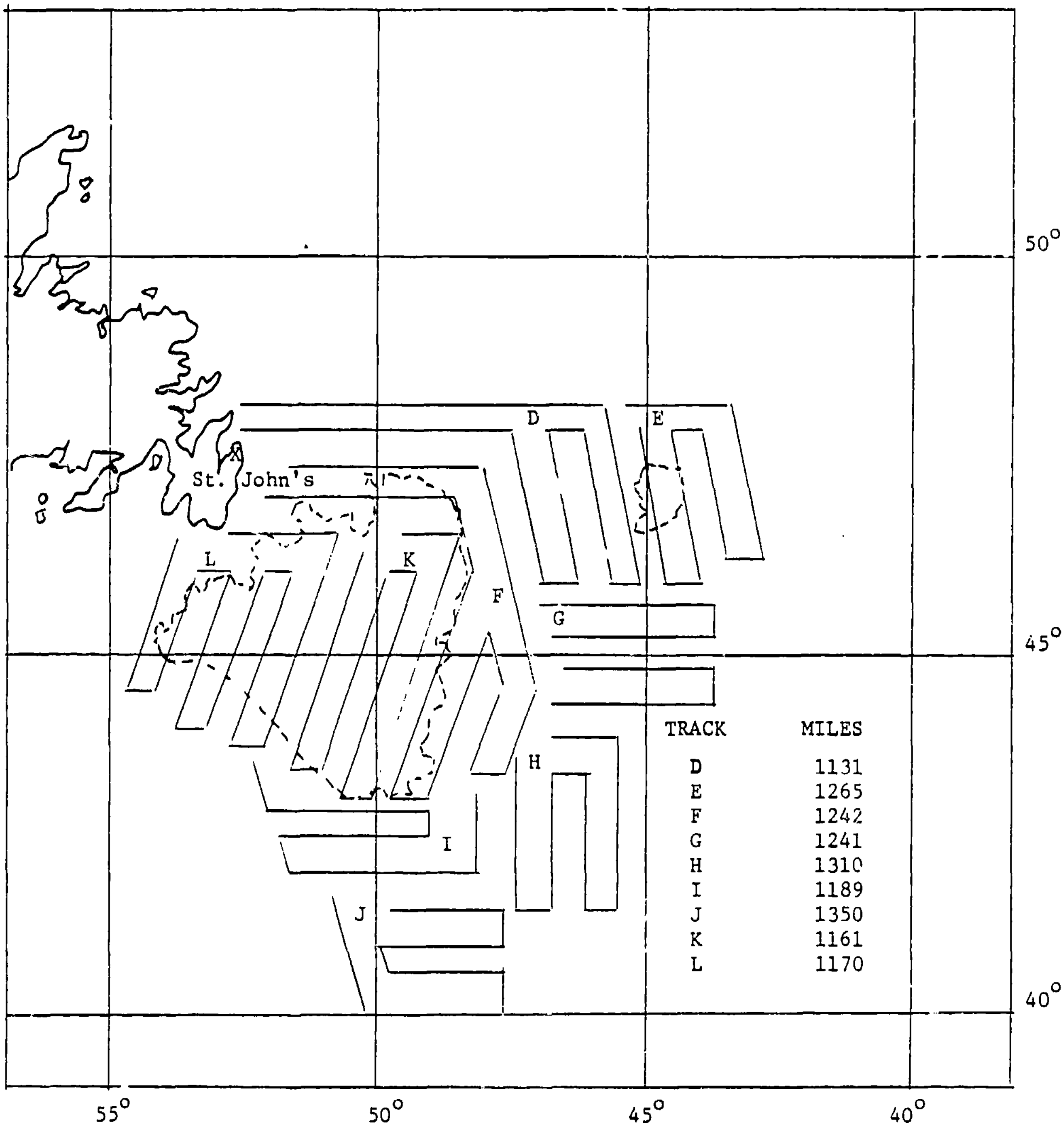

Figure IV-2. International Ice Patrol Standard Flight Plans.

TABLE IV-XXVII
MONTHLY SYNOPTIC WEATHER DATA - ARGENTIA

MONTH	VISIBILITY/ CEILING <½ mi/<300 ft %	VISIBILITY/ CEILING >55 yd, <¼/<150 ft %	WIND SPEED >33 KT %	WIND SPEED >41 KT %	MEAN WIND SPEED (KTS)
January	7.7	5.8	10.0	1.2	20.3
February	6.7	5.5	10.2	1.9	21.2
March	8.8	6.9	8.8	1.2	19.5
April	11.5	10.0	5.2	.9	16.6
May	17.9	16.5	1.8	0	13.6
June	35.2	23.7	1.0	.2	12.5
July	32.9	31.2	.3	.1	11.3
August	20.6	19.0	.5	.2	12.2
September	12.2	11.0	2.0	.6	14.1
October	7.9	6.9	3.8	.7	16.3
November	9.1	7.5	6.7	2.1	18.0
December	7.1	5.8	10.4	.9	19.9

TABLE IV-XXVIII
PROFILE LIST

Mission: MSA ICE PATROL, SURVEY OF NORTH ATLANTIC FOR ICEBERGS (IIP)

Profile Designator	TASKS: Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi): Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
5.1.1	0		1	25	25						100*
5.1.2	0		1	25	50						100*
5.1.3	200		1	25	25						50*
5.1.4	200		1	25	50						50*

*A total requirement of approximately 150 days. Either 5.1.1 and 5.1.3 will be used or 5.1.2 and 5.1.4 will be used depending on cost effectiveness.

TABLE IV-XXIX
PROFILE LIST

Mission: MSA AIRBORNE RADIATION THERMOMETER (ART) SURVEYS

	TASKS										
				Search (1,000 n^2mi)							
Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
5.2.1	50				50						25
5.2.2	100				25						25
5.2.3	500				25						50

TABLE IV-XXX
PROFILE LIST

Mission: MSA NOAA DATA BUOY OFFICE (NDBO) SUPPORT

Profile Designator	TASKS										
	Transit (nmi)	Patrol (nmi)	Station Keeping/Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
5.3.1		100							100		2
5.3.2		200							100		2
5.3.3		500							100		2
5.3.4		1000							100		2

Summary of Airship Participation in MSA Operations

There is potential for airship utilization in the following MSA operations:

a. International Ice Patrol (IIP)

- has high endurance and payload capability
- less constrained by poor visibility and ceiling than HC-130

b. Airborne Radiation Thermometry (ART)

- has high endurance and payload capability
- instrumentation can be isolated from heat and vibration sources
- safe low altitude (500 feet or less) platform

c. NOAA Data Buoy Office Support (NDBO)

- investigation of disabled buoys
- search for drifting buoys

d. Miscellaneous

- ferrying cargo and personnel
- aerial photography
- environment survey

PORT SAFETY AND SECURITY PROGRAM

Objective

The objective of the Port Safety and Security (PSS) Program is to safeguard the nation's navigable waters and adjacent shore areas, including ports and their related facilities, from accidental or intentional harm.

Program Description

The Ports and Waterways Safety Act (PWSA) of 1972 was written to prevent damage to, or destruction or loss of any vessel, bridge, or other structure on, in, or near the navigable waters of the U.S. and to protect the navigable waters and the resources therein from environmental harm resulting from vessel or structure damage.

The Port Safety and Security Program is administered by the Coast Guard Captains of the Port (COTPs). The Program is complex and interfaces with several other program areas.

Currently, there are over 50 Captains of the Port with approximately 1,600 field billets designed for Port Safety/Security and Marine Environmental Protection duties. These functions include monitoring and supervision of oil transfer and hazardous cargo operations, cleaning-up pollution, conducting harbor patrols, inspecting and surveying waterfront facilities, establishing safety and security zones as required, and controlling movements and anchorages.

The many and varied activities of the PSS program can be categorized into the following major areas:

- prevent intentional or accidental mishandling of cargo in U.S. ports and waterways;

- prevent threats and acts of espionage, sabotage, and intelligence gathering;

- reduce the likelihood of fires and explosions in the port areas;

- reduce the probability of ship collisions or groundings;

- assist vessels to transit U.S. ports safely and economically in a minimum of time;

- promote unified and consolidated rules of the nautical road in accordance with international regulations for preventing collisions at sea;

- enhance cargo security within the entire marine terminal complex.

Vessel traffic management is an important means of assuring safe operation in certain ports and waterways. This function is provided by Coast Guard Vessel Traffic Services (VTS). Using a VHF-FM communication network, and in most cases some form of electronic surveillance, information on vessel positions and movements is collected by a shore-based vessel traffic center. After analyzing the data, the VTS provides accurate and comprehensive information to vessels on the status of other vessels and other relevant navigation information. In addition, congestion or other conflict situations are predicted as far in advance as possible. Vessels are alerted to such potential problems so that corrective measures can be taken.

Potential Airship Missions

Three missions have been identified under the PSS program in which airships could be utilized. These are:

- PSS Escort
- PSS Port Traffic Control
- PSS Fire Fighting Equipment

The escort mission is to provide traffic separation from, and escort to, vessels handling Class "A" explosives and cargoes of particular hazard, such as liquid natural gas, which present a high risk to port areas. By keeping station in the vicinity of the vessel, an airship could provide a platform for direct observation over a large area, a means for direct communication with the vessel or any traffic in the vicinity, and a quick response capability to respond to any problems that arise. The high visibility of the airship would provide a presence to alert all traffic within the area.

The port traffic control operation is similar to the escort mission in that the airship is maintained over a small area providing wide area surveillance through radar and visual observation. Computer facilities and traffic control personnel would be stationed on board and could communicate to port traffic via VHF transmissions. Because of its mobility the airship could respond to port emergencies or be available for close observation.

The Coast Guard is involved in fire fighting operations less than 25 times a year. In fire fighting operations the airship could provide logistics support, transporting large pumping equipment to the scene. Also, if required, it could serve as a platform for command, control, and communications. If an airship were available, it could be used for logistics of these operations. Therefore, the PSS Fire Fighting Equipment mission has been included in this airship analysis.

Missions Profiles

Tables IV-XXXI through IV-XXXIII specify a total of 18 profiles for the three PSS missions. The first mission is associated with the escort of vessels carrying hazardous cargo. The exact nature of these operations depends upon the port in which the escort is being provided. As before, the profiles are selected to span the nature of these operations.

The second mission, port traffic control, is the only mission of this study that is a new mission, proposed on the basis of the airship's capabilities. Therefore, there are no existing operations upon which to base a profile, nor is there an identifiable requirement from which the annual occurrence can be determined. The profiles given for this mission are given in Table IV-XXXII, as an example of what the potential requirement for such an operation could be. The exact details of such a mission will have to await the development of an airship and additional analysis.

The third mission under the PSS program, fire fighting equipment, also has a very low frequency of occurrence. The profiles given in Table IV-XXXIII are provided to span the range of possible missions in which an airship may participate. The payloads for the logistics task are associated with either a large pump or the fire fighting equipment set.

Summary of Airship Participation in PSS Operations

For the PSS program the following missions have been identified for airship utilization:

TABLE IV-XXXI
PROFILE LIST

Mission: PSS ESCORT

Profile Designator	TASKS										
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search ($1,000\ n^2mi$)				Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
				Visual	Instrument	Pollution	ASW				
6.1.1	50	20	3								100
6.1.2	100	50	6								100
6.1.3	100	100	12								100
6.1.4	200	50	6								100
6.1.5	200	10	12								100

TABLE IV-XXXII
PROFILE LIST

Mission: PSS PORT TRAFFIC CONTROL

Profile Designator	TASKS										Occurrence
	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi)				Board (hr)	Logistics (lb)	Tow (hr)	
				Visual	Instrument	Pollution	ASW				
6.2.1		50	4								0
6.2.2		100	4								0
6.2.3		50	7								0
6.2.4		100	7								0
6.2.5		100	10								0

TABLE IV-XXXIII
PROFILE LIST

Mission: PSS FIRE FIGHTING EQUIPMENT

Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n²mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
6.3.1	0		4						100		1
6.3.2	0		4						2,700		1
6.3.3	0		20						100		1
6.3.4	0		20						2,700		1
6.3.5	100		4						100		1
6.3.6	100		4						2,700		1
6.3.7	100		20						100		1
6.3.8	100		20						2,700		1

a. Escort of vessels carrying hazardous cargoes

- station keeping in vicinity of vessel
- large area surveillance
- direct communication
- quick response;

b. Port traffic control

- mini vessel traffic services (vts)
- simultaneous observation, command, control, and communications platform
- quick response;

c. Provide fire fighting equipment

- logistics support
- command and control

SEARCH AND RESCUE PROGRAM

Objective

The objective of the Search and Rescue (SAR) Program is to minimize loss of life, injury, and property damage by rendering aid to persons and property in distress in the marine environment, including the inland navigable waters.

Program Description

Search and Rescue is the mission which is most readily identified with the Coast Guard. This mission is one of the Coast Guard's most traditional functions and continues to demand the highest priority.

Economic and technological advances have changed the search and rescue clientele. The rapid expansion of recreational boating, the increase of powered fishing vessels, and the accepted responsibility of the United States to provide a greater degree of assistance to the mariner on the high seas, has created new demands for providing search and rescue capability. The Coast Guard has responded to these demands by evolving search and rescue systems that encompass stations, ships, aircraft, and boats which are linked by modern communications networks, and centrally controlled and directed by rescue coordination centers.

The current national SAR plan has established three SAR regions; Inland, Maritime, and Overseas. The Coast Guard is the designated coordinator for the Maritime region. SAR facilities have been established at numerous points along the East, West, and Gulf Coasts, and in Alaska, Hawaii, American Samoa, and Puerto Rico.

The Maritime SAR region reaches deep into the Atlantic and Pacific and embraces all of the Gulf of Mexico. It should be noted, however, that 92 percent of all SAR incidents occur within 25 miles of the U.S. coastline.

Potential Airship Missions

Of all the Coast Guard programs, SAR probably has the most diversified operating requirements. Because of the variety of services provided, it is difficult to allocate the responses to a small number of categories. However, within the degree of generality of this study, the following six categories can adequately describe the mission profiles:

- SAR Search
- SAR Search and Provide Equipment
- SAR Search, Provide Equipment, and Board
- SAR Search, Board, and Tow
- SAR Board and Assist
- SAR Tow

There are factors that complicate the analysis of missions for the SAR program. A platform does not have to be allocated to the SAR program to attempt SAR operations. A platform may be involved with a different mission when a SAR requirement occurs. The platform will interrupt its assigned mission and undertake the SAR mission. Therefore, when responding to a SAR occurrence, the exact status of a platform depends upon whether it is interrupting an ongoing mission or is assigned from its base. Factors such as fuel load, endurance, and payload will differ for the two situations. In specifying the airship variable payload for all programs identified in this study, rescue equipment is included. The airship is always prepared for a SAR interrupt. The first consideration in assigning a platform to a SAR operation is whether the platform is adequate for the nature of the incident. Of all the capable platforms, the platform that is least expensive to operate and can rapidly respond, is assigned to the mission. On this basis only missions of greater than ten miles from shore are considered for airship response. For shorter missions, boats or helicopters should be sufficient for most operations. This is not to say that airships are inadequate for such operations but that they usually will not be the platform of choice for these missions.

With the ability to hover, the airship can maintain its position directly over a vessel in distress, providing direct observation or communications. A winch provides the ability to lower a man and boat into the water, lift someone from the water, or directly from the deck. It is also possible to lower fuel, supplies, a dewatering pump, or firefighting equipment directly to the vessel. It is also assumed that the airship will be able to tow vessels of up to 150 feet or more.

Mission Profiles

For the six SAR missions, there are a total of 49 profiles specified in Tables IV-XXXIV through IV-XXXIX. It has been assumed that airships will participate in medium and long range SAR operations (greater than ten miles offshore). It has also been assumed that SAR operations will be handled as separate missions. This ignores the general procedure of interrupting existing operations to participate in SAR. All of the profiles incorporate the transit task which accounts for transit from the airbase to the scene of the SAR mission.

TABLE IV-XXXIV
PROFILE LIST

Mission: SAR SEARCH

Profile Designator	TASKS: Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi): Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
7.1.1	50		0	1	1						2,000
7.1.2	50		0	5	5						500
7.1.3	50		2	2	2						100
7.1.4	50		4	2	2						100
7.1.5	100		0	1	1						500
7.1.6	100		0	5	5						100
7.1.7	100		2	3	3						50
7.1.8	100		4	3	3						10
7.1.9	100		10	5	5						200
7.1.10	500		0	1	1						200
7.1.11	500		0	5	5						200
7.1.12	500		2	5	5						50
7.1.13	500		10	5	5						25
7.1.14	1,000		0	1	1						100
7.1.15	1,000		0	10	10						50
7.1.16	1,000		2	5	5						25
7.1.17	1,000		10	5	5						5

TABLE IV-XXXV
PROFILE LIST

Mission: SAR SEARCH AND PROVIDE EQUIPMENT

Profile Designator	TASKS: Transit (nmi)	Patrol (nmi)	Station Keeping/Trail (hr)	Search ($1,000\ n^2mi$): Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
7.2.1	50		2	1	1				500		100
7.2.2	50		2	5	5				500		50
7.2.3	50		2	5	5				1,000		100
7.2.4	100		2	3	3				500		20
7.2.5	100		2	3	3				1,000		20
7.2.6	500		2	3	3				500		10
7.2.7	500		2	3	3				1,000		20
7.2.8	1,000		2	5	5				500		10

TABLE IV-XXXVI
PROFILE LIST

Mission: SAR SEARCH, PROVIDE EQUIPMENT, AND BOARD

Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
7.3.1	50		2	1	1			1	500		5
7.3.2	100		2	1	1			1	500		5
7.3.3	500		2	1	1			1	500		5
7.3.4	1,000		2	1	1			1	500		5

TABLE IV-XXXVII
PROFILE LIST

Mission: SAR SEARCH, EQUIP, BOARD, AND TOW

	TASKS										
				Search (1,000 n^2mi)							
Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
7.4.1	50		2	1	1			1	0	25	100
7.4.2	50		4	1	1			1	500	25	50
7.4.3	2		2	3	3			1	0	50	25
7.4.4	100		4	3	3			1	500	50	5
7.4.5	500		2	3	3			1	0	250	5
7.4.6	500		4	3	3			1	500	250	5

TABLE IV-XXXVIII
PROFILE LIST

Mission: SAR SEARCH, BOARD, AND ASSIST

Profile Designator	TASKS: Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi): Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (h.)	Occurrence
7.5.1	50		2	1	1			1			1,500
7.5.2	50		4	1	1			1			500
7.5.3	100		2	3	3			1			200
7.5.4	100		4	5	5			1			100
7.5.5	500		2	5	5			1			100
7.5.6	500		4	3	3			1			10
7.5.7	1,000		2	3	3			1			100
7.5.8	1,000		4	3	3			1			50

TABLE IV-XXXIX
PROFILE LIST

Mission: SAR SEARCH AND TOW

Profile Designator	TASKS: Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n²mi): Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
7.6.1	50		1	1	1					25	1,000
7.6.2	50		4	1	1					25	20
7.6.3	100		1	3	3					50	100
7.6.4	100		4	3	3					50	5
7.6.5	500		1	3	3					250	25
7.6.6	1,000		1	3	3					500	2

In analyzing the SAR program, a group of profiles were specified for each mission. The task composition was varied from profile to profile over a variety of parameters to assure spanning the types of profiles that would be encountered in actual operations. On the basis of the Search and Rescue Assistance Reports data base, the occurrences of the profiles were then specified. Each of the categories of assistance were correlated with the seven tasks used to create the profiles. The categorization of SAR assistance categories with the specified missions is given in Table IV-XL. On the basis of this correlation it is felt that the profiles give a good representation of the nature and frequency of the SAR mission in which an airship would be expected to participate. It is unlikely that an airship would be available for all of the specified missions. However, it could be valuable assistance in all of these occurrences, if avai-lable.

It is obvious that, on a given SAR, more than one task may be required. Since assistance to personnel is analyzed separately from assistance to property, the combination of these task occurrences is hard to identify. In specifying the number of occurrences for each profile, an attempt has been made to maintain the correct proportions and the approximate total of all SAR occurrences greater than ten miles.

Summary of Airship Participation in SAR Operations

Airship utilization has been considered for long range rescue operations ten miles or greater from the shore. Airships could be particularly useful for such operations because airships:

- Have High Sweep Rates
- Can Deliver Large Payloads
- Can be Used for Boarding Vessels
- Can Tow Vessels in Distress
- Have High Endurance

ICE OPERATIONS PROGRAM

Objective

The objective of the Ice Operations (IO) Program is to facilitate maritime transportation and other activities in the national interest in ice-laden domestic and polar waters. The services provided in the IO program also assist in meeting the needs of marine safety and environmental protection in the ice environment.

Program Description

In 1936, a Presidential Executive Order established national policy on use of vessels for icebreaking operations in channels and harbors. The Coast Guard was directed to keep channels and harbors open for the reasonable demands of commerce insofar as practicable by performing icebreaking operations. In response to a determination that the national interest would best be served by concentrating all icebreaking resources in one agency, the U.S. Navy transferred its icebreakers to the Coast Guard in 1965.

TABLE IV-XL
CATEGORIZATION OF CATEGORIES OF ASSISTANCE

SEARCH

- None
- Failed to locate
- Located
- Rescued
- Vectored other platform
- Communications
- Safe Conduct
- Aborted
- Navigational assistance
- Stood-by
- Escort
- Stood-by, escort

SEARCH AND PROVIDE EQUIPMENT

- Refueled
- Delivered equipment

SEARCH. PROVIDE EQUIPMENT, AND BOARD

- Dewatered
- Fought fire
- Dewatered and escort
- Refloat and escort
- Provide doctor
- Provide doctor and escort

SEARCH, EQUIP, BOARD, AND TOW

- Dewater and Tow
- Fight fire and tow
- Refloat and tow
- Equipment, pump, and tow
- Relieve and tow

SEARCH, BOARD, AND ASSIST

- Non-medical evacuation
- Medevac
- Assist personnel

SEARCH AND TOW

- Tow
- Stand-by and tow

Icebreaking services are provided for three major purposes:

- to assist in the safe and timely movement of maritime traffic;

- to prevent and control flooding resulting from ice accumulation in domestic waterways;

- to support scientific research and other national interests in the polar regions.

Because of the differences between the geographic areas in which these activities are conducted, the IO program can be best understood by considering polar and domestic operations separately.

Polar Operations - In the polar regions, icebreakers escort resupply ships into ice-laden areas, carry fuel and cargo to isolated U.S. installations, survey uncharted waters, collect meteorological and oceanographic data, and serve as platforms to carry research scientists into remote areas.

Domestic Operations - One of the most important responsibilities of the Coast Guard is to keep open to shipping domestic traffic routes and ports that are normally utilized year-round. The Ice Operations Program also attempts to extend navigation seasons in ice-laden areas when such extensions are considered in the national interest. For example, the Coast Guard has been one of the major participants in the multiagency Great Lakes season extension project. The Coast Guard also cooperates with other agencies to prevent and control flooding caused by ice jams. Performance of these duties requires icebreaking services as well as the collection and dissemination of information (mapping).

Aircraft perform surveillance patrols to evaluate ice conditions and recommend ship routes through areas having ice formulation.

Potential Airship Missions

As a result of the initial review of Coast Guard operations, one IO mission is envisioned for the airship:

- Aerial Ice Reconnaissance (AIR)

As defined by the program standards, reference [64], the IO AIR operational requirements are as follows:

BIa	- Arctic Alaskan Shipping Season (Type III facilitation)	2. Three flights/week from Bering St. to Pt. Barrow. Three flights/week along Alaskan North Slope.

BIb - Sub-Arctic Alaskan Shipping Season (Type III facilitation)	2. Average one flight/week over Bristol Bay/southern Bering sea area. Weekly flight over Cook Inlet/Prince William Sound area.
BIIa - Great Lakes Shipping Season (Type III facilitation)	3. Daily flights over critical areas. Twice weekly flights over ice areas.
BIIb - St. Lawrence Seaway Shipping season (Type III facilitation)	3. Average three flights/week over Seaway.
BIIc - Northeastern U.S. Shipping Season (Type II/I facilitation)	2. Flights over Penobscot and Kennebec Rivers as needed. Two flights/week in vicinity of Long Island.
BIId - Upper Missippi R. Shipping Season (Type II facilitation)	3. Two flights/week from St. Louis to Quad. cities, Ill. January-mid-February, from St. Louis to Burlington, Iowa mid-February to April.
BIIe - Illinois R. Shipping Season (Type II facilitation)	3. Two flights/week from Chicago to Grafton, Ill. throughout ice season.

Currently under development is the Radar Image Processor (RIP) to be used in conjunction with the Side Looking Airborne Radar (SLAR) for the purpose of mapping ice. Although it is still in the development stage, the equipment associated with RIP is expected to be too large and heavy for an MRS, and therefore, an HC-130 would be required for ice mapping using this equipment. An airship would be more than capable of handling an instrument package of this expected size and weight. A problem may exist, however, in using SLAR on-board an airship. Because of its slow speed, relative to an HC-130, the effect of drift on the airship may increase the processing requirements to obtain the same resolution using the same antenna. Countering this effect is the fact that, due to the size of the airship, the size of the SLAR antenna can be significantly increased. As antenna size increases, the resolution increases. Therefore, the two factors, slow speed and large antenna, may more than counter each other, giving the airship a greater sweep width and possibly a greater sweep rate (sweep width times speed) than an HC-130. A development effort to modify the SLAR and its processor would be required to obtain optimal performance from an airship for this mission.

The nature of IO missions allows for preplanning of the operations, as opposed to ELT, MEP, or SAR operations, where external factors determine the platform requirements. The exact configuration of the operations using airships for IO missions may be modified to take best advantage of the long endurance of an airship as well as basing and operating constraints.

Again, the ability of the airship to operate at low altitudes, as well as altitudes of up to 5,000 feet, may be useful in IO operations. This allows for close in visual observation of ice formation and also permits operation in conditions of low ceiling or visibility.

Mission Profiles

Eight profiles have been specified in Table IV-XLI for the Aerial Ice Reconnaissance (AIR) mission. Based upon the program standard the following correspondence between the profiles and the missions has been specified.

Profile Number	Mission
8.1.1	Penobscot and Kennebec Rivers Hudson River Long Island
8.1.2	St. Louis to Quad cities, Ill. St. Louis to Burlington, Iowa Chicago to Grafton, Ill.
8.1.3	Great Lakes
8.1.4	Cook Inlet/Prince William Sound
8.1.5	Bristol Bay/Bering Sea
8.1.6	St. Lawrence Seaway
8.1.7	Alaskan North Slope
8.1.8	Bering St. to Pt. Barrow, Alaska

The determination of the task specifications is based upon the size and length of the specific operational area. Consideration was taken of potential airship basing in determining the transit task requirement.

These mission profiles are based upon current operating procedures which are specified considering the capabilities of the available resources (HH-3s, HH-52s, HC-130s, and HU-16s). These missions could be reconfigured to optimize the utilization of the airship.

Summary of Airship Participation in IO Operations

The airship has great potential for Aerial Ice Reconnaissance (AIR) operations of the IO program since this platform:

- would have sufficient range to survey most areas
- will utilize Side Looking Airborne Radar (SLAR)
- should be capable of carrying the Radar Image Processor (RIP)

Mission Definition and Analysis Conclusion

The purpose of this mission analysis was to provide a structure from which to evaluate potential airship participation in Coast Guard programs. The

TABLE IV-XLI
PROFILE LIST

Mission: IO DOMESTIC ICE PATROL

Profile Designator	Transit (nmi)	Patrol (nmi)	Station Keeping/ Trail (hr)	Search (1,000 n^2mi) Visual	Instrument	Pollution	ASW	Board (hr)	Logistics (lb)	Tow (hr)	Occurrence
8.1.1	0				10						25
8.1.2	0				15						30
8.1.3	0				60						100
8.1.4	100				30						25
8.1.5	400				30						25
8.1.6	500			12							50
8.1.7	800				100						75
8.1.8	1,200				60						75

analysis is based upon current operating procedure as performed by existing assets. Only those missions in which the capabilities of airships could be utilized in a manner consistent with current operations were considered. No consideration was given to missions that required handoff of operations from one airship to another or to another platform type. Nor was consideration made of operations requiring refueling or remanning of the airship, both of which are feasible and consistent with historical airship operations. If a mission was expected to exceed the capabilities of a single airship it was not evaluated as part of this analysis.

CHAPTER V
CONCEPTUAL VEHICLE SIZING AND PERFORMANCE

In order to examine the concept of maritime patrol airships, it was essential to arrive at vehicle point designs. The sizing and conceptual design process to determine technical feasibility was required in order to develop realistic costs in the performance of maritime operations.

Based upon the mission analysis of the preceeding chapter, more detailed specifications of eight profiles (one for each program) were generated to be used as guidance in the point design analysis. These profiles were chosen to be representative of the type of mission associated with each of the programs, to be sufficiently difficult that an design airship that is capable of the mission profile is also capable of performing most of the other missions in the program, and that the profile was not too demanding such that the point design airship's capabilities would be in excess of those needed for most of the other missions.

For each of these selected profiles a script scenario was generated. These scenarios specified each of the operations in sequence, the parameters associated with the operations (speed, weight, payload, etc.) and duration of the operation. Each task from takeoff to landing was so specified. In addition, an itemized list of payload and crew size was specified. These eight script scenarios and payload requirements are given as Appendix D. In the upper left of each script scenario is a description of the type of mission. The total mission duration is given on the upper right.

The actual sizing of LTA vehicles, not unlike other air vehicles, is a complicated process. References [65] and [66] are classic airship design texts which testify to this fact. While technology has changed, certain fundamental vehicle considerations remain the same today. With modern numerical techniques LTA design can be more comprehensive and can be accomplished much faster.

For MPAS the requirements of the eight representative profiles were analyzed by the Naval Airship Program for Sizing and Performance (NAPSAP). This computer program is capable of sizing vehicles to mission requirements and then evaluating these vehicles as the mission is performed. The influence of nearly 40 key design parameters is closely monitored. This program[67], developed at the Naval Air Development Center, is described briefly in Appendix C.

Table X-I summarizes the representative profile requirements. The most demanding performance parameters for the airship are underlined in each profile. Note that altitude significantly affects airship performance. For a buoyant vehicle this is a function of air density - at lower altitudes where the air is more dense, more weight can be buoyed up[6, 7, 13]. The large surface areas characteristic of airships result in large amounts of skin friction drag. This causes airships to be very sensitive to design speed. While LTA vehicles can be propelled faster, an increasing penalty must be paid to compensate for the increasing drag[13].

TABLE V-I
MPA MISSIONS SUMMARY

TASKS	ENFORCE LAWS AND TREATIES; SEARCH AND BOARD	MARINE ENVIRONMENTAL PROTECTION: CLEAN-UP	MIL. OP./MIL. PREPAREDNESS: TOW ASW ARRAYS: ATTACK	PORT SAFETY AND SECURITY: HAZARDOUS VESSEL ESCORT	SEARCH AND RESCUE-SEARCH, BOARD, AND TOW	AIDS TO NAVIGATION-BUOY MAINTENANCE	MARINE SCIENCE ACTIVITIES; ICE PATROL (ST. JOHNS)	ICE OPERATIONS: ICE MAPPING (GREAT LAKES)
Duration (Hours)	27.5	12.5	26.5	8.35	13.6	17.0	35.5	20.5
Total Payload (lb.)	7,669	22,372	10,929	6,237	7,910	7,396	7,761	7,482
Cruise Speed (Knots)	50	50	40	40	60	50	60	60
Dash Speed (Knots)	90	—	90	—	90	—	—	—
Crew (200 lb. each)	11	6	11	6	8	8	—	—
Maximum Altitude (Feet)	5,000	5,000	5,000	5,000	5,000	1,000	5,000	5,000
Tow	—	—	Sonar	—	Ship	—	—	—

The resulting output of the NAPSAP analysis is presented in Table V-II. Note that since the missions were quite different a wide range of airship design sizes resulted. Simplifying assumptions for this analysis were to fix the vehicle fineness ratio (length over diameter) and buoyancy ratio (static lift over total lift) based on reference [27].

The eight vehicles sized range from 282,300 ft.^{3} for PSS to 992,165 ft.^{3} for MSA. This size class places the maritime airship well within the bounds of previous Navy airships[6, 7]. From this spectrum of vehicles the smallest airship capable of performing all profiles was selected as the candidate for further investigation involving sensitivity studies and costing. The vehicle selected was sized for the MEP mission. Note that actually the MSA mission resulted in the largest vehicle, but it was determined that the MEP vehicle could perform the MSA mission at a lower altitude (1,000 feet) in a satisfactory manner.

The MEP vehicle or ZP-X is compared to vehicles sized to the same profiles by two different contractors in Chapter VII.

Appendix E discusses the sensitivity of this vehicle to changes in four major design parameters: design dash speed, design altitude, structural weight, and total drag coefficient.

TABLE V-II
CONCEPTUAL VEHICLES SIZED FOR EIGHT COAST GUARD MISSIONS

MISSION	ELT	MEP	MO/MP	PSS	SAR	A/N	MSA	IO
Volume, (ft^3)	586,494	783,696	700,045	282,390	392,154	447,330	992,165	607,678
Static Lift, (lbs)	32,092	46,917	38,305	15,454	21,458	24,477	54,289	33,251
Dynamic Lift, (lbs)	5,224	7,638	6,236	2,515	3,493	3,985	8,838	5,413
Length, (ft)	277	305	294	217	242	253	330	280
Diameter, (ft)	63	69.3	67	49	55	57.5	75	64
Fineness Ratio, (ℓ/d)	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Buoyancy Ratio	.86	.86	.86	.86	.86	.86	.86	.86
Horsepower Required	1,471	1,927	1,651	942	1,142	1,236	2,076	1,506
Gross Weight, (lbs)	37,316	54,554	44,541	17,967	24,951	28,462	63,127	38,664
Empty Weight, (lbs)	20,850	27,674	24,527	10,816	14,478	16,289	33,717	21,540
Useful Load, (lbs)	16,466	26,880	20,014	7,151	10,473	12,173	29,410	17,124
Empty Weight Fraction	.559	.507	.551	.602	.580	.572	.534	.557
Fuel Weight. (lbs)	8,812	5,057	6,650	915	2,568	4,752	21,638	9,706

CHAPTER VI
ESTIMATED LIFE CYCLE COSTS AND LOGISTICS

INTRODUCTION

The estimation of the costs of building a modern airship is tentative at best. Cost data available for constructing and operating airships is based upon 30-year-old technology. The cost estimates contained in this section are based upon projections of historical data and by comparison of cost of construction and operation of modern heavier-than-air craft.

The only available data for curent operations of airships are associated with the operations of the Goodyear advertising airships. These data are probably not applicable because of the nature of the operations and the technology of the airship involved. The Goodyear airships (GZ-20) are a World War II design and do not reflect the significant advances made in materials and aeronautical technology in the last 30 years. The British AD-500, an airship which incorporated some of the technological advances such as vectored propulsion and molded composite structures, was successfully flown in February of 1979.

All of the data used in this section are based upon the extrapolation of cost data generated in other recent studies. All references are cited. Two costing approaches are used: Life Cycle Cost (LCC) and Standard Rate Costs. LCC are emphasized but standard rates are also calculated, based upon Coast Guard procedures.

Life cycle costs are herein defined as the sum of research, development, test, and evaluation (RDT&E), investment and operating costs. For the purpose of the cost benefit analysis these costs are prorated on the basis of the total number of operating hours in the lifetime of the airship. Standard rates are the sum of the actual operating and maintenance costs, actual personnel cost, overhead and administrative costs, and depreciation costs[68], calculated for each hour of use of the vehicle.

LOGISTICS

Basing and Maintenance Facilities

Based upon a preliminary estimate of the total Coast Guard mission requirements, a potential annual utilization of airships is between 100,000 to 125,000 hours per year. If we assume that each airship flies 2,400 hours per year, a requirement of from 42 to 52 airships is established. If geographic distribution of airships similar to the MRS basing is assumed, there would be nine airship bases. If each base has five airships, a total of 45 airships for operations would be required. An additional five airships would be purchased for training, research and development, and ready spares, making a total buy of 50 airships.

The locations of the nine MRS bases is given in Table VI-I. This study, being a first order study, has not evaluated the real estate requirements of the airship operations and the analysis of the availability of the real estate at the MRS bases. In that the Maritime Patrol airship is expected to be VTOL capable, the area required for their operation should be minimal, primarily consisting of a mooring circle for each airship plus facilities for Aerospace Ground Equipment (AGE) and Ground Support Equipment (GSE).

Hangar facilities will not be provided at each base. Hangars will exist at depot maintenance facilities. The procedure of mooring the airships without hangar facilities at each base is consistent with many World War II operations and the operations of the Goodyear advertising airships. The major concern of not having hangars is associated with weather phenomena. At the more northern bases, equipment for the removal of snow and ice from the airship envelope will be required. In the event of very severe storms or hurricanes, the airships should be flown from the area as are heavier-than-air craft. The airships can weather less severe storms by being flown at their mooring masts.

Routine maintenance would be provided at the mast. For major maintenance operations and overhaul, two depot maintenance facilities would be required, one on the Each Coast and one on the West Coast. The government still owns airship facilities at Moffett Field, California; Tustin, California; and Lakehurst, New Jersey. These facilities would require modernization and negotiation with the present users (U.S. Navy) to obtain access.

Availability and Utilization

Based upon current Coast Guard requirement that restricts aircrews to 800 hours flying time a year, it will be assumed that three crews are required per airship, and that an airship will be utilized for 2,400 flight hours per year. This is equivalent to 27 percent mission utilization.

Typical utilization for long range commerical aircraft are 42.5 percent, 37.9 percent, and 31.5 percent for the B-747, DC-10, and L-1011 respectively. These averages are based upon the cumulative experience of 12 U.S. airlines[42].

In addition to actual mission time, service time is required before and after each flight, as well as overhaul time and general maintenance. Table VI-II provides a breakdown of the annual utilization of the Maritime Patrol airship[41] (modified for the projected utilization of 2,400 mission hours annually). The airship is expected to be available for missions or on missions 89 percent of the time and will be unavailable due to scheduled or unscheduled maintenance 11 percent of the time.

The airship will be assumed to have a 12-year lifetime. The envelopes of the Goodyear advertising airships are replaced every eight years. The use of modern materials is expected to extend the expected life of the envelope. The car would be refurbished at the time of the envelope replacement. There is no residual value associated with the car at the end of the 12-year lifetime. With the assumption of 2,400 flight hours annually, the airship will have a total of 28,800 flight hours over its 12-year lifetime.

TABLE VI-I
MRS BASES

Astoria, Oregon

Sacramento, California

Corpus Christi, Texas

Mobile, Alabama

Miami, Florida

Elizabeth City, North Carolina

Cape Cod, Massachusetts

Traverse City, Michigan

Borinquen, Puerto Rico

TABLE VI-II
ANNUAL UTILIZATION

27.4 Percent - Mission

4.1 Percent - Services

7.0 Percent - Maintenance

61.5 Percent - Ready

Crew Requirements

Based upon the analysis of Coast Guard mission requirements, the expected endurance of a mission will vary from a few hours to over 30 hours. Table VI-III gives the size of the crew as a function of mission duration. The composition of the crew is given in Table VI-IV as a function of crew size.

To accommodate the various crew sizes, the Maritime Patrol airship is assumed to have a car of modular design. This is consistent with the Goodyear advertising airship where the passenger seats can be replaced with equipment for the advertising "night sign," or by television equipment and crew for coverage of sporting events. This is also true of modern commercial aircraft, e.g., B-747. Because of its historical habitability and ease of control, the operation of an airship is not very fatiguing and, therefore, can be handled by a relatively small crew.

Life Cycle Costs

The category breakdown of the Life Cycle Costs (LCC) for airships is given in Table VI-V. Three categories are given: contract investment cost (those costs associated with the initial procurement); non-contract investment costs (the cost of those items that must be obtained but are not included in initial procurement); and operating and support costs.

The contract investment costs have three major components: RDT&E, investment, and helium. These can, and have been, combined into one cost which will be associated with the unit acquisition cost. While the RDT&E cost could be calculated, it is easiest to specify it as a percentage of the first unit production cost. It is assumed, in this study, that RDT&E is equal to the first unit production costs. Helium costs are also included in the estimate of the unit production cost.

The non-contract investment costs are associated with capital and start-up costs not included in the procurement of the airship. This includes spare parts, initial training, operating bases, and equipment. The cost of spare parts is included in the estimate of the unit acquisition costs. The major training cost is associated with the procurement of training devices and training airships. This cost will be accounted for as a percentage of the airship acquisition cost. Facilities costs are determined separately.

Operating and support costs are associated with the daily operation of the airship. These include operating personnel costs, maintenance costs, fuel costs, and helium costs. The estimates of these costs are based upon operating experience of the Coast Guard and the Navy for small aircraft.

Unit Acquisition Costs

The evaluation of acquisition costs are based upon estimates made in recent studies. Due to the gap in the development of LTA technology, it is not possible to obtain a comprehensive analysis of these costs. The RDT&E and production costs specified in this section are based upon Cost Estimating Relationships

TABLE VI-III
CREW SIZE

MISSION DURATION	CREW SIZE
0 - 10 hours	5
10 - 20 hours	8
More than 20 hours	13

TABLE VI-IV
CREW COMPOSITION

POSITION	RANK	CREW SIZE 5	8	13
Pilot	CDR			1
Pilot	LCDR	1	1	1
Co-Pilot	LT	1	1	1
Co-Pilot	LTJG		1	1
COM/NAV	CPO	1	1	2
Radar/Sensor Operator	PO1	1	3	4
Visual Observer/Rigger	PO3	1	1	3

TABLE VI-V
LIFE CYCLE COST COMPONENTS

CONTRACT COSTS

- RDT&E
  - Airframe
  - Power Plant
  - Avionics
  - Spares
  - GSE Facilities
  - Helium
- Investment
  - Airframe
  - Power Plant
  - Avionics
- Helium

NON-CONTRACT INVESTMENT COSTS

- Spares
  - Airframe
  - Power Plant
  - Avionics
  - GSE
- GSE
- Training
- Facilities

OPERATING AND SUPPORT COSTS

- Personnel
- Training
- Facility and Organization Equipment
- Maintenance
  - Unit Level
  - Depot Level
- POL
- Helium

(CER's) developed from historical data and regression analysis of the historical trends of heavier-than-air aircraft costs. Based upon essentially the same data, using four different interpretations of the data, four estimates of the production cost of a modern non-rigid airship have been obtained. Each approach is consistent with the appropriate cited reference.

An estimation of the RDT&E costs is more difficult. The applicability of technological advances in heavier-than-air craft development of LTA vehicles would have to be evaluated. The possible incorporation of light-weight, high performance engines and composite materials, modern fabrics, etc., impact on the design of a modern LTA vehicle. The approximate cost of RDT&E associated with this technology remains to be determined. As estimated in each of the four costing approaches, it is assumed that the RDT&E costs are equivalent to the production cost of the first vehicle.

Associated with every production process is a learning curve. The unit cost decreases with increased production due to increased efficiency, improved procedures, and proration of set-up costs. A learning curve of 80 to 85 percent[7, 15] has been assumed for each of the four costing procedures.

The general procedure for obtaining the unit cost for a buy of N is

$$\text{Unit Cost} = (\text{RDT\&E})/N + (\text{First Unit Cost}) \times N^{-(\text{learning factor})}$$

where:

RDT&E	is the research, development, test, and evaluation cost, assumed to be equal to the first unit cost
N	is the number of units purchased
First Unit Cost	is the production of the first unit
Learning Factor	is an exponential factor that reflects the learning experience.

The basis, therefore, of all of the costing is an estimate of the first unit cost.

The four costing procedures used can be itemized as:

- Costing based upon speed and volume of the airship, using regression analysis of historical airships. An 80 percent learning curve is used[43].

- Costing based upon airship point design analysis as calculated on a weight basis. An 80 percent learning curve is used[44].

- Costing based upon systems weights. Learning curve a function of system[69].

- Cost estimates of Goodyear Aerospace Corporation for a Maritime Patrol airship. An 85 percent learning curve is assumed[45].

Unit Cost as a Function of Speed and Volume

Reference [43] provides the formula

$$c = .000239 s^{25.1} V^{.33}$$

where

c = first unit cost, FY-77 dollars x 10^6

s = maximum speed in kts

V = volume in cubic feet x 10^6

For the point design airship with a 90 kt capability and a 783,696 cubic feet volume, the first unit cost is $27.8 million.

This estimate of the first unit cost is considered excessive and, as will be seen, not consistent with the other three approaches. There are two major flaws with this approach. The first problem is that the regression analysis was performed using data for both rigid and non-rigid airships. The highest speed airships are generally rigid airships which have higher first unit costs in relation to their displacement volume.

The second problem is that most of these airships are of the 1920's or 1930's design and do not reflect the great technological advancements, especially in engine performance. In that time period, in order to increase the speed of the airship, a great penalty was paid in propulsion weight. To lift this weight a significant increase in displacement volume was necessary. With the light weight high performance engines available today this penalty does not have to be paid.

For an airship that has a first unit cost of $27.8 million, assuming a similar RDT&E cost and an 80 percent learning curve, the unit cost for a buy of 50 is $8.45 million. This is considered high and probably, at least, represents an upper estimate of the cost.

Unit Cost as Compared to the ZPG-X

A popular approach to analysis of the first unit production cost is based upon the empty weight of the airship. The ZPG-X was a candidate patrol platform in the Advanced Naval Vehicle Concepts Evaluation Study (ANVCE)[27]. It is a non-rigid airship of 1.5 MCF with an empty weight of 62,300 lbs. In reference [4], the acquisition cost of the ZPG-X was estimated on the basis of its empty weight as compared to the empty weight of historical airships. Sophisticated adjustments were made to account for lighter materials, increased productivity, and the escalation in cost of military aircraft.

In reference [44], a cost of $1,335/kg. ($877/lb.) was specified for the first unit of the ZPG-X. Using the empty weight of 27,674 lbs. (12,553 kg.)

assumed for the point design airship, we obtain a first unit cost of $16,750,000. Assuming RDT&E equals the first unit cost and using a learning curve of 80 percent, the average unit cost for a buy of 50 is $5.1 million.

This is probably a good estimate of the airship cost. It may still be high in that the inflation factor, used to convert the historical data associated with the cost of building airships, is based upon military aircraft trends. This inflation factor reflects increased sophistication in the products as well as escalating production costs. Although the Maritime Patrol airship may be extending the state-of-the-art in airship design, it is expected to use off-the-shelf aircraft and materials technology. Its actual inflation factor is probably more like that of commercial aircraft, which is must less severe.

Cost Based Upon System Weights with Variable Learning Curves

The third approach used in evaluating the unit cost of a buy of 50 airships is similar to the previous approach except it breaks the airship down by subsystem and varies the learning curve by subsystem. The same basic historical data with corrections for productivity, technology, and inflation are used in this approach as were used in the previous approach.

In reference [67], the first unit costs and unit cost for a buy of 5, 10, 20, 30, and 50 are specified on the basis of airframe, propulsion, and systems costs. The costs for the first unit and for 50 units for the three component systems are summarized in Table VI-IV. For the point design airship the component weights are:

Structure - 18,447 lbs.
Propulsion - 4,985 lbs.
Systems - 4,242 lbs.

This gives the first unit cost of $11,350,000. Assuming RDT&E is equal to the first unit cost and using the costs for a buy of 50 from Table VI-IV, the unit cost for a buy of 50 is $3.9 million.

This is probably a low estimate of the airship cost. The data used to generate these cost numbers and learning curves is based upon rigid airship construction costs. The learning curve for rigid airships, especially structure costs, is probably steeper than for non-rigid airships.

Cost Based Upon Goodyear Estimates

The final approach to obtaining the acquisition cost of a maritime patrol airship is based upon a first cut estimate of the cost of such an airship by Goodyear Aerospace Corporation[45]. Their estimate is for a buy of 20 assuming an 85 percent learning curve. By extending this buy to 50 a unit purchase price of $5.04 million is obtained (assuming the same 85 percent learning curve).

Assumed Unit Acquisiton Cost

The different approaches to the acquisition costing have produced four different estimates which are summarized in Table VI-VII. The range of costs is

TABLE VI-VI
COMPONENT SYSTEMS COSTS

SYSTEM	1st UNIT COST ($/lb)	UNIT COST FOR 50 ($/lb)
Structure	412	112
Propulsion	336	143
Systems	490	209

TABLE VI-VII
ACQUISITION COST SUMMARY

APPROACH	FIRST UNIT COST $ MILLION	RDT&E $ MILLION	UNIT COST FOR A BUY OF 50 $ MILLION
Speed/Volume Regression	27.8	27.8	8.45
Empty Weight	16.75	16.75	5.1
Component Weight	11.35	11.35	3.9
Goodyear Estimate	---	---	5.04

from $3.9 to $8.45 million. The first three estimates are in 1977 dollars and the last is 1979 dollars. It will be assumed in the remainder of this life cycle cost analysis that the unit cost of 50 airships is $5.0 million.

Four different costing procedures have been used, but they basically reflect different interpretations of the same data. These estimates are made on the basis of cost analysis of data associated with 30 to 40 year old technology. An attempt has been made to compensate for technology improvement, increased productivity, and inflation.

The inflation factor applied to these historical costs is based upon military aircraft experience. While some of the factors reflect general increased in the cost of living and the cost of improvement in technology, much of this factor reflects increases in performance and sophistication of military aircraft. The historical inflation factor for commercial aircraft is not as great as that for military aircraft.

Another assumption that impacts on the acquisition cost estimate is that the RDT&E cost is equivalent to the first unit production cost. This is low by historical standards. However, the basic design of the Maritime Patrol airship is not radically different from traditional non-rigid airships. The major requirement is the transfer of current aerospace technology to the design and production of a modern airship.

The estimate for the Maritime Patrol airship is a first estimate, and an effort was made to utilize previous cost analyses and to be as consistent with the approaches (as detailed in the references) as possible. A 10 percent or even 20 percent error in the acquisition cost should not significantly impact on the cost analysis of the mission profiles presented later in this report.

Facilities Cost

In addition to the airship acquisition cost, the cost of building bases and modifying existing facilities is included in the investment cost.

Table VI-VIII provides an estimate of the cost of building facilities for airships at existing Coast Guard bases. The basing cost ($3,442,000) prorated over five airships per base, adds an investment cost of $688,400 per airship. Assuming that the airships will be based at existing Coast Guard facilities, the cost of real estate has not been included. Hangar costs also have not been included. It is assumed that at the bases, airships will be moored at the mast. Hangars will only be considered at maintenance depots as previously indicated.

In addition to basing, maintenance facilities would be required. Two maintenance depots (one on the East coast and one on the West coast) could be set up at existing airship facilities. However, all of these have been adapted for other purposes and would require improvement. Table VI-VIX gives an estimate of the cost of modernizing Moffett Field and Lakehurst[15].

TABLE VI-VIII
GSE/AGE PER BASE
FIVE AIRSHIPS/BASE

EQUIPMENT	UNIT COST	TOTAL COST
Helium Trailer	1 @ $107,000	$ 107,000
Fuel Truck	2 @ $ 51,000	$ 102,000
Ballast (Water Storage)	2 @ $ 45,000	$ 90,000
Stick Mast	5 @ $190,000	$ 950,000
Mooring Circle	5 @ $343,000	$1,715,000
Personnel Carrier	1 @ $ 29,000	$ 29,000
Helium Storage	$402,000	$ 402,000
P.O.L.	$ 40,000	$ 40,000
		$3,442,000

TABLE VI-VIX
COST OF MODERNIZATION OF DEPOT FACILITIES
(1977 Dollars)

LOCATION	MOFFETT FIELD	LAKEHURST
Hangar	$ 432,000	$3,000,000
Mooring Circle	2,725,000	2,725,000
Perm. Mast	670,000	670,000
Helium Facility	402,000	268,000
Addn. Helium Storage	402,000	402,000
P.O.L.	40,000	40,000
TOTAL	$4,721,000	$7,105,000

The total cost ($11,960,000) of improving these two facilities must be prorated over the total buy of 50 airships. Therefore, the investment cost per airship associated with the modernizing the maintenance facilities is $239,200.

Initial Training Costs

The training category included under non-contract investment costs is primarily associated with the construction of facilities and equipment for training personnel in the operations and maintenance of airships as well as the cost of instruction. An example flight training curriculum is given in Table VI-X. In establishing the number of airships required for Coast Guard operations, five airships were provided for research and development and training. In addition to trainer airships, equipment costs for training may include flight simulators and other training devices. Assuming that the five extra airships are not exclusively used for training, and the additional training devices must be purchased, a cost increment of 10 percent of the unit acquisition will be assumed for investment training costs.

Total Investment Cost

All of the components of the investment costs have been specified. The unit acquisition cost including RDT&E, helium, and spares is $5 million. Facilities cost for both bases and maintenance facilities including GSE is about $900,000 prorated for each airship. The initial training cost is $500,000. Therefore, the total investment cost is approximately $6.4 million per unit.

Operating Costs

In this analysis we will concern ourselves with the personnel, maintenance, and consumable costs. Facility and organization equipment maintenance costs have not been included in this analysis becaused they are comparable to the costs of other air platform costs. All other cost estimates are based on Coast Guard or Navy experience in operating aircraft.

Personnel Costs

The single largest cost of operating an airship is the cost of personnel. The crew size is a function of the expected duration of a mission and has been specified in Table VI-IV. The annual cost for each member of the crew based on rank is given in Table VI-XI. These adjusted costs for the pay and allowance budget are based on reference [70].

Based upon current Coast Guard restrictions of 800 hours on flight hours, for 2,400 hours of operation, three flight crews would be required per airship. Because of the relative habitability and ease of operation of airships this 800 hour restriction could be modified or eliminated. Table VI-XII gives the hourly crew cost for the three crew sizes assuming an 800 hours/year restriction, a 1,000 hours/year restriction, and the actual hourly rate assuming 2,920 working hours a year. The latter costs are equivalent to the method used in determining the Standard Rate of Operation for a Coast Guard vehicle. Additional discussion of the Standard Rate is included in a later section.

TABLE VI-X
EXAMPLE FLIGHT TRAINING CURRICULUM

LTA Familiarization

Primary Airship Ground School Course

Advanced Airship Ground School Course

Airship Flight Training

TABLE VI-XI
CREW COST ($80)

POSITION	RANK	COST
Commander	CDR	$62,000
Pilot	LCDR	57,400
Co-Pilot	LT	49,400
Com/Nav.	PO1	29,700
Radar Op.	PO1	29,700
Sensor Op.	PO1	29,700
Vis. Observer/Rigger	PO3	22,100

TABLE VI-XII
PRORATED CREW COST

ENDURANCE (HR)	CREW SIZE	TOTAL COST ($)	HOURLY COST ($) 800 HR/YR	1,000 HR/YR	2,920 HR/YR (STANDARD RATE)
≤10	5	188,300	235.38	188.30	64.49
10< ≤20	8	288,700	360.88	288.70	98.87
>20	13	454,300	567.88	454.30	155.58

From Table VI-XII it is seen that there is a large variation in the crew cost as a function of assumed flight hours. The costs based on the Standard Rate and the costs assuming an 800 hour restriction differ by a factor greater than three. It should also be noted that a high penalty is paid, because of the flight restriction, on long endurance missions. Although the members of the crew are actually on duty less than half of the time for missions of greater than 20 hours, the total mission time is accredited against the flying time allowance. For long endurance missions crew operation requirements are more like ship operations than aircraft operations.

Replacement Training

Under operating costs is the cost of training any replacement of the flight crew or maintenance crew. We have assumed that there is a complete changeover of personnel on an average of every eight years. Based upon an initial training cost of $500,000 and this estimate of turnover, the average replacement training cost per airship is $62,500 or $26.04 per flight hour.

Maintenance Costs

For this analysis, maintenance is divided into two categories: direct maintenance and overhaul. Direct maintenance will be handled at the airship bases. Overhaul will be handled at an overhaul facility, i.e., Lakehurst or Moffett Field.

The maintenance of an airship is an area in which improvement in technology will have significant impact. With the increase in reliability of the systems and the advent of sophisticated electronic test equipment, there can be little comparison between the historical airship maintenance requirements and the maintenance of a modern airship. Estimates of maintenance requirements, therefore, will be based on projections derived from current aircraft experience.

Direct Maintenance

The direct maintenance cost estimate is based upon the analysis of three platforms:

- The projection for a new Coast Guard Short Range Rescue (SRR) helicopter[71]

- Analysis of the ZPG-X for the Advanced Naval Vehicles Concepts Evaluation Study (ANVCE)[42]

- Experience for the P-3C naval patrol aircraft[15]

The new SRR (a small helicopter designed to replace the HH-52A) is projected to require four maintenance manhours per flight hour (MMH/FH). A helicopter provides a more rugged operating environment with greater stress on its components.

Table VI-XIII is a summary of the projected maintenance requirements for the ZPG-X which at 1.5 million ft^3 displacement is twice the displacement of the

TABLE VI-XIII
DIRECT MAINTENANCE SUPPORT REQUIREMENT,
MAN-HOURS/AIRCRAFT-MONTH
1,000 HOUR UTILIZATION
(REFERENCE [42])

1990 IOC - PEACETIME

SHOP	SM[1]	UM[2]	SS[3]	US[4]	(O)	(I)	TOTAL
POWER PLANT	4.3	48.0	9.8	31.2	93.4	29.2	122.3
STRUCTURES	1.8	19.9	4.1	13.0	38.7	12.1	50.9
HYD/PNE	0.1	1.0	0.2	0.6	1.9	0.6	2.6
ELECT/INST	1.4	16.8	3.2	10.3	30.7	9.6	40.2
COM/NAV	2.3	25.2	6.1	16.4	49.0	16.3	64.3
AVIATOR EQ.	1.2	13.1	2.7	8.5	25.6	8.0	33.6
TOTAL	11.1	123.0	25.1	80.0	239.1	74.8	313.9

[1] Scheduled Maintenance
[2] Unscheduled Maintenance
[3] Scheduled Support
[4] Unscheduled Support

point design maritime patrol airship[42]. In Table VI-XIII, (0) and (I) stand for differing levels of maintenance. Level (0) maintenance is performed on-board the airship. Level (I) maintenance refers to repairs requiring removal of components from the airship at the airship base. Based upon this analysis it is estimated that 3.77 maintenance man-hours are required for each flight hour (83 flight hours per month).

The P-3C is a naval patrol aircraft used for long duration anti-submarine warfare (ASW) operations. The maintenance man-hour requirement for the P-3C is included in Table VI-XIV. Excluding avionics, the P-3C requires 3.94 maintenance man-hours per flight hour. The maintenance requirements for the P-3C avionics is very high. Most of this is associated with the sophisticated ASW equipment.

Based upon a comparison of these figures, it is estimated that the maintenance requirement for the maritime patrol airship is 4.0 MMH/FH.

Included in the maintenance requirement is the need for ground handling of the airship during takeoff and landing. In that the Maritime Patrol airship is assumed to have a hover capability, the ground handling requirements should be significantly less than the historical requirements. It should be possible to handle the airship with three or four men, however, it is assumed there is a ground crew of eight. It is also assumed that the airship will make approximately 100 takeoffs and landings per year and that it takes one-half hour for each landing or takeoff. Therefore, 800 man-hours are spent for ground crew operations per airship per year. Based upon 2,400 flight hours per airship per year, this comes to .33 ground crew man-hours per flight hour.

The ground crew is part of the maintenance crew. The exact positions and rank for the maintenance has not been identified. To be conservative in costing the maintenance personnel, twice the average enlisted salary was used, $23,200/year. Assuming an average manpower utilization of 2,000 hours, the cost of direct maintenance per flight hour is $46.40.

Some of the routine maintenance could be handled by the flight crew, both during flight operation and on the ground. In that there currently is an annual limit of 800 flight hours per crew member, a majority of the time the crew is available for other duties. It will be assumed that 50 percent of the maintenance can be handled by the flight crew. Therefore, the additional life cycle cost for direct maintenance will be assumed to be $23.20 per flight hour.

Overhaul

Overhaul will be performed at designated facilities such as Lakehurst, Moffett Field or equivalent facilities. These facilities will have hangars in which the overhaul operations will be performed. The cost of upgrading these facilities has been accounted for in the investment cost.

The estimate of overhaul costs is based upon analysis of helicopter repair and projections of the SRR costs. Based upon analysis of the Coast Guard

TABLE VI-XIV
DIRECT MAINTENANCE REQUIREMENTS

BASIS	ESTIMATE
SRR	4 MMH/FH
APJ Estimate[41]	3.69 MMH/FH
P-3	
Airframe	3.20 MMH/FH
Power Plant	.74 MMH/FH
Avionics	7.13 MMH/FH
Maritime Patrol Airship	4 MMH/FH

Maintenance Management Listing, for both the HH-3F and the HH-52A, 12 percent of the maintenance time is spent on repair of the rotor head and associated equipment.

It has been projected that the SRR will cost $117.64 per flight hour for maintenance. Assuming that 12 percent of this cost is associated with the rotor, the overhaul cost of the SRR minus the rotor is $104.78/FH. The expected lifetime utilization of the SRR is 10,500 flight hours. Over its lifetime an equivalent of 74 percent of the SRR's initial cost is expended on overhaul. When RDT&E costs are included in the initial cost, the equivalent cost of overhaul, excluding rotor, is 61 percent.

It has been assumed that the maritime patrol airship will have a life-time utilization of greater than 2.5 times that of the SRR. The SRR is a much more severe operating environment, with greater vibration and a higher speed of operation. Therefore, the overhaul costs will be prorated as a function of the initial cost plus RDT&E by a factor of two instead of the actual ratio of lifetime utilization hours. From the above, the overhaul costs for the maritime patrol airship are assumed to be 122 percent of the initial cost, including RDT&E of the airship or $6.1 million over its lifetime. This is equivalent to $211.81 per flight hour. This is more than double the overhaul cost for the SRR, excluding rotor maintenance, on a flight hour basis and probably is overly conservative.

Consumables

There are two major classes of consumables required for airships: POL (petroleum, oil, and lubricants) and helium. POL consumption is a function of the mission.

The 1979 Coast Guard prices for JP4 and JP5 were 55¢/gal. and 63¢/gal. respectively. Assuming the airship uses JP4 (6.91 lbs./gal.) the cost of fuel is 8.4¢ per pound. This cost is expected to escalate significantly with the price of all petrolium products. For the point design airship, based upon current prices, POL will run between $15 and $75 per flight hour depending on speed and heaviness.

Among all aircraft, the requirement to account for replacement of the lifting gas is unique to airships. Due to the slight permeability of the envelope, there is some loss of helium and some contamination of the helium by air. There is also some loss of helium due to valving of the airship under extreme conditions. It will be assumed that one replacement volume of helium is required every two years. The cost of helium is extremely low due to lack of demand. Its cost is $40 per 1,000 ft^3. Most of this cost is due to transportation costs. This is equivalent to a cost of $6.53 per flight hour. This cost will probably change with the construction of large numbers of airships. The demand will increase (including a variety of industrial applications) but the transportation charges may decrease due to the steadier demand. This is also an area in which modern technology may impact. Modern fabrics should have lower permeability than the past fabrics[22], decreasing the need for replenishment of the helium.

Total Life Cycle Costs

The assumptions made and the value of each of the components of the life cycle costs have been specified. Table VI-XV gives the breakdown of these costs. Based upon these costs, the life cycle cost prorated on a flight hour basis runs from $750/FH to $1,150/FH. The difference in the rate depends on the type of mission in which the airship is employed. For long endurance missions, costs increase because of high crew costs. High speed operations or missions requiring lift of heavy payload consume fuel at a higher rate and are, therefore, more expensive.

As previously stated, the single largest contribution to the life cycle costs is personnel. Because of the flight hour restriction, there is a low man power utilization. Because of the habitability of the airship, a low fatigue factor is expected and, therefore, this restriction could be relaxed.

Based upon these cost factors, it is possible to determine the life cycle cost of performing each mission.

Standard Rate

An alternative approach to calculating the cost of performing a Coast Guard mission is through the use of the Standard Rate calculation. In this approach the costs are calculated on an hourly basis for the time personnel or an asset is utilized.

The method of calculating the Standard Rate is given in reference [68] and summarized here:

Hourly Personnel Costs - take base pay, subsistance, BAQ, enlisted clothing maintenance, and government contribution to Social Security (twice actual salary) and divide by 2,920 hours for hourly rate

Fuel - hourly rate for fuel consumed

Other - all actual operating and maintenance costs

Depreciation - the actual acquisition cost divided by the number of years of its expected life-time multiplied by 8,760, the number of hours per year.

In determining the standard rate, the sum of personnel, fuel and other costs are added and multiplied by 1.25 to account for overhead and administrative expenses.

Using this approach, the following costs are obtained for the standard rate of the airship:

TABLE VI-XV
SUMMARY OF LIFE CYCLE COSTS

CONTRACT INVESTMENT COSTS		
Unit Acquisition Cost (Including RDT&E)	$5,000,000	
NON-CONTRACT INVESTMENT COSTS		
Unit Basing Cost	$ 688,400	
Unit Depot Facility Cost	$ 239,200	
Initial Training Cost	$ 500,000	
TOTAL INVESTMENT COSTS	$6,427,600	
Prorated over 28,800 hr/lifetime		$233.18/FH
OPERATION AND SUPPORT COSTS		
Personnel (Assuming 800 hr/yr limitation)		
Crew Size		
5		$235.38/FH
8		$360.88/FH
13		$567.88/FH
Replacement Training		$ 26.04/FH
Direct Maintenance		$ 23.20/FH
Overhaul Maintenance		$211.81/FH
POL		$5 - $75/FH
Helium		$ 6.53/FH

1.	Personnel	$ 64.49 - $155.58		
2.	Fuel/Helium	$ 10.00 - $ 85.00		
3.	Other	$244.14		
4.	1.25 x (1,2,3)		$399.09 - $610.01	
5.	Depreciation		$ 47.56	
6.	Total			$446.01 - $654.28

These can be compared to the rates for Coast Guard cutters, aircraft, and selected boats as given in Table VI-XVI. For missions for less than ten hours at low speeds, the Maritime Patrol airship is cheaper to operate than any aircraft and all cutters except the WMEC 143. For long endurance missions (greater than 20 hours) the standard rate for the airship is comparable to the rate of the HU-16E and less than the HC-130s or the high endurance cutters.

TABLE VI-XVI
STANDARD RATES

PLATFORM	1 PERSONNEL ($/HR)	2 FUEL ($/HR)	3 OTHER ($/HR)	1.25X(1,2,3) ($/HR)	DEPRECIATION ($/HR)	TOTAL ($/HR)
WHEC 378	580.99	91.	173.	1,056.24	53	1,109.24
WHEC 327	533.51	84.	146.	954.39	10	964.39
WMEC 230	305.39	24.	119.	560.49	12	572.49
WMEC 213	270.64	32.	143.	557.05	10	567.05
WMEC 210	236.44	27.	80.	429.30	18	448.30
WMEC 205	270.64	27.	187.	605.80	19	624.80
WMEC 143	171.17	15.	62.	310.21	5	315.21
WPB-95	51.47	13.	84.	185.59	2	187.59
WPB-82	21.36	9.	48.	105.45	2	107.45
HC-130C	130.52	287.21	664.	1,352.16	13	1,365.16
HC-130H	130.52	287.21	314.	880.91	13	893.91
HU-16E	67.82	43.70	378.	611.90	3	614.90
HH-3F	81.31	65.65	574.	901.20	9	910.20
HH-52A	49.60	23.13	286.	448.41	3	451.41

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CHAPTER VII
VEHICLE CASE STUDIES

In addition to an in-house design approach MPAS was conceived to include built-in second and third opinions as to conceptual vehicle designs to perform the missions specified in Chapter IV. These industry opinions could then be over-laid on the in-house design to examine areas of agreement and disagreement. The reader will note that despite some differences in vehicle configurations, essential features such as volumetric dimensions, empty weight, and performance were found to be quite similar.

CASE STUDY NO. 1: GOODYEAR ZP3G[46]

(Goodyear Aerospace Corporation, Akron, Ohio)

The conceptual design of the ZP3G is shown in Figure VII-1. It is an 875,000 cubic foot, hover-capable airship of the non-rigid structural variety. Its overall length is 324 feet and the maximum diameter of the envelope is approximately 73 feet. In this configuration the propulsion units are shown in the cruise or conventional take-off position. The forward propellers, tilt, plus or minus 90° and the stern propulsion system tilts, plus 90° for VTOL operation. The vehicle gross weight is 60,664 pounds with an empty weight of 33,740 pounds. The envelope is fabricated of modern Dacron and the conceptual design uses four ballonets.

Bow stiffening and the X-type tail for the ZP3G concept are of conventional design. The "X" type empennage provides the necessary ground clearance for short running take-offs in overloaded conditions. A base structure for the fin suspension cables is an added feature since it eliminates the fin catenary and reduces the number of brace cables. The car is supported at the floor level by the internal and external catenaries. A separate catenary system for the forward propulsion system divorces the power plant from the car to reduce the noise and vibration level for the crew. Location of the forward propellers in this position is also necessary to balance the thrust forces during the hover mode of operation. The stern propulsion system is mounted on an inverter "Vee" tail which tilts with the propeller. The "Vee" tail greatly improves control effectiveness in both hover and low speed cruise via ruddevator deflection in the propeller slip stream.

The forward propulsion system employs cross-shafting to maintain efficient fuel consumption in the intermediate speed ranges and provide a one-engine-out capability. Engines are horizontally mounted externally on pylons. The propeller gear box and the rotating thrust axis mechanisms are located outboard of the engines. Characteristics and improved control capabilities of this arrangement are discussed in reference [23].

Principle characteristics of the ZP3G conceptual design are listed in Table VII-I. The envelope volume of 875,000 cubic feet is the design volume. With Dacron fabric the increase in volume due to stretch is assumed to be 2 percent.

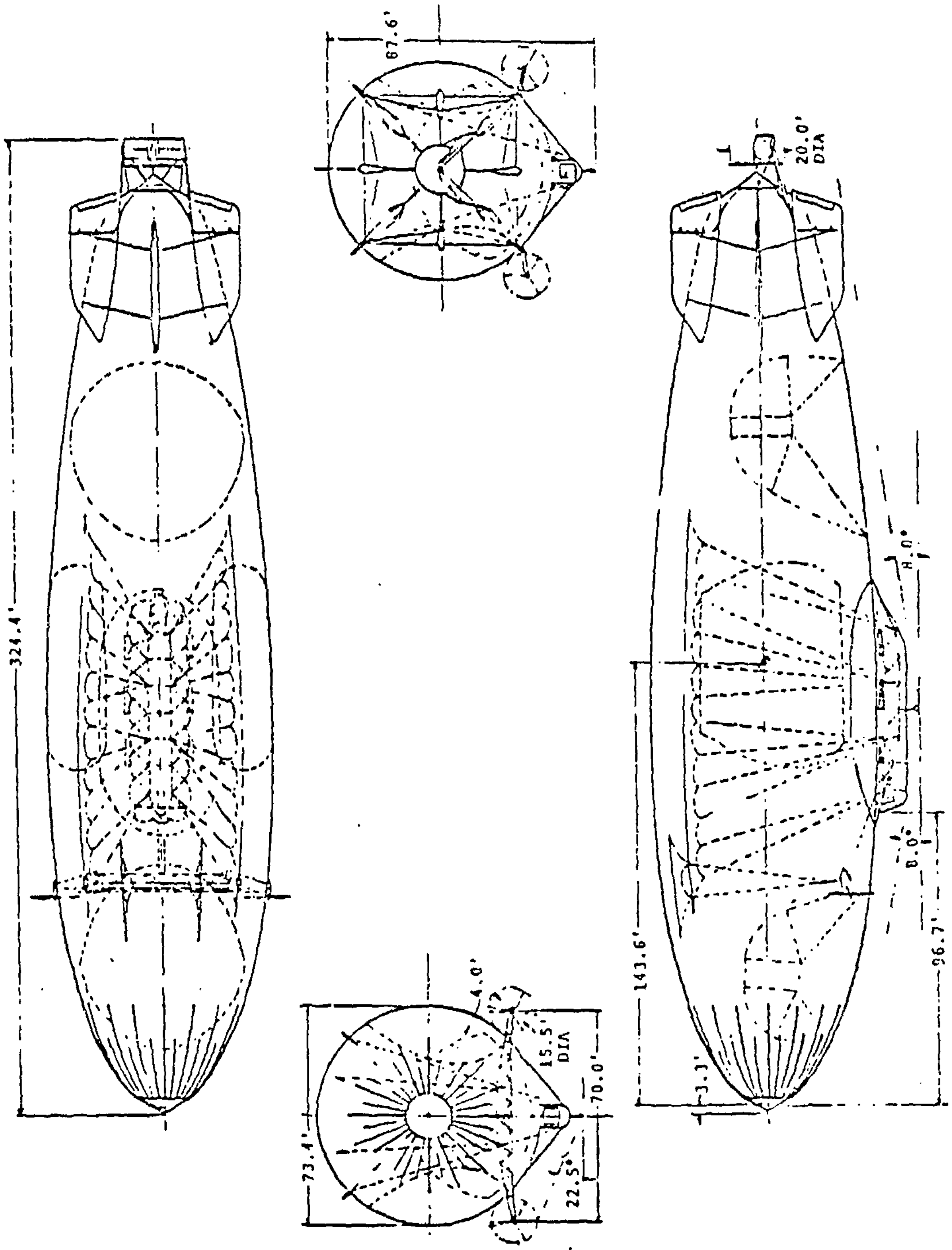

Figure VII-1. Goodyear ZP3G Airship.

TABLE VII-I
MAJOR CHARACTERISTICS

Envelope Volume	875,000 Cu Ft
Ballonet Volume	216,250 Cu Ft
Fineness Ratio	4.40
Beta Factor	.86
Static Lift @ 2,000 Ft Altitude	52,164 Lb
Dynamic Lift	8,500 Lb
Maximum Gross Weight	60,664 Lb
Weight Empty including Fixed Mission Payload	38,160 Lb
Useful Load	22,504 Lb
Power Plant	
(3) Allison GMA-500	800 Shp Ea.

A ballonet volume of 216,250 cubic feet permits the airship to fly missions at 5,000 feet altitude. Under standard atmospheric conditions it limits the ballonet ceiling to 9,700 feet.

The gross weight of 60,664 lb. could be increased 3,200 lb. when a vectored thrust STOL operation is desired. This, in turn, would increase the useful payload to 25,704 lb.

The performance summary is listed in Table VII-II. Maximum speeds are taken at sea level using the take-off thrust of all engines. Range is listed at 40 and 50 knots minimum speed. Although the 40 knot velocity obtains an additional 100 nautical miles; the 50 knot reduces flight time by 25 percent.

For conventional take-off the vehicle attitude assumes a maximum pitch angle of 6° to assure a margin of safety for tail clearance. The performance for acceleration and deceleration uses maximum power at sea level. To accelerate from zero velocity the airship is considered to be neutrally buoyant. For the time to decelerate, from the 97 knot maximum speed, a six second transition phase is assumed to change the propeller from zero to full reverse thrust. In the table, range and endurance assumes that the vehicle is operating at the 2,000 ft. altitude with a useful payload of 6,370 lbs. Lift-off is STOL with vectored thrust and the performance is based on 90 percent of the maximum fuel load of 23,750 lbs. Figure VII-2 presents a possible configuration of the ZP3G car. The basic car is over 70 ft. long and 7.5 ft. wide. It provides for maximum crew facilities, the large radar, and a winch for towing or hoisting. This particular configuration shows provisions for carrying an inflatable 15 ft. boat with a 70 horsepower outboard motor. The boat is raised and lowered with two hydraulic utility winches with access to the boat made through trap doors in the car floor.

Table VII-III presents a summary weight break-down for the ZP3G[43]. A matrix showing performance adequate for all design missions is presented as Table VII-IV. From the wide variation in take-off conditions such as heaviness for the different missions, it is evident how much an optimized design is influenced by its design mission.

The ZP3G, is a near-term low-risk conceptual design. The envelope is of modern Dacron fabric; most of the rigid structure is state-of-the-art aluminum of steel alloys, and the engines for the propulsion system start PFRT (preliminary flight rating tests) in October 1979. The design provides improvements in slow speed control and incorporates a vertical take-off and landing capability. At sea level, in the neutrally buoyant condition, the top speed is 97 knots. The maximum ferry range is 3,407 nautical miles with a 4,420 lb. fixed onboard payload, a crew of six, and provisions for five days. Lift-off weight of the vehicle less fuel is 40,110 lb. Maximum endurance with the same payload, at a 25-knot minimum speed is 101 hours. The low-speed control of the ZP3G provides the capability to tow an acoustic array for passive ASW screening operations. It also permits towing a disabled ship with up to 400-ton displacement at 6 knots. This displacement would approximate a ship 120 ft. long with a 26 ft. beam.

TABLE VII-II
ZP3G PERFORMANCE SUMMARY

MAXIMUM SPEED (8,500 LB HEAVY)	94 KNOTS
MAXIMUM SPED (8,500 LB HEAVY, REAR ENGINE ONLY) (MAXIMUM CONTINUOUS POWER)	52 KNOTS
MAXIMUM SPEED (NEUTRALLY BUOYANT)	97 KNOTS
RANGE @ 40 KNOTS $\geq$	3,407 N.M.
RANGE @ 50 KNOTS $\geq$	3,290 N.M.
BEST CLIMB VELOCITY	71 KNOTS
RATE OF CLIMB AT MAXIMUM POWER	3,375 FT/MIN.
RATE OF CLIMB LIMITED BY AIR SYSTEM	2,400 FT/MIN.
CONVENTIONAL TAKE-OFF DISTANCE (8,500 LB HEAVY)	1,025 FT.
VELOCITY @ LIFT-OFF	50 KN
DISTANCE TO CLEAR 50 FT. OBJECT	2,400 FT.
VELOCITY @ CLEARANCE HEIGHT	65 KN
TIME TO ACCELERATE TO 40 KNOTS (NEUTRALLY BUOYANT)	15 SEC.
TIME TO ACCELERATE TO 92 KNOTS (95 PERCENT MAXIMUM SPEED, NEUTRALLY BUOYANT)	64 SEC.
TIME TO DECELERATE FROM 97 KNOTS TO 0 (NEUTRALLY BUOYANT)	55 SEC.
ALTITUDE LIMIT	5,000 FT.
BALLONET CEILING	9,700 FT.
ENDURANCE $\geq$ 25 KNOTS	101 HRS.

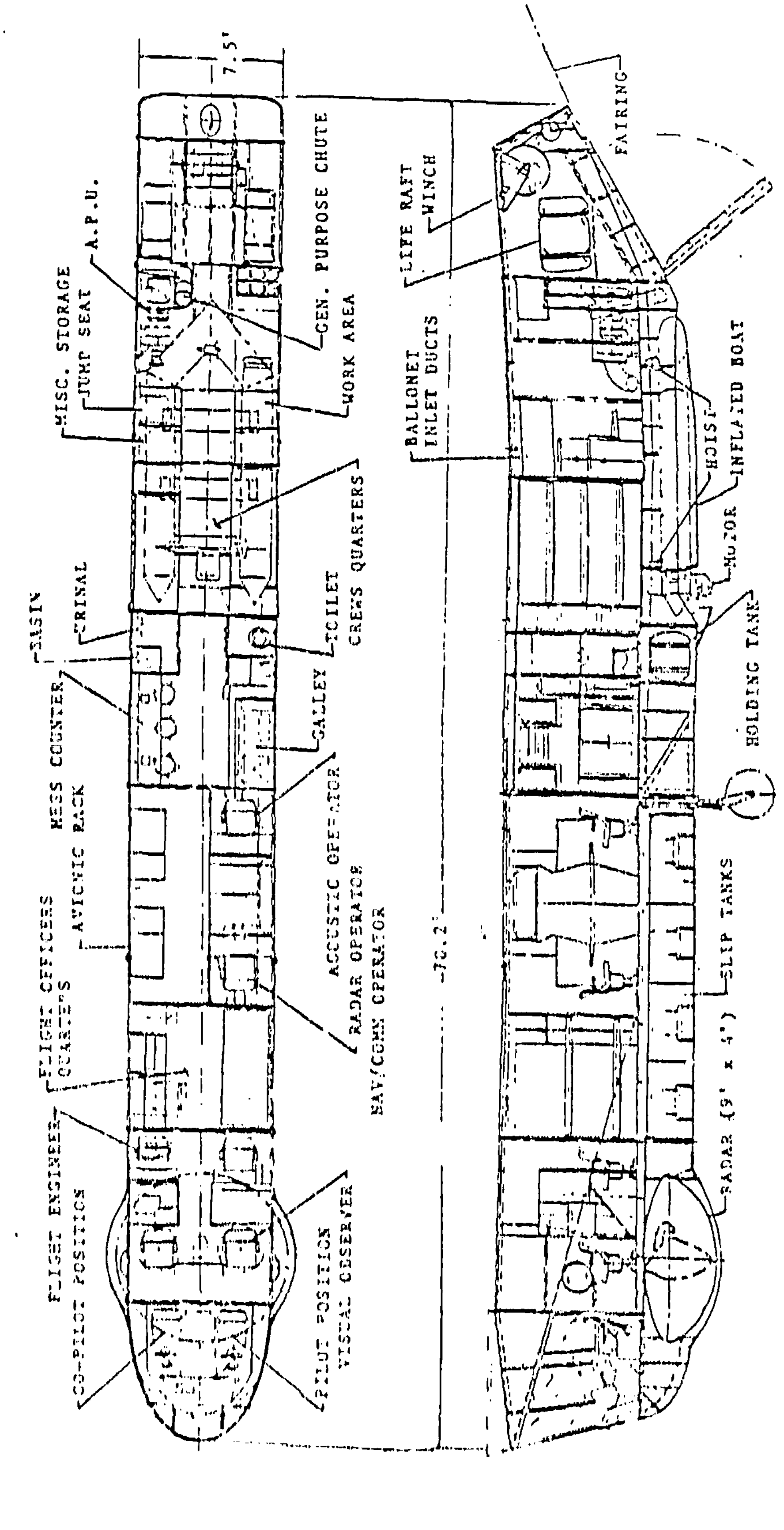

Figure VII-2. Goodyear ZP3G Inboard Profile.

TABLE VI-III
ZP3G WEIGHT BREAKDOWN

	LBS
Envelope	11,605
Empennage	3,030
Car	4,293
Landing Gear	818
Pressure System	1,188
Surface Controls	1,062
Ballast System	510
Outrigger and Carry Through	2,711
Fwd Propulsion	1,726
Aft Propulsion	2,146
Fuel System	1,586
Furnishings and Equipment	3,065
Fixed Payload	4,420
TOTAL	38,160

*See Appendix A for more detailed weight breakdown.

TABLE VII-IV
CONCEPTUAL VEHICLE CHARACTERISTICS FOR VARIOUS MISSION PROGRAMS

MISSION	TOTAL MISSION PAYLOAD	MAX WT LESS BALLAST [LB]	FUEL USED + RESERVE [LB]	TAKE OFF HEAVINESS (LB)	MAX BALLAST [LB]	MAX VELOCITY [KTS]	MAX ALTITUDE [FT]	MISSION ENDURANCE [HR]	MAX ENDURANCE @ MAX T.O.G.W
ELT	7758	53759	12261	8500	5837	90	5000	27.5	32.5
MEP	22461	60664	4427	8500	12609	50	2000*	12.5	12.5
MOF	10540	55111	10431	8500	3054	90	5000	27.5	30.4
PSS	6237	42046	2068	3000	8636	40	5000	8.4	53.4
SAR	6999	49373	8634	8500	6809	90	5000	13.6	26.6
A/W	7453	47823	3575	7000	6859	50	1000	17.0	34.[illegible]
MSA	7850	58915 59379	17325 17789	8500 11700	8293 5500	60	2000 5000	35.5	39.5
IO	7509	51357	10108	8500	6825	60	5000	20.5	30.5

*Valve helium (73000 Ft^3) for 5000 ft

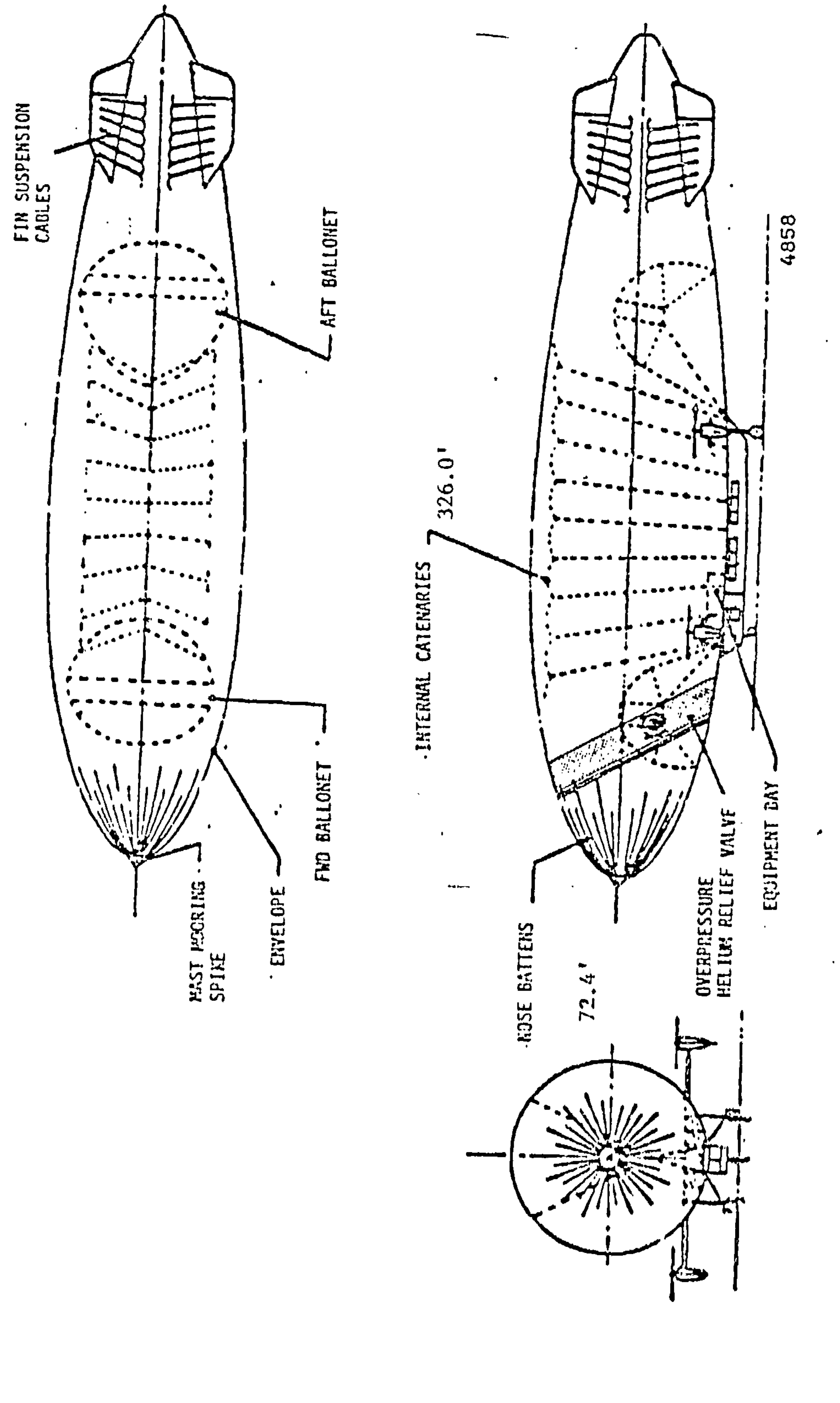

Figure VII-3. Bell Aerospace Textron Maritime Patrol Airship.

CASE STUDY NO. 2: BELL MPA[47]

(Bell Aerospace Textron, New Orleans, Louisiana)

A basic configuration (Figure VII-3) was assumed having the general features detailed in the following paragraphs. The gross weight is 65,274 pounds and empty weight is 33,019 pounds. The envelope volume is 858,437 cubic feet. The airship was assumed to be a non-rigid pressure airship with conventional ballonets fore and aft, internal suspension system, nose stiffening, and an empennage (and X-tail is shown in Figure VII-3). A prime envelope fabric candidate is the standard Dacron-neoprene, aluminized on the outside. Other envelope candidates would include laminated mylar fabric/aluminum foil composites, as well as Kevlar-reinforced materials.

The four turboprop propulsion units are less conventional. They incorporate reversible thrust, and both the turbine engines and propellers are tilted from vertical to horizontal for forward flight, and vertical for hovering, taxiing, or VTOL. Lateral thrust components for precision hover in crosswings is obtained by vectoring the propeller thrust from the hub, or by cyclic pitch. To permit the tilting of the engines and propellers, they are mounted outboard on out-riggers. These propulsion units would be similar to those used on the XV-15 (Bell Model 301) aircraft. To provide the desired pitch and yaw control, the rotors must be located an appreciable distance apart. A rigid structure is provided between the propulsion units.

A tricycle landing gear is employed, consisting of a single wheel under the forward end of the car and two others at the aft end, and is retractable. Each wheel is castered. Using downward and horizontal thrust components, the airship can be held stable on the ground and taxied to a mooring mast or even into a hangar in moderate crosswinds.

An advanced automatic mooring system is proposed for the airship. Although batten stiffening will be used on the airship nose, the conical mooring mast that will be used appears to be the soft-nose mooring mast which has been developed for tethered balloons. As shown in Figure VII-4, the patrol airship, with its high degree of hover and taxi precision, is nosed into the cone of the mooring mast, which guides the nose to the center so that the nose cone spike of the airship mates and locks into a female fitting at the apex of the cone.

The cone with the airship is then free to turn 360 degrees of azimuth. An aft tie-down line for the airship would use a hook running on a circular track. This tie-down hook would attach to the aft landing gear to prevent kiting (see Figure VII-5).

The Bell MPA design includes a flotation system to permit water landing at sea (Figure VII-6). Inflatable, retractable, vertical floats are also considered because of their inherent stability as flotation devices. For added flotation stability sea anchors may be deployed and retracted automatically as part of the vertical float deployment and retraction. The floats are attached to both the main and nose gears. Sea anchors are extended from nose and tail locations to develop pitching stability in rough-water conditions.

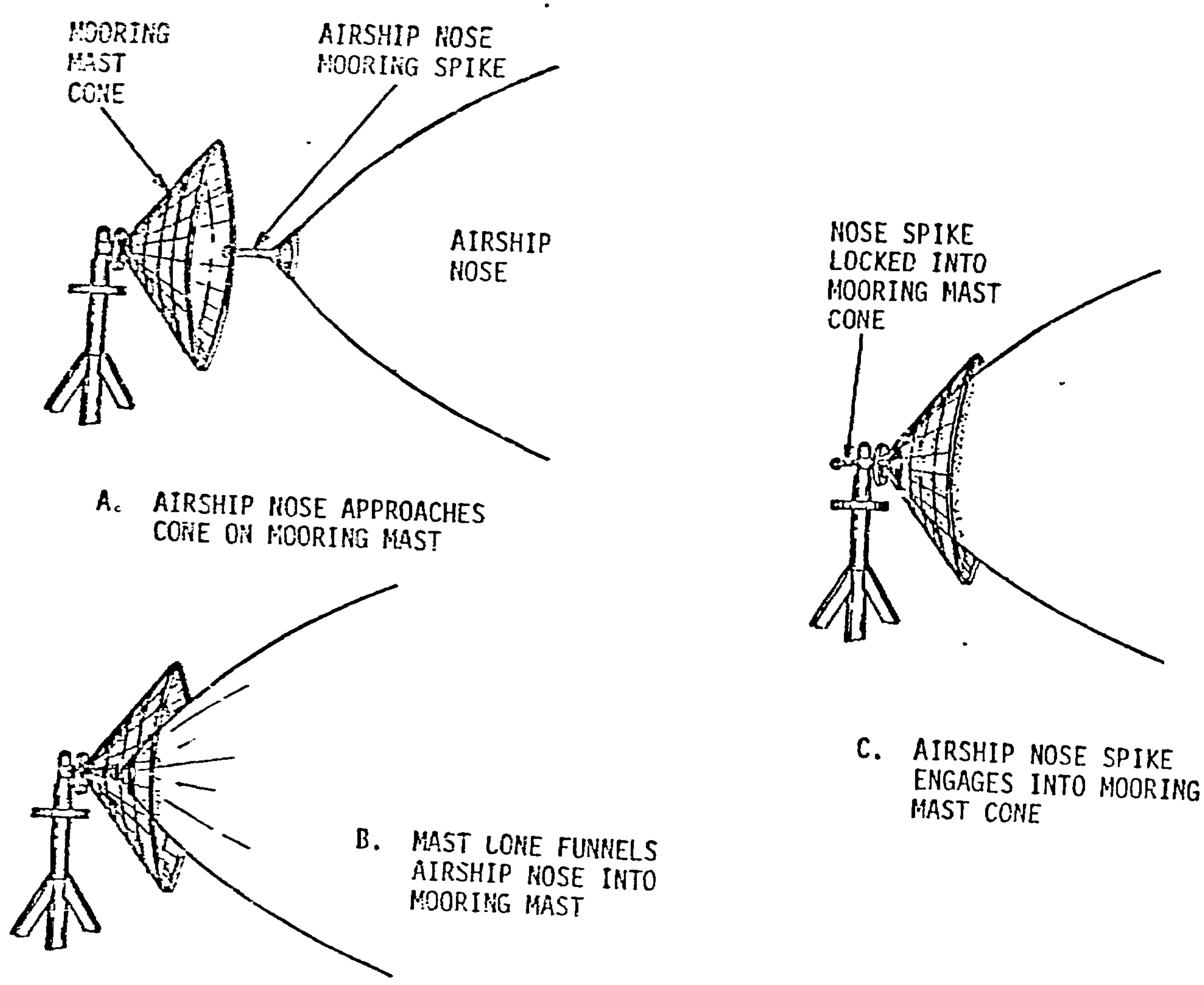

Figure VII-4. Bell Aerospace Airship Automatic Mooring Mast Engagement Technique.

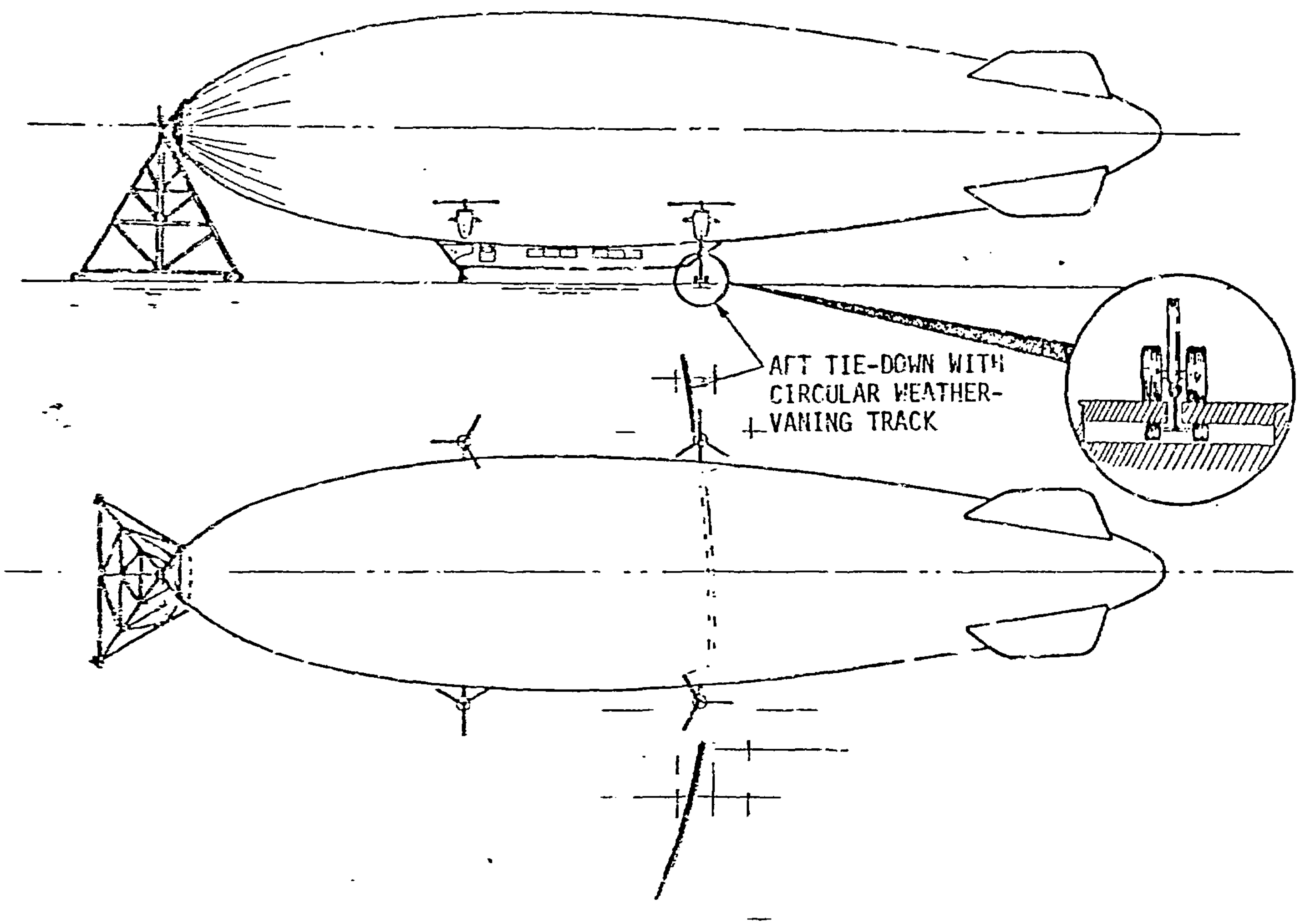

Figure VII-5. Bell Aerospace Airship Mooring and Tie-Down System.

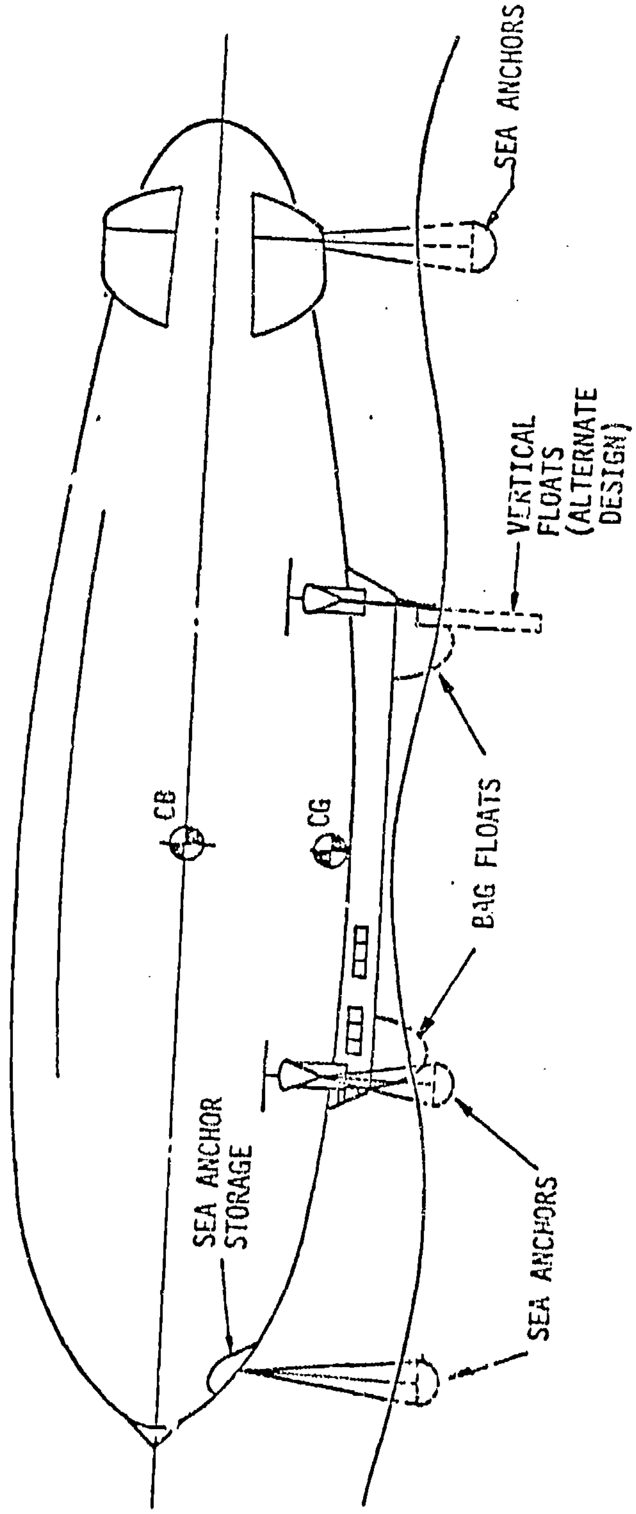

Figure VII-6. Bell Aerospace Flotation and Sea Anchor System.

The MPA may either take off vertically with the rotors thrusting directly upward, or it may make a conventional running takeoff down a runway with the rotors in a horizontal-thrust position. By inclining the rotors at some forward angle, a running takeoff with an extra-heavy load could be made, using dynamic lift from the envelope to augment the buoyant lift and the vertical-propulsive-thrust component. The length of the takeoff would be a function of the amount of overload; however, most overload takeoff lengths would be relatively short (on the order of hundreds of feet rather than thousands).

In flight, the airship is initially heavy, and is flown at a positive angle of attack to provide dynamic lift to offset the heaviness in the conventional manner, with engines providing horizontal thrust. If needed, some upward tilt of the engines may be employed. As fuel and supplies are consumed, the airship becomes lighter, reaching neutral buoyancy when about 60 percent of the fuel has been used. The angle of attack is reduced to maintain equilibrium, becoming approximately zero at neutral buoyancy, and is made negative to provide negative dynamic lift as the MPA becomes lighter than air. If necessary (e.g., at low speed), the rotors can be given a tilt to provide a downward component of thrust. Maximum forward speed is obtained when the airship is neutrally buoyant and the rotor thrust is parallel to the axis of the airship.

Landing is the reverse of takeoff. Negative thrust is used when the airship is light, and a lateral component of this thrust counteracts wind during hover and landing. It is also used for ground-taxi control.

Table VII-V presents the major characteristics of the Bell MPA design. Table VII-VI provides an empty weight breakdown. The basic, key features of the Bell MPA are low-speed control, ground taxi capability, elimination of the need for ballast or ballast transfer, and a sea anchor and float combination. These features are primarily a result of a concept using the tilt-quad-rotor reversible-thrust propulsion system.

For summary purposes the conceptual designs presented as cases studies 1 and 2 are compared with the conceptual design generated by in-house efforts (discussed in Chapter V). Table VII-VI presents the comparison by highlighting major geometric and performance characteristics of all three conceptual LTA vehicle designs.

Several distinctions are apparent as these three designs are examined. Table VII-VIII summarizes the major differences. Note that the primary distinction (since size is nearly the same) is the lesser buoyancy ratio for the Bell vehicle. This provides a greater load carrying capacity (increased gross weight due to additional dynamic lift) but at the price of twice the installed power.

TABLE VII-V
MAJOR CHARACTERISTICS

Envelope Volume	858,437 Cu Ft
Ballonet Volume	223,194 Cu Ft
Fineness Ratio	4.5
Beta Factor	.73
Static Lift @ 2,000 Ft Altitude	44,658 lbs
Dynamic Lift	17,917 lbs
Maximum Gross Weight	65,274 lbs
Weight Empty	33,019 lbs
Useful Load	32,256 lbs
Power Plant (4)	1,077 each
Maximum Speed	104 knots
Design Altitude	5,000 feet

TABLE VII-VI
BELL MPA EMPTY WEIGHT BREAKDOWN

Envelope	13,854 lbs
Empennage	1,569 lbs
Car	3,000 lbs
Landing Gear	4,006 lbs
Pressure System	1,565 lbs
Surface Controls	1,061 lbs
Ballast System	0 lbs
Outriggers and Internal Support	2,834 lbs
Propulsion	4,685 lbs

TABLE VII-VII
COMPARISON OF MPAS CONCEPTUAL POINT DESIGNS

ITEM	GAC ZP3G [1]	BAT MPA [2]	NADC ZP-X
Envelope Volume	875,000	858,437	783,696
Length	324	326	305
Diameter	73.4	72.4	69.3
Static Lift @ 2,000 Ft.	52,164	44,658	44,243
Dynamic Lift	8,500	17,917	7,638
Horsepower Required	2,400	4,306	1,927
Gross Weight	60,644	65,274	54,554
Empty Weight	33,740	33,019	27,674
Useful Load	22,504	32,256	26,880
Buoyancy Ratio	.86	.73	.86
Max. Altitude	10,000	10,000	10,000
Max. Speed	97	104	90

[1] Goodyear Aerospace Corporation
[2] Bell Aerospace Textron

TABLE VII-VIII
DISTINCTIVE CONCEPTUAL VEHICLE FEATURES

ITEM	NADC ZP-X	GAC ZP3G	BELL MPA
Propulsion	Three gas turbine engines with propellers	Three gas turbine engines with propellers	Four gas turbine engines with prop/rotors
Buoyancy	Typical of non-rigids, β = .86, must collect ballast	Typical of non-rigids, β = .86, must collect ballast	Less than typical, β = .73, no ballast collection
Thrust Management	VTOL capable, some reverse thrust on props for landing	VTOL capable, some reverse thrust on props for landing	VTOL capable, high degree of reserve thrust on prop/rotors for "light" condition
Ground Handling	As in previous airship operation aided by precision hover capability	As in previous airship operation aided by precision hover capability	Employs "space-type" ground docking system
Miscellaneous		Detailed layout of car was considered	Has water landing system

CHAPTER VIII
EFFECTIVENESS ANALYSIS

INTRODUCTION

The mission analysis has established that there is a potential for utilizing airships in Coast Guard missions. Based upon a small sample of these missions a conceptual airship design was specified, as discussed in Chapter VI. The purpose of the effectiveness analysis is to determine the level of potential utilization and effectiveness of the point design airship across the spectrum of mission profiles described in Chapter IV.

To perform this analysis a computer program was written. This program determines if the point design airship is capable of performing each of the mission profiles, the cost of performing a profile, the hourly cost of operations, the time required to perform the mission and the total flight hour requirement on an annual basis for each profile. The results of this analysis have been tabulated and are presented in this chapter.

It is to be emphasized that the concern of the study has been to evaluate if airships can perform Coast Guard missions in a cost effective manner with sufficient need to warrant an R&D program. This chapter addresses the last two concerns. In Chapter IV it was concluded that a modern airship can be expected to perform a wide variety of Coast Guard missions.

The remainder of this chapter will discuss the computer model, present and analyze the results, and provide a brief comparison of airships to existing platforms.

COMPUTER MODEL

The main purpose of the computer model is to give a first order estimate of the cost of utilizing a point design airship for existing Coast Guard mission requirements. The model measures three functions of the airship operation: the cost of performing the mission; the determination if the mission is within the capabilities of the airship design; and the duration of the mission. A brief description of the program is provided below and the listing of the program is included in Appendix G.

The computer program cycles through the seven tasks as specified for each of the mission profiles. For each of the included tasks, the duration and fuel consumption are calculated. If a task is not included in a profile, obviously, no calculations are made for the task. The determination of the duration of the task is a function of the type of task. For the transit and patrol tasks, which are specified in distance traveled, the duration is calculated by dividing the distance by the specified speed. For the station keeping, board, and towing tasks, the measure of the tasks is duration. The duration of a logistics task is assumed to be one hour. The duration of a search task is determined by dividing the area to be searched by the sweep rate. Each type of search has a specified sweep rate. The duration of a search mission requiring more than one type of search is determined by the dominant search type. It is assumed that the various types of search are occurring simultaneously.

The fuel consumption is calculated on the basis of airship speed, type of task, and the heaviness of the airship. Piecewise linear Specific Fuel Consumption (SFC) curves, as a function of payload, have been assumed. The fuel consumption is constant for all payloads up to the static lift capability. For payloads in excess of the static lift capability, the SFC increases linearly with the payload weight.

When the airship is operating heavy, requiring dynamic lift, the consumption rate changes as fuel is consumed. As fuel is consumed the weight of the airship decreases requiring less power for the dynamic lift. In the model, in the dynamic lift regime, the following equation was developed based estimated fuel consumption.

$$C = A(e^{st} - 1)$$

where

C = the amount of fuel consumed in time t

A = a constant of integration taken from estimated specific fuel consumption data for the weight of the airship at the beginning of the task interval

s = the slope of the Specific Fuel Consumption curves in the dynamic lift regime

t = the time interval to perform a task

The crew size and associated weight is calculated as a function of the mission duration. The crew size is 5, 8, or 13 if the mission is less than 10 hours, between 10 and 20 hours, or greater than 20 hours, respectively. Each crew member is assumed to weight 200 lbs. and require 25 lbs. of stores.

As implemented in the program, the requirements for each task are calculated in the order in which they are input to the program, starting with Task 1, Transit, and cycling through to Task 7, Tow. If a task is not specified for a profile, no contribution for that task is calculated. This approach ignores the actual time sequence of events in operations. The computation starts by calculating the fuel requirement and duration of the transit task independent of when the transit task occurs in the actual operation. Next, the fuel consumption and duration of the Patrol task is calculated, etc. The effect of this approach is important in the determination of the fuel consumed.

As the fuel requirement for a task is calculated, it is added on to the payload weight. When the sum of the payload and consumed fuel exceeds the static lift capability, the fuel consumption rate for a task is calculated on the basis of the dynamic lift requirement. Therefore, although the fuel consumption is calculated starting with Task 1 and cycling through to Task 7, this is equivalent to performing the tasks in reverse order. Task 7, when specified, will always be performed with a full load of fuel and Task 1, when specified, will always be performed with just enough fuel to perform the tasks plus fuel for takeoff and landing and a reserve of 10 percent. As the duration of the mission exceeds 10 or 20 hours, the weight of the crew is incremented to account for increased crew size.

Costs are calculated on the basis of fixed costs, including investments, maintenance, and overhaul; personnel costs; and POL costs. Both the hourly operating cost and total mission costs are calculated.

The output of the model includes the hourly and mission cost, fuel consumed, mission duration, and total annual missions hours for each profile. An example of the printout from the program is given in Table VIII-I. The first 11 columns summarize the mission profile and are input to the program. The next column is the average hourly cost, followed by the total cost of performing the mission. Both of these costs are based upon the life cycle cost estimates given in Chapter VII. The next column gives the total fuel consumed performing the mission. The next column lists the duration of a single mission and the last column gives the annual flight hour requirement associated with all occurrences of a profile. If a profile exceeds the capabilities of a specified vehicle it is noted in the output, e.g., profile 2.1.17. The complete printout is given in Appendix H. In addition, statistics are compiled for each program on the number of profiles, number of occurrences, and total flight hour requirement, categorized by mission endurance.

PROJECTED UTILIZATION

In Chapter IV a total of 264 mission profiles were identified for potential airship utilization. On the basis of the computer analysis, the point design airship is capable of performing 211 of these profiles. Of the 53 profiles beyond the capability of the airship, 43 are associated with the Military Operations/Military Preparedness Program. Because of the nature of the MO/MP program, the specification of these profiles was not based upon existing operations but, rather, preliminary estimates of the airships capability. Of the remaining ten profiles that exceed the point design airship capability, nine are associated with distant ELT operations (off of Alaska) and one is associated with a logistics operation for the MEP program (delivery of 17,000 lbs. of clean-up equipment). The point design airship, however, was capable of performing a similar MEP logistics operation (17,000 lb. payload) but with a shorter transit distance and station keeping requirement.

When the number of potential missions (number of profiles times their occurrences) are considered, of a possible 13,116 flights, as specified in Chapter IV, the airship is capable of 12,860. Since occurrences are not specified for the MO/MP program, the 43 profiles beyond the point design airship's capability are not considered in the total annual mission requirements.

The composition of the potential airship utilization by program is given in Table VIII-II. For each program the number of specified profiles, the annual

TABLE VIII-I
SAMPLE COMPUTER PRINTOUT

ID NUMBER	MISSION PAYLOAD	TASK 1	TASK 2	TASK 3	TASK 4	TASK 5	TASK 6	TASK 7	SEARCH TYPE	OCCUR-ENCE	HOURLY COST	TOTAL COST	FUEL (LBS)	DURATION (HRS)	TOT (HR
1.1.1	1289.	50.0	150.0	1.0	0.0	0.0	2000.0	0.0	1	10	$ 751.14	$ 4131.25	1718.5	5.50	55.
1.1.2	1289.	50.0	300.0	2.0	0.0	0.0	2000.0	0.0	1	10.	$ 751.05	$ 7135.01	2958.5	9.50	95.
1.1.3	1289.	100.0	200.0	2.0	0.0	0.0	5000.0	0.0	1	10	$ 751.07	$ 6384.07	2648.5	8.50	85.
1.1.4	1289.	100.0	300.0	2.0	0.0	0.0	5000.0	0.0	1	10	$ 876.54	$ 9203.70	3268.5	10.50	105.
1.1.5	1289.	100.0	200.0	4.0	0.0	0.0	5000.0	0.0	1	10	$ 876.54	$ 9203.70	3268.5	10.50	105.
2.1.1	734.	0.0	0.0	0.0	20.0	0.0	0.0	0.0	1	10	$ 1083.44	$ 21668.80	6200.0	20.00	200.
2.1.2	734.	0.0	0.0	0.0	35.0	0.0	0.0	0.0	1	75	$ 1083.44	$ 37920.40	10850.0	35.00	2625.
2.1.3	734.	0.0	100.0	4.0	20.0	0.0	0.0	0.0	1	25	$ 1083.44	$ 28169.44	8060.0	26.00	650.
2.1.4	734.	0.0	100.0	6.0	35.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 46587.91	13330.0	43.00	4300.
2.1.5	734.	50.0	0.0	0.0	3.0	0.0	0.0	0.0	1	10	$ 750.94	$ 3003.76	1240.0	4.00	40.
2.1.6	734.	50.0	50.0	4.0	10.0	0.0	0.0	0.0	1	50	$ 876.44	$ 14023.04	4960.0	16.00	800.
2.1.7	734.	50.0	0.0	0.0	15.0	0.0	0.0	0.0	1	50	$ 876.44	$ 14023.04	4960.0	16.00	800.
2.1.8	734.	50.0	50.0	2.0	15.0	0.0	0.0	0.0	1	100	$ 876.44	$ 16652.36	5890.0	19.00	1900.
2.1.9	734.	50.0	0.0	0.0	20.0	0.0	0.0	0.0	1	25	$ 1083.44	$ 22752.24	6510.0	21.00	525.
2.1.10	734.	50.0	100.0	4.0	20.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 29253.88	8370.0	27.00	2700.
2.1.11	734.	50.0	200.0	10.0	70.0	0.0	0.0	0.0	2	200	$ 1083.44	$ 41531.86	11883.3	38.33	7666.
2.1.12	734.	150.0	50.0	2.0	5.0	0.0	0.0	0.0	1	50	$ 876.44	$ 9640.84	3410.0	11.00	550.
2.1.13	734.	150.0	100.0	4.0	20.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 31419.76	8990.0	29.00	2900.
2.1.14	734.	500.0	50.0	2.0	25.0	0.0	0.0	0.0	1	50	$ 1083.44	$ 41170.71	11780.0	38.00	1900.
2.1.15	734.	500.0	100.0	4.0	50.0	0.0	0.0	0.0	2	200	$ 1083.44	$ 35392.38	10126.7	32.67	6533.
2.1.16	734.	500.0	200.0	8.0	100.0	0.0	0.0	0.0	2	100	$ 1084.49	$ 60008.21	17876.7	55.33	5533.
2.1.17	734.	2000.0	100.0	4.0	25.0	0.0	0.0	0.0	1	50					
FUEL CONSUMED= 26706.7 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.1.18	734.	2000.0	150.0	6.0	50.0	0.0	0.0	0.0	1	25					
FUEL CONSUMED= 57774.9 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.1.19	734.	2000.0	200.0	8.0	100.0	0.0	0.0	0.0	2	50					
FUEL CONSUMED= 37376.3 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.1.20	734.	1000.0	0.0	8.0	15.0	0.0	0.0	0.0	1	300	$ 1083.44	$ 46587.91	13330.0	43.00	12900.
2.2.1	734.	0.0	100.0	4.0	20.0	2.0	0.0	0.0	1	25	$ 1093.44	$ 30336.32	8680.0	28.00	700.
2.2.2	734.	0.0	100.0	6.0	35.0	2.0	0.0	0.0	1	100	$ 1083.46	$ 48755.52	13959.1	45.00	4500
2.2.3	734.	50.0	50.0	2.0	10.0	2.0	0.0	0.0	1	10	$ 876.44	$ 14023.04	4960.0	16.00	160.
2.2.4	734	50.0	50.0	2.0	15.0	2.0	0.0	0.0	1	50	$ 1093.44	$ 22752.24	6510.0	21.00	1050.
2.2.5	734.	50.0	100.0	4.0	20.0	2.0	0.0	0.0	1	10	$ 1083.44	$ 31419.76	8990.0	29.00	290.
2.2.6	734.	50.0	200.0	10.0	70.0	4.0	0.0	0.0	2	100	$ 1083.44	$ 45865.63	13123.3	42.33	4233.
2.2.7	734.	150.0	50.0	2.0	5.0	2.0	0.0	0.0	1	10	$ 876.44	$ 11393.72	4030.0	13.00	130.
2.2.8	734.	150.0	100.0	4.0	20.0	2.0	0.0	0.0	1	100	$ 1083.44	$ 33586.63	9610.0	31.00	3100.
2.2.9	734.	500.0	50.0	2.0	25.0	4.0	0.0	0.0	1	25	$ 1083.44	$ 45504.48	13020.0	42.00	1050.
2.2.10	734.	500.0	100.0	4.0	50.0	4.0	0.0	0.0	2	100	$ 1083.44	$ 39726.14	11366.7	36.67	3666.
2.2.11	734.	500.0	200.0	8.0	100.0	2.0	0.0	0.0	2	200	$ 1084.85	$ 62178.24	18786.1	57.33	11466.
2.2.12	734.	2000.0	100.0	4.0	25.0	4.0	0.0	0.0	1	50					
FUEL CONSUMED= 29711.7 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.2.13	734.	2000.0	150.0	6.0	50.0	2.0	0.0	0.0	1	25					
FUEL CONSUMED 61159.9 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.2.14	734.	2000.0	200.0	8.0	100.0	2.0	0.0	0.0	2	50					
FUEL CONSUMED= 41617.7 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.2.15	734.	1000.0	0.0	8.0	15.0	2.0	0.0	0.0	1	50	$ 1083.46	$ 48755.52	13759.1	45.00	2250.
2.3.1	734.	25.0	50.0	15.0	15.0	2.0	0.0	0.0	1	2	$ 1083.44	$ 36295.23	10385.0	33.50	67.
2.3.2	734.	25.0	50.0	2.0	15.0	2.0	0.0	100.0	1	1	$ 1079.46	$ 32892.91	7555.0	30.50	30.
2.3.3	734.	50.0	100.0	20.0	20.0	2.0	0.0	0.0	1	2	$ 1093.46	$ 48755.52	13959.1	45.00	90.
2.3.4	734.	100.0	100.0	20.0	50.0	2.0	0.0	0.0	1	1					
FUEL CONSUMED= 30521.1 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.3.5	734.	1000.0	200.0	50.0	50.0	2.0	0.0	0.0	1	2					
FUEL CONSUMED= 28726.2 GREATER THAN LIMIT =18842.31															

TABLE VIII-II
AIRSHIP UTILIZATION

PROGRAM	PROFILES NUMBER	PROFILES PERCENT	MISSIONS (ANNUAL) NUMBER	MISSIONS (ANNUAL) PERCENT	FLIGHT HOURS (ANNUAL) NUMBER	FLIGHT HOURS (ANNUAL) PERCENT
A/N	5	2	50	0	445	0
ELT	32 (9)*	15	2330(255)*	18	85807	47
MEP	22 (1)*	10	846 (1)*	7	166441	9
MC/MP	66 (43)*	31	--	--	--	--
MSA	11	5	418	3	8642	5
PSS	18	9	508	4	5948	3
SAR	49	23	3312	65	55608	30
IO	8	4	405	3	11083	6
TOTAL	211 (53)*		12860 (256)*		183472	

*( ) represents proposed profiles or mission occurrences beyond the capability of the point design airship.

number of missions, and the total annual flight requirement are given. The percentage by program of the total utilization is also given.

Both the number of profiles and annual number of missions were specified based on the analysis discussed in Chapter IV. The annual flight hour requirement was calculated by the computer program. This analysis shows that there is a potential for using airships 183,000 hours a year. Assuming 2,400 flight hours per year for an airship, there is a potential requirement for over 75 airships. Of this requirement 47 percent of the flight hours are associated with operations of the ELT program. Thirty percent of the flight hours are associated with SAR operations. None of the other programs account for more than 10 percent of the flight hour requirement. MO/MP does not have any flight hour requirement due to the contingency nature of this program.

MISSION DURATION

To determine the significance of endurance for the airship role in Coast Guard operations, the annual flight hours requirements, grouped by ten hour intervals of mission endurance, were plotted in a histogram. Figure VIII1 shows that the flight hour requirement remains at a fairly constant level for the first five groupings. The requirement varies from 27,000 hours for missions of 20 to 30 hours, up to 39,000 hours for missions of 40 to 50 hours. The average flight duration is 14.3 hours.

In the cost analysis, a buy of 50 airships was assumed. With five of these airships for training and research and development, there would be 45 operational airships. If totally utilized, the 2,400 flight hours per year, the airships would be operational 108,000 hours. From Figure VIII-1 it is seen that this availablility is sufficient to satisfy all requirements up to missions of between 30 to 40 hours. Because of scheduling and operational considerations, it is unlikely that the 45 airships could fulfill all of these missions.

Although this analysis indicates that it is possible to have the point design airship operate on missions of longer than 40 hours endurance, this is unlikely, except under extreme conditions. Because of the generality of this study, the car of the airship was assumed to be of modular design, allowing modification to the interior of the car to accommodate the needs of a mission. It is unlikely that the basic car design could be modified to handle the habitability requirements of missions greater than two days (approximately 50 hours). Therefore, without the redesign of the car and an associated increase in the size of the airship, missions of over 50 hours are probably beyond crew endurance.

While the annual requirement for flight hours remains fairly constant for missions of from 0 to 50 hours, the number of missions is greater for short duration operations and decreases with increasing flight duration. Figure VIII-2 is a histogram of the annual number of missions as function of flight duration. An overwhelming number of missions are of duration of less than ten hours. Annually, there are approximately 7,500 missions of less than ten hours, many of these associated with SAR operations.

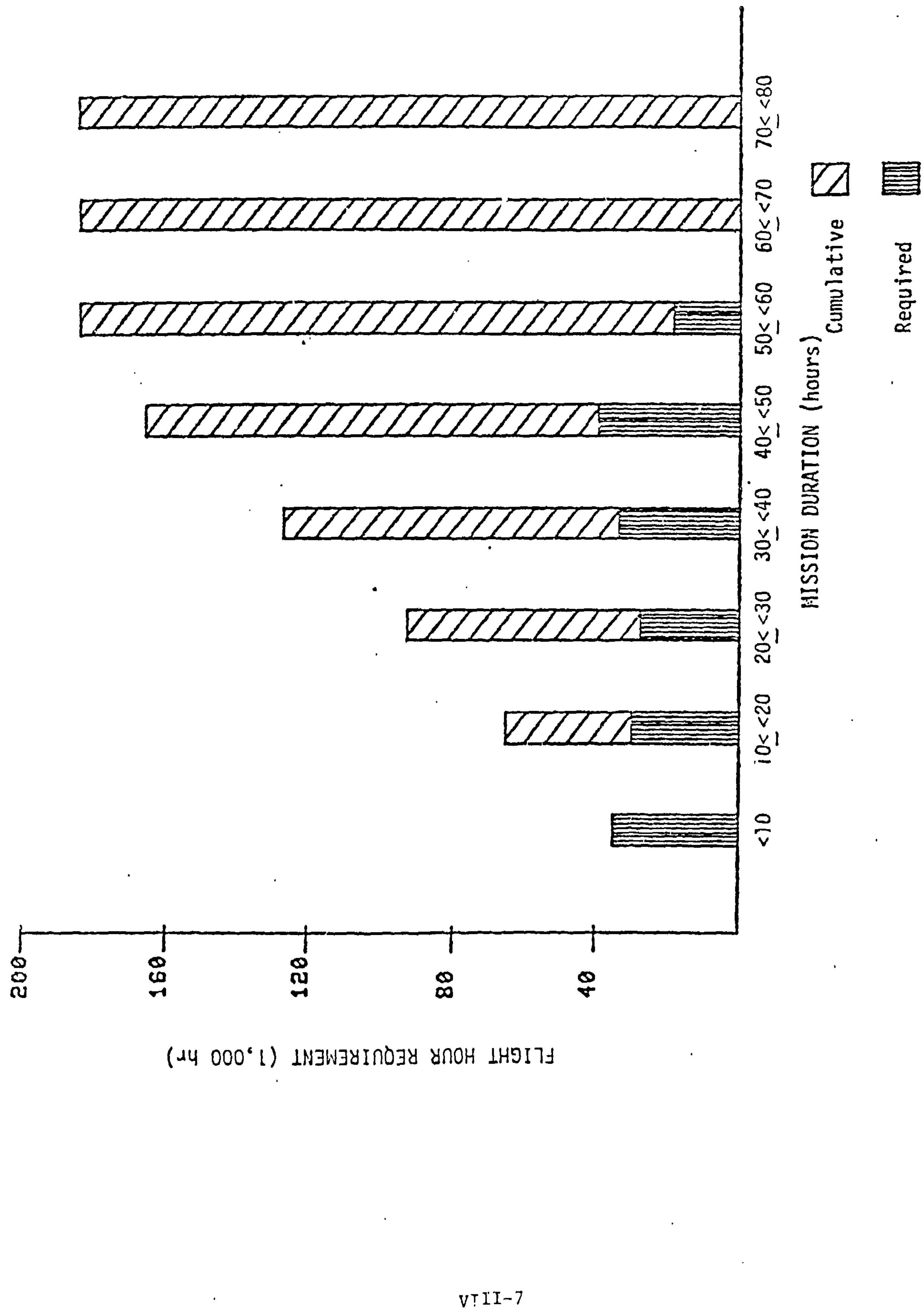

Figure VIII-1. Total Flight Hour Requirement for all Specified Programs.

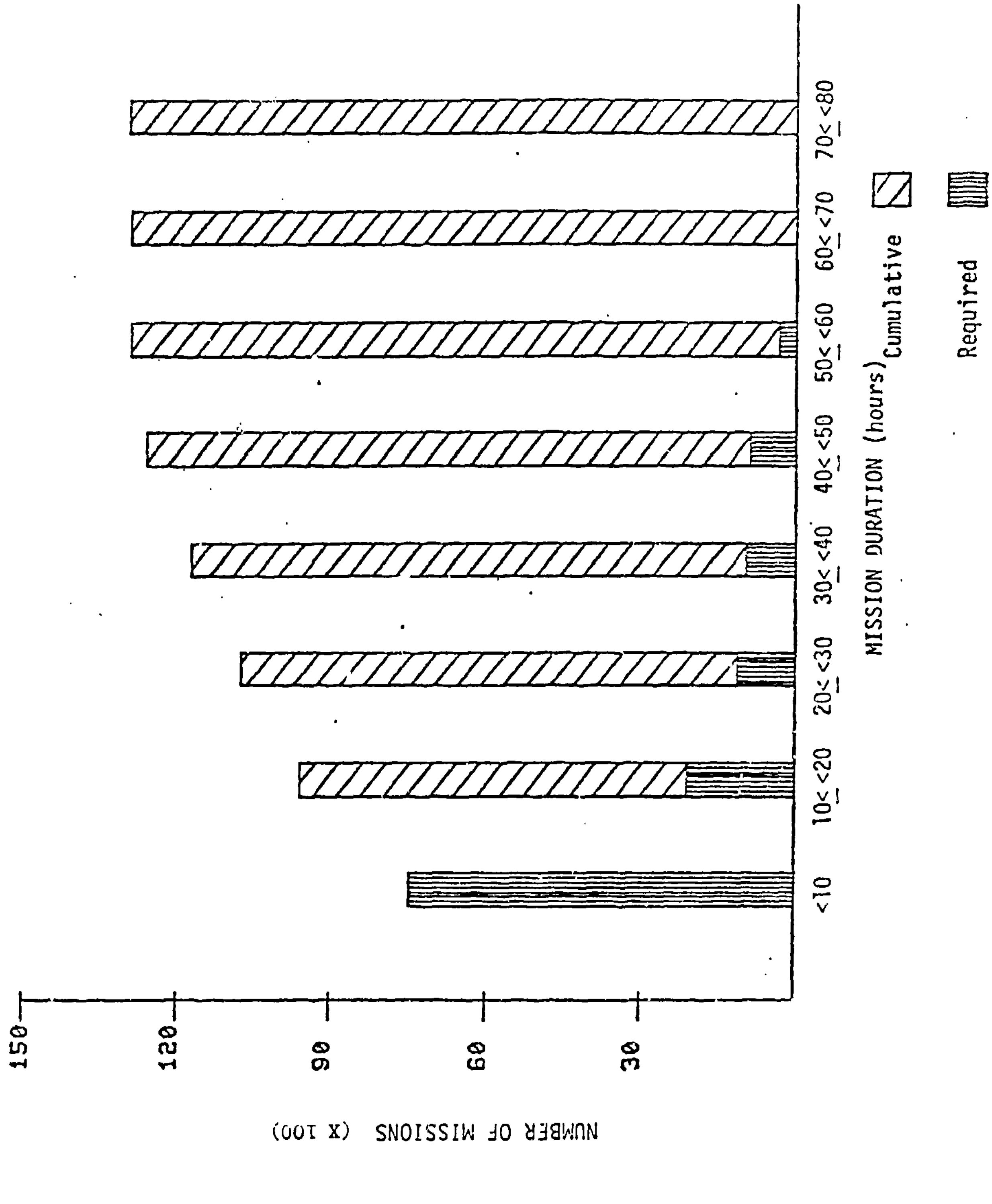

Figure VIII-2. Total Number of Missions for all Specified Programs.

A similar histogram of the breakdown of the number of profiles by flight endurance is given in Figure VIII-3. Again, the most frequently occurring profiles are those of shorter duration. This indicates that in performing the mission analysis, as described in Chapter IV, the operations chosen for airship participation were those of shorter duration. Since this analysis is based upon operations as they are performed by existing Coast Guard assets, the operations are not necessarily specified in a manner that are optimal for airship operations. A more thorough analysis, in which mission operations are configured for optimal utilization of a point design airship, will probably have most missions of from 20 to 30 hours duration.

Similar histogram analysis has also been performed for each of the eight Coast Guard programs of interest. These are given in Appendix F. Note that the scale varies from histogram to histogram. Also, because of the contingency aspects of the MO/MP program, there are no flight hours or mission requirements histograms. Review of these figures indicates two distinct groupings or programs. In the A/N, PSS, and SAR programs, shorter missions (less than 20 hours) tend to predominate. The longer missions tend to predominate for MO/MP operations also. This implies that there may be a requirement for the design of two distinct airships, a smaller one of about 15 hour endurance and a larger one of about 40 hour endurance. The smaller airship could be designed for more economical operation whereas the larger airship (probably of similar design as the point design airship) would have greater capability.

TASK ANALYSIS

The potential utility of an airship for Coast Guard missions comes from its ability to perform a number of operations well. It is not that the airship especially excels at any one task, but given an aggregation of tasks, typical of Coast Guard missions, it should provide superior capabilities. Because of the higher speed, aircraft will generally be better wide area search platforms. Because of their stability and lower speed, however, airships may be ideal for detailed search or search for small objects. For boarding operations and long endurance requirements, ships are better. But for the large number of operations that mix these tasks, airships offer great potential.

To determine the nature of the mix of tasks in the spectrum of the Coast Guard missions evaluated in this study, the task composition of the potential utilization of the airship was analyzed. Tables VIII-III through VIII-VIII present both the number and percent of the operations of each program requiring a task function. This data is provided for the number of profiles, the annual number of missions, and for annual number of flight hours. Programs in which none of the profiles require a particular task are not listed.

In Table VIII-III, both the transit and patrol task requirements are combined. Both of these tasks require the same airship capabilities, differing only in their contribution to mission success. All eight programs have missions that require transit or patrol. Over all of the Coast Guard operations evaluated in this study, 95 percent of the profiles, 97 percent of the annual missions flow, and 90 percent of the total flight hour requirement, are associated

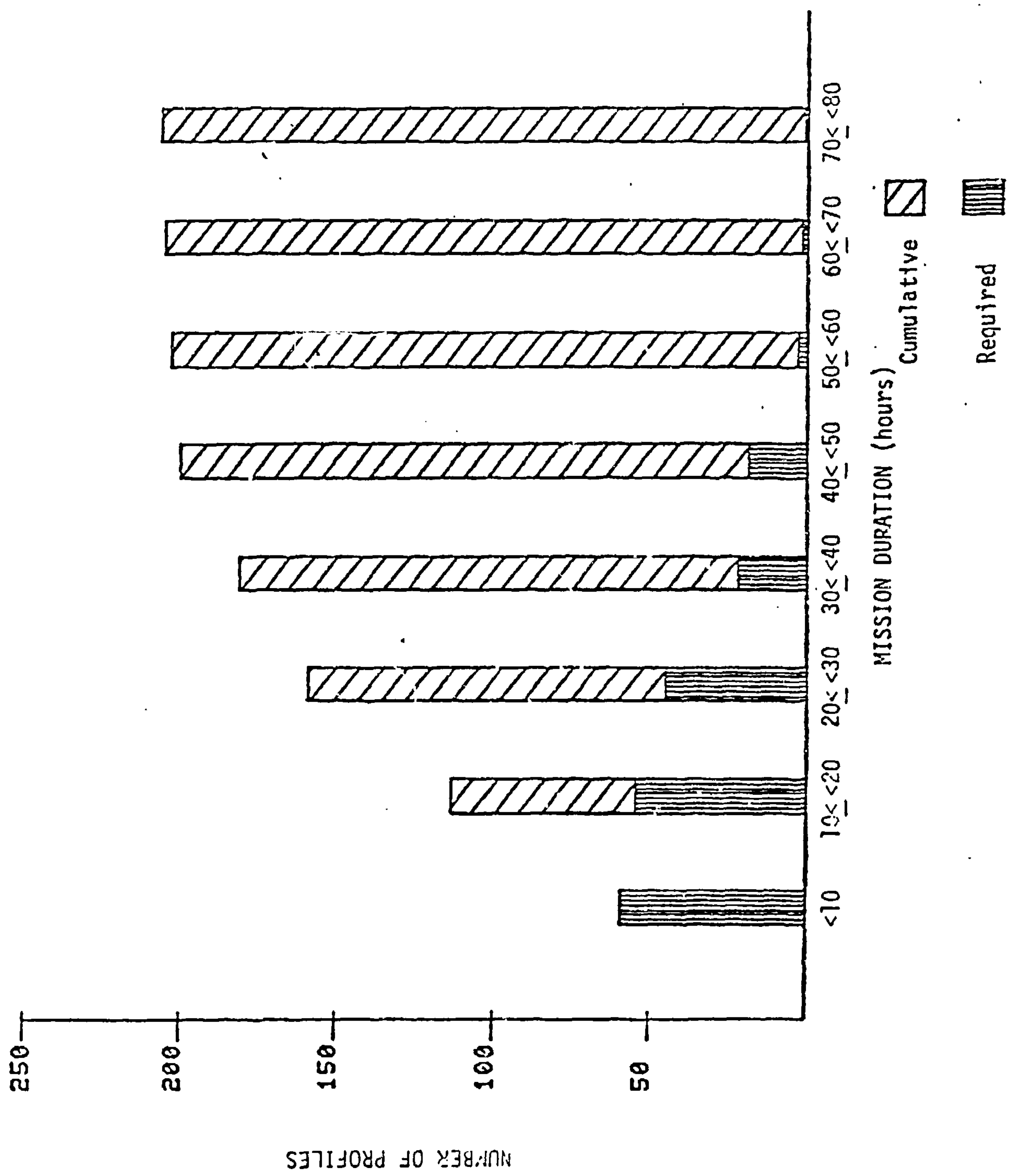

Figure VIII-3. Total Number of Profiles for all Specified Programs.

TABLE VIII-III
TRANSIT OR PATROL REQUIREMENTS

PROGRAM	PROFILES NUMBER	PROFILES PERCENT	MISSIONS (ANNUAL) NUMBER	MISSIONS (ANNUAL) PERCENT	FLIGHT HOURS (ANNUAL) NUMBER	FLIGHT HOURS (ANNUAL) PERCENT
A/N	5	100	50	100	445	100
ELT	30	94	2245	96	82482	97
MEP	22	100	846	100	16441	100
MO/MP	66	100	--	--	--	--
MSA	9	82	218	52	5276	61
PSS	14	78	504	99	5900	99
SAR	49	100	8312	100	55608	100
TO	5	63	250	62	8850	80
TOTAL	200	95	12416	97	175000	95

TABLE VIII-IV
STATION KEEPING/TRAIL REQUIREMENTS

PROGRAM	PROFILES NUMBER	PROFILES PERCENT	MISSIONS (ANNUAL) NUMBER	MISSIONS (ANNUAL) PERCENT	FLIGHT HOURS (ANNUAL) NUMBER	FLIGHT HOURS (ANNUAL) PERCENT
A/N	5	100	50	100	445	100
ELT	27	84	2160	93	81127	95
MEP	22	100	846	100	166441	100
MO/MP	20	30	--	--	--	--
MSA	4	36	400	96	4357	50
PSS	18	100	508	100	5948	100
SAR	41	84	4662	56	37608	68
TOTAL	157	65	8626	67	145926	80

TABLE VIII-V
SEARCH REQUIREMENT

PROGRAM	PROFILES NUMBER	PROFILES PERCENT	MISSIONS (ANNUAL) NUMBER	MISSIONS (ANNUAL) PERCENT	FLIGHT HOURS (ANNUAL) NUMBER	FLIGHT HOURS (ANNUAL) PERCENT
ELT	32	100	2330	100	85307	47
MEP	6	27	534	63	12952	79
MO/MP	53	86	--	--	--	--
MSA	7	63	410	98	8566	99
SAR	49	100	8312	100	55608	100
IO	8	100	405	100	11081	100
TOTAL	155	73	11911	93	173514	95

TABLE VIII-VI
BOARDING REQUIREMENTS

PROGRAM	PROFILES		MISSIONS (ANNUAL)		FLIGHT HOURS (ANNUAL)	
	NUMBER	PERCENT	NUMBER	PERCENT	NUMBER	PERCENT
ELT	21	66	915	39	32782	38
MEP	2	9	20	2	240	1
MO/MP	12	22	--	--	--	--
SAR	18	37	2810	34	22827	41
TOTAL	53	25	3745	29	55849	30

TABLE VIII-VII
LOGISTICS REQUIREMENTS

PROGRAM	PROFILES NUMBER	PROFILES PERCENT	MISSIONS (ANNUAL) NUMBER	MISSIONS (ANNUAL) PERCENT	FLIGHT HOURS (ANNUAL) NUMBER	FLIGHT HOURS (ANNUAL) PERCENT
A/N	5	100	50	100	445	100
MEP	7	32	47	18	304	2
MO/MP	13	20	--	--	--	--
MSA	4	36	8	2	76	1
PSS	8	44	8	2	104	2
SAR	15	31	410	5	3812	7
TOTAL	52	25	523	4	4741	3

TABLE VIII-VIII
TOW REQUIREMENT

PROGRAM	PROFILES NUMBER	PROFILES PERCENT	MISSIONS (ANNUAL) NUMBER	MISSIONS (ANNUAL) PERCENT	FLIGHT HOURS (ANNUAL) NUMBER	FLIGHT HOURS (ANNUAL) PERCENT
ELT	1	3	1	0	30	0
MO/MP	30	45	--	--	--	--
SAR	12	24	1342	16	10037	18
TOTAL	43	20	1343	10	10067	5

with missions that require the transit or patrol task. If the efficiency of the airship in performing the transit or patrol tasks is improved, by either increasing the speed or decreasing the cost of operations, the efficiency of over 95 percent of all missions will be increased.

The station keeping/trail task requirement is analyzed in Table VIII-III. In this table, seven programs are listed; the IO program does not contain any missions requiring station keeping or trail. There is a lower requirement for this task than for transit or patrol; however, for three programs (A/N, MEP, and PSS), all missions require this task. Overall improvement in the station keeping/trail capability of the airship, by decreasing the fuel consumption, would impact on 60 percent of the missions.

Six programs require search capability. A/N and PSS do not. As seen in Table VIII-V, 100 percent of the ELT, SAR, and IO missions require search. Overall, 93 percent of all of the proposed airship missions for the Coast Guard will include search operations. The type of search may vary from mission to mission, some using sonar equipment, others using radar or special instrumentation, etc. Because of its large size and payload capability, the airship offers opportunities to improve sensor performance through design modification not possible in most other aircraft. Improved sensor capability will impact on a large number of proposed airship missions.

Boarding is required for missions of four of the programs (ELT, MEP, MO/MP, and SAR). Overall, only 29 percent of the proposed missions will require a boarding capability. Boarding requires both the capability for the airship to hover, as well as, a mechanism for transferring the boarding party to the platform. It is assumed that both capabilities are within the state-of-the-art of current technology. Limited boarding capabilities have been demonstrated in past airship operations. If, however, this capability cannot be attained, less than 30 percent of the proposed missions would be affected.

Logistics is another task that requires the airship to hover. Six of the programs have missions that include logistics operations (only ELT and IO do not). As shown in Table VIII-VII, only 4 percent of all of the proposed Coast Guard missions include logistics. However, all of the A/N missions include logistics operations. Besides hovering, logistics tasks require the airship to have a constant tension winch and are limited by the payload capability. The payloads for the specified logistics operations can be as large as 17,000 lbs. (for the ZP-X design). Again, if the airship is not capable of hover, it will probably not be able to perform the logistics tasks.

The last task requirement, tow, is analyzed in Table VIII-VIII. Only three programs (ELT, MO/MP, and SAR) require a towing capability. A total of 10 percent of the proposed missions include the towing task. Airships have demonstrated a towing capability. With the addition of a hover capability, the efficiency and extent of towing operations should increase.

The capability to hover is necessary for the performance of both the boarding and logistics tasks. Table VIII-IX presents the results of the analysis of the hover requirement. Only the IO program does not have missions that require the hover capability. This table accounts for missions that

TABLE VIII-IX
HOVER REQUIREMENTS

PROGRAM	PROFILES NUMBER	PROFILES PERCENT	MISSIONS (ANNUAL) NUMBER	MISSIONS (ANNUAL) PERCENT	FLIGHT HOURS (ANNUAL) NUMBER	FLIGHT HOURS (ANNUAL) PERCENT
A/N	5	100	50	100	445	100
ELT	21	66	915	39	32782	38
MEP	9	41	67	20	544	3
MO/MP	23	35	--	--	--	--
MSA	4	36	8	2	76	1
PSS	8	44	8	2	104	2
SAR	26	53	3140	38	25592	46
TOTAL	96	45	4188	33	59543	32

contain either the boarding or logistics task. Missions that require both are only counted once. Only 33 percent of all of the proposed missions require a hover capability. The largest number of missions requiring hover are associated with the SAR program. The largest number of flights hours for missions including tasks associated with hover are associated with the ELT mission. If the ability to hover is not attainable, there is still a sufficient requirement for airship participation in Coast Guard operations. There still remains a potential of 123,000 flight hours annually.

COST ANALYSIS

As part of the computer program, for each profile, both the hourly cost and total mission cost were calculated based upon the life cycle cost. As computed on an hourly basis, most of the cost components are independent of the nature of the mission. These include investment, maintenance and overhaul costs. The two exceptions are personnel costs and POL costs. As discussed in Chapter VII, the personnel costs are dependent on the duration of a mission. The longer the mission the larger the crew, varying from 5 for missions of less than 10 hours to 13 for missions of greater than 20 hours. POL cost depends upon the mix of tasks required for a mission. High speed or hover consume much more fuel than cruising. Station keeping consumes less. Therefore, the hourly cost varies from profile to profile. However, since crew costs are a dominant component of the life cycle cost, the hourly cost can be approximated for three distinction situations. For missions of less than ten hours, the hourly cost is approximately $750/hour. For missions between 10 and 20 hours, the cost is approximately $875/hour, and for missions of greater than 20 hours the approximate cost is $1,085/hour.

The cost of a mission will vary with the length of the mission. For all of the missions analyzed, the cost extremes are $1,127 for a 1 1/2 hour MO/MP logistics support mission to $117,659 for a 110 hour MO/MP towed array search mission. The cost of delivering ADAPTS equipment to a MEP cleanup operation ten miles off-shore is $2,823. The cost of doing a SAR operation can be as little as $1,501 for an operation 25 miles from the airbase, to $13,440 for an operation 500 miles off-shore. This mission includes towing the vessel back to port. These costs are all based upon the life cycle costs, which tend to be significantly higher than standard rate costs.

Obviously, the cost will vary from mission to mission. It is highly unlikely that the conceptual design airship will be able to perform missions of 110 hours especially with a crew of 13. Missions of from 30 to 40 hours will cost between $32,000 and $43,000. The complete printout of mission cost is given in Appendix H.

COMPARATIVE ANALYSIS

The thrust of this analysis has been on the determination of the feasibility of using airships in Coast Guard operations. However, to put this analysis in perspective with the current use of Coast Guard platforms, a brief comparative analysis was performed. Both the fuel efficiency and cost of performing selected missions was analyzed.

The most frequently occurring of the proposed airship missions were chosen for this analysis. Thirteen profiles are given in Table VIII-X. All profiles that have an expected occurrence of 200 times or more per year are included. All of these profiles are associated with either the ELT program or SAR. There is no reason to believe that these profiles are not typical of the spectrum of profiles analyzed in this study.

The airship cost and fuel requirements for these missions were compared with those of the following Coast Guard platforms:

- HC-130B
- HH-3F
- MEC 210
- HEC 378
- HU-25A (MRS)

To perform this analysis, estimates of the expected performance for these platforms had to be specified. Table VIII-XI lists the values used. Cruise speed is used for the aircraft, and maximum speed is used for the cutters. The instrument sweep rates are calculated based upon the radar detection range against a large target (150 M^2 cross section)[28]. The visual sweep rate for aircraft is assumed to be about 1/5 of the instrument sweep rate. For ships, the visual sweep rate is assumed to be about the same as the instrument sweep rate. Fuel consumption is specified for cruising speed except where noted. In determining fuel consumption for the cutters, the lower figure is used for station keeping/trail, boarding, logistics, and towing tasks. The higher rate is used for transit, patrol, and search tasks. For the cutters, the fuel consumption assumptions are highly favorable to the cutters in that the performance is calculated at a higher speed than that associated with the fuel consumption.

In that this is a brief analysis, approximate numbers were used to specify the performance of these platforms. In all cases the numbers chosen for these platforms will reflect their performance or enhance it. Therefore, in the comparative analysis, if there is a bias, it is against the airship.

Based upon the performance parameters, the mission duration for each of the platforms in each of the missions specified in Table VIII-X was calculated. Table VIII-XII summarized the results. Missions that exceed the endurance of a platform are noted with an E. Missions that require a capability beyond those of a platform are denoted with an X. These are associated with aircraft operations that require towing or hover (for the HC-130 and MRS) or delivery or large payloads (MRS). A "?" is used to denote that the operation is questionable. Profile 2.2.11 requires a 57 hour LTA missions and even though the point design airship is capable of this mission, it is questionable if, for the specified crew size, the crew could endure such a prolonged mission. For the MRS, the 7.1 missions are noted with "?s". This is a search only SAR mission, but the MRS would not be able to provide assistance if needed. Additional platforms may have to be called in.

TABLE VIII-X
MOST FREQUENTLY OCCURRING LTA PROFILES

I.D. NUMBER	TASK 1 (nmi)	TASK 2 (nmi)	TASK 3 (hr)	TASK 4 (10000 n^2mi)	TASK 5 (hr)	TASK 6 (lb)	TASK 7 (nmi)	OCCURRENCES
2.1.11	50	200	10	70	0	0	0	200
2.1.15	500	100	4	50	0	0	0	200
2.1.20	1000	0	8	15	0	0	0	300
2.2.11	500	200	8	100	2	0	0	200
7.1.1	50	0	0	1	0	0	0	2000
7.1.2	50	0	0	5	0	0	0	500
7.1.5	100	0	0	1	0	0	0	500
7.1.10	500	0	0	1	0	0	0	200
7.1.11	500	0	0	5	0	0	0	1500
7.5.2	50	0	4	1	1	0	0	500
7.5.3	100	0	2	3	1	0	0	200
7.6.1	50	0	1	1	0	0	25	1000

TABLE VIII-XI
PARAMETERS FOR OTHER COAST GUARD PLATFORMS

PLATFORM TYPE	SPEED (KTS)	INSTRUMENT SWEEP RATE (1,000 n^2mi)	VISUAL SWEEP RATE (1,000 n^2mi)	ENDURANCE (HRS)	FUEL CONSUMPTION
HC-130-B	210	10.5	2.0	11.8	4,800 lbs/hr
HH-3F	126	5.0	1.0	5.7	850 lbs/hr
MEC 210	18	.65	.65	167	39.7 gals/hr[2] 175.5 gals/hr[3]
HEC 378	29	1.0	1.0	103/753[1]	79.8 gals/hr[2] 260 gals/hr[4]
MRS	230	11.5	2.0	4.5	1,750 lbs/hr

[1] Low Speed
[2] Auxiliary Equipment Rate
[3] 14 kt
[4] 11 kt (diesel)

TABLE VIII-XII
COMPARATIVE MISSION CAPABILITY

PROFILE NUMBER	DURATION BY PLATFORM TYPE (HR)					
	LTA	HC-130	HH-3F	MEC 210	HEC 378	MRS
2.1.11	38	18.0E	26.0 E	132.0	86.0	17.0 E
2.1.15	33	11.5	19.0 E	114.5	72.5	11.0E
2.1.20	43	20.0 E	31.0 E	87.0	57.0	20.0 E
2.2.11	57 ?	X	35.5 E	203.0 E	96.0	X
7.1.1	2	1.0	1.5	4.5	2.5	1.0 ?
7.1.2	6	2.5	5.5	10.5	6.0	2.5 ?
7.1.5	3	1.0	2.0	7.0	4.5	1.0 ?
7.1.10	11	2.5	5.0	29.5	18.0	2.5 ?
7.1.11	15	4.5	9.0 E	35.5	22.0	4.5 ?
7.5.1	5	X	4.5	7.5	5.5	X
7.5.2	7	X	6.5 E	9.5	7.5	X
7.5.3	8	X	7.0 E	13.0	9.5	X
7.6.1	5.5	X	X	8.0	6.0	X

X - Not capable of mission

? - Doubtful capability

E - Exceeds endurance of a single platform

COST COMPARISON

Because life cycle costing is not always calculated in a consistent manner, the standard rate was used for cost comparison. Table VIII-XIII summarizes the standard rates previously given in Chapter VII. The standard rate for the LTA platform varies with crew size and fuel consumption. Based upon these estimates, the cost of performing the 13 missions was calculated and is given in Table VIII-XIV.

The cutters are always more expensive to operate than the airship. The MRS, when capable, is less expensive to operate than the airship. In the five SAR missions where the MRS and HC-130 are suitable, they would not be able to provide assistance if necessary without support from other platforms. In the missions the HH-3F is capable of performing, it is always more expensive than the airship.

In one-half of the six missions for which the HC-130 is capable, it can do so at a lower cost than the airship. For two of the remaining missions it is more expensive, and for one mission the costs are about the same. The HC-130 currently performs all six of the missions. The mission given by Profile 2.1.15 is associated with the inspection of Ground Fishing off of Alaska. The 7.1 profiles are long range rescue operations.

FUEL CONSUMPTION COMPARISON

Airships are very efficient users of fuel. As opposed to aircraft, which are completely dependent on dynamic lift, most of an airship's lift is provided by the bucyancy of the lifting gas. In that air is less dense than water, there is much less drag on an airship than on a ship.

Table VIII-XV compares the fuel consumption of the six platforms for the 13 mission profiles. The airship's consumption is given in both gallons and pounds. Gallons are the standard unit for ships and pounds are the standard unit for aircraft. The airship is assumed to use JP-4 which weight 6.51 pounds/gallon.

The MRS and the HH-3F use from one and one-half to three times as much fuel as the airship on a given mission. The HC-130 uses from four to eight times as much fuel. In many cases, the cutters use over ten times as much fuel.

CONCLUSION

In this chapter we have shown that there is a high potential utilization of airships in a diversity of Coast Guard missions. It is the ability of the airship to capably perform the tasks that are required on many of the Coast Guard missions that makes it an attractive platform. In the most frequently occurring missions, standard rate costs are comparable to aircraft and cheaper than cutters.

The emphasis of this analysis has been on the quantitative aspects of Coast Guard operations. The quality of an airship performing these tasks cannot really be determined until a modern airship is built. It is expected that by the nature of an airship, which combines attractive capabilities of both aircraft and ships, Coast Guard missions can be conducted very efficiently.

TABLE VIII-XIII
STANDARD RATE FOR SELECTED COAST GUARD PLATFORMS

PLATFORM TYPE	STANDARD RATE ($/HR)
LTA	450 - 600
HC-130B	1,365.16
HH-3F	910.20
MEC 210	448.30
HEC 378	1,109.24
MRS* (HU-25A)[32]	614.90

*Estimate also based on HU-16E operational experience

TABLE VIII-XIV
STANDARD RATE COST OF MISSIONS

PROFILE NUMBER	COST BY PLATFORM TYPE ($1,000)					
	LTA	HC-130	HH-3F	MEC 210	HEC 378	MRS*
2.1.11	22.8	E	E	59.2	95.4	E
2.1.15	19.8	15.7	E	51.3	80.4	E
2.1.20	25.8	E	E	39.0	63.2	E
2.2.11	34.2 ?	X	E	E	106.5	X
7.1.1	.9	1.3	1.4	2.0	2.8	.61 ?
7.1.2	2.7	3.4	5.0	4.7	6.7	1.5 ?
7.1.5	1.3	1.3	1.8	3.1	5.0	.61 ?
7.1.10	5.0	3.4	4.6	13.2	20	1.5 ?
7.1.11	6.8	6.1	E	15.9	24.4	2.8 ?
7.5.1	2.2	X	4.1	3.4	6.1	X
7.5.2	3.2	X	E	4.3	8.3	X
7.5.3	3.6	X	E	5.8	10.5	X
7.6.1	2.5	X	X	3.6	6.7	X

X - Not capable of mission

? - Doubtful capability

E - Exceeds endurance of a single platform

* - Based upon HU-16E experience and reference [32]

TABLE VIII-XV
FUEL CONSUMPTION FOR ITEMIZED MISSION PROFILES

(AIRCRAFT - POUNDS; SHIPS - GALLONS)

PROFILE		LTA	HC-130	HH-3F	MEC 210	HFC 378	MRS
2.1.11	pounds	11883	72000 E	22100 E			29750 E
	gallons	1825			21804	20567	
2.1.15	pounds	10127	46000	16150 E			19260 E
	gallons	1556			19460	18138	
2.1.20	pounds	13330	80000 E	26350 E			35000 E
	gallons	2048			14179	13384	
2.2.11	pounds	18766 ?	X	30175 E			E
	gallons	2886			34262 E	23168	
7.1.1	pounds	620	4800	1275 E			1750 ?
	gallons	95			790	650	
7.1.2	pounds	1860	12000	4875			4375 ?
	gallons	286			1842	1561	
7.1.5	pounds	930	4800	1700			1750 ?
	gallons	143			1228	1171	
7.1.10	pounds	3410	12000	4250			4375 ?
	gallons	524			5176	4682	
7.1.11	pounds	4650	21600	7650 E			7875 ?
	gallons	714			6229	5723	
7.5.1	pounds	1550	X	3825			X
	gallons	238			909	890	
7.5.2	pounds	2170	X	5525 E			X
	gallons	333			988	1049	
7.5.3	pounds	2480	X	5950 E			X
	gallons	381			1874	1930	
7.6.1	pounds	1230	Z	X			X
	gallons	189			1268	1380	

X - Not capable of mission
? - Doubtful capability
E - exceeds endurance

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CHAPTER IX
CONCLUSIONS

As a consequence of the effort described in the preceeding chapters the following conclusions are presented:

1. Airships appear on the basis of this first order analysis to have direct, cost-effective application to many maritime patrol needs.

By virtue of low operational cost (fuel efficiency) and pleasant crew environment (low vibration and noise), airship maritime patrol systems merit strong consideration.

2. Airships appear technically feasibile in maritime patrol roles.

The vehicle abilities necessary to perform the duties discussed in this report have in almost all cases been demonstrated by prior naval airship operation. One ability which has not yet been demonstrated - helicopter-style hover - appears fully achievable in the course of normal aircraft technology development. It is important to also note that the size of vehicles designed to perform the specified missions fall well within the size class of past Navy non-rigid airships.

3. Airships are not a panacea for all requirements but they do possess unique capabilities.

- Large size - deterrent in "presence" role
- Long endurance - days and weeks
- Wide speed band - slow for close observation to 100 knots for rapid transit
- Fuel efficient - hundreds not thousands of pounds of fuel per hour
- No noise into the water - for ASW and oceanographic roles
- Hover capable - for data gathering or boarding
- Excellent crew environment - low noise, low vibration, low acceleration
- Minimal ground facility requirement - long runways not necessary, and hangars only for assembly and major overhaul
- Broad weather envelope - outstanding in low visibility conditions

- Multi-mission capable - adaptable to many mission configuratons but also able to do multiple tasks on same mission (e.g., search, hover, board or retrieve, patrol, command and control, etc.)

- Stable platform - for communication, command, control in environmental protection role for example

- Very safe low altitude aircraft

4. Airships deserve special notice for energy efficient operation.

While this feature is somewhat mission dependent, it appears over a sampling of the most frequent CG missions to require:

50 percent of the fuel required for helicopters

20-50 percent of the fuel required for airplanes

15-16 percent of the fuel required for cutters

CHAPTER X
RECOMMENDATIONS

Based on the conclusions presented in the preceding chapter, several recommendations are described below:

1. LTA vehicle experimental flight demonstrations are recommended for technical and operational validation in performance of maritime patrol missions.

The implementation of this recommendation could take a variety of paths. These are listed in order of "most-for-your-money" preference accompanied by pertinent remarks.

a. Lease for demonstration purposes a modern technology airship capable of performing modern maritime operations.

Remarks. As of this date, no such vehicle exists. Several firms in the commercial sector (both U.S. and foreign) are presently making claims to have such vehicles available in six months to three years.

b. Modify an existing airship to include some modern technology features. Examples might include the addition of propulsion units which could provide a measure of hover ability or a reconfiguration to allow for the deployment/retrieval of an inflatable board.

Remarks. As of this date two firms operate vehicles which could be considered for this option. A two year program is estimated to achieve suitable vehicles.

c. The final option would be to use an existing airship - which contains no modern technology - to perform some current maritime missions. It is estimated that a flight demonstration period of six months should be sufficient to explore the operational potential for several interested government agencies.

2. It is recommended that Coast Guard requirements be determined for logistic and operational factors (training, maintenance, basing, utilization, etc.) in light of the unique abilities of airships.

3. It is recommended that in-depth point design studies of candidate vehicles address issues such as hover techniques, ground equipment definition, vehicle fabrication methods, detailed vehicle lay-outs and scaling effects for a demonstration vehicle.

This analysis should be guided by a flight validation program (Recommendation 1).

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APPENDIX A

ENVIRONMENTAL FACTORS IN AIRSHIP OPERATIONS

INTRODUCTION

Of importance in discussion of the operational feasibility of airships is consideration of the environmental factors. There are four major weather phenomena which affect the operations of air platforms. They are:

- Visibility and Ceiling Height
- Precipatation (Ice or Snow)
- Thunderstorms and Hurricanes
- High Winds

The airship contemplated for Coast Guard operations will have the following characteristics:

- 90^+ kt speed
- VTOL and hover capability
- greater than 25 hour endurance

The combination of these characteristics reduces somewhat the influence of environmental factors on operations.

The purpose of this discussion is to examine the effects of the four itemized weather conditions on the operations of a conceptual Coast Guard airship design and to compare them to the operations of heavier-than-air craft under similar conditions. Synoptic weather data (reference [A-1]) for 15 coastal areas consistent with Coast Guard operating areas has been compiled and is presented in Table A-I. This table will be referenced frequently for comparisons of airship operational limitations to operational limitations of other Coast Guard platforms.

VISIBILITY AND CEILING

Of the four weather conditions considered, an airship probably offers the greatest operational advantage for conditions of poor visibility and low ceilings. These conditions impact on both ground operations and flight operations. The minimum acceptable sight distance is a function of the minimum operating speed of the platform. A VTOL airship can operate at zero velocity and, therefore, could operate in a situation of essentially zero visibility. A major consideration in takeoffs and landings is the ability to determine the clearance over obstacles. A true VTOL platform does not have to worry about obstacles once it has identified its landing area, assuming that adequate instrument landing equipment is available.

Takeoff restrictions on current Coast Guard aircraft are dependent on whether there is an alternate place to land. For airship operations, this requirement should be much less restrictive. Because of its long endurance ability an airship, if it is ever in a situation where it is incapable of landing because of weather conditions, can either "wait out" the weather or transit considerable distances to other landing areas.

TABLE A-I
ANNUAL SYNOPTIC WEATHER DATA

LOCATION		VISIBILITY/CEILING			WIND	WIND	PREDOMINANT WIND		MEAN	SEA	SEA
NAME	LONG./LAT.	<½ mi/ 300 ft %	<¼ mi/ 150 ft %	<50 y/ 150 ft %	>33 kt %	>41 kt %	Direction	%	WIND SPEED (kt)	HEIGHT >23 ft %	HEIGHT >8 ft %
Argentia	45-47N/53-56W	13.8	12.4	12.3*	5.3	1.6	W	22.0	16.2	.5	19.
Boston	42N-Coast/66W-Coast	7.2	6.3**	5.6	3.0	.8	NW	16.8	14.2	.1	8.
New York	40N-Coast/72W-Coast	4.9	4.4**	4.2	1.6	.4	NW	14.7	12.2	.1	3.
Cape Hatteras	34-36N/75W-Coast	1.6	1.4**	1.2	2.7	.7	N	17.3	15.0	.2	11.
Miami	25-29N/78-81W	.7	.5	.5	.6	.1	E	21.7	11.9	0	5.
Guantanamo	18-20N/74-76W	.3	.2	.2	.2	0	NE	32.1	10.8	0	6.
Pensacola	27N-Coast/86-89W	.8	.5	.5	.5	.1	NW	13.9	11.7	0	5.
New Orleans	27N-Coast/89-92W	1.0	.7	.6	.6	.1	NW	14.2	11.8	0	5.
Corpus Christi	26N-Coast/95W-Coast	1.4	1.0	1.0	.8	.1	N	16.7	12.7	0	4.
San Diego	31-34N/Coast-120W	2.2	1.9	1.9	.2	0	NW	32.1	9.7	0	2.
San Francisco	36-38N/Coast-126W	4.7	3.9	3.8	1.7	.3	NW	46.1	14.2	.1	14.
Eureka	40-42N/Coast-127W	8.8	7.9	7.8	3.3	.7	N	31.5	15.2	.41	16.
Astoria	46-48N/Coast-127W	4.0	3.2	3.1	2.6	.7	NW	27.0	13.1	0	14.
Kodiak	56N-Coast/151-157W	6.3	5.6	5.5	4.8	1.2	SW	14.8	13.0	.1	12.
Adak	51-55N/172-180W	15.4	14.6	13.3	5.0	1.7	SW	16.3	15.2	.6	21.

*Visibility >55 yd, <½ mi
**Approximately

The prescribed weather minimums for Coast Guard aircraft are given in reference [A-2] and are reproduced in Figure A-1. In Table A-I, two columnes are given for visibility/ceiling restrictions. The first column gives the annual percentage of the time that the ceiling is less than 300 feet and visibility is less than one-half mile. The second column is the annual percentage of the time the ceiling is less than 150 feet and the visibility less than 50 yards.

Table A-I shows that in Adak and Argentia, operations can be significantly impacted by poor visibility/ceilings. For both of these areas Coast Guard operations are predominantly seasonal. The Argentia area is important for Marine Science Activities (MSA), primarily during the months of March through July. In Table A-II the visibility conditions and wind conditions for Argentia are listed for each month of the year. The visibility/ceiling is generally much poorer during the operational months with poor visibility conditions occuring over 35 percent of the time for the month of June. This poor visibility has a significant impact on current MSA operations. In Adak there is also a strong seasonal dependence on visibility/ceiling conditions. Also, the greatest Coast Guard operational requirement is in the spring and summer months. The Enforcement of Laws and Treaties (ELT) requirements are greatest in the months of April through July. It will be noted in Table A-III that for Adak, the visibility/ceiling is poor over 25 percent of the time for the month of July.

Poor visibility/ceilings will not only preclude heavier-than-air craft operations by preventing takeoffs and landings but will interfere with mission operations. In most search and surveillance operations, a great deal of reliance is placed on visual observations. This is true of ship operations as well as air operations. Under poor visibility/ceiling conditions, airships offer advantages over current Coast Guard ships or air platforms. Airships can manouver at slow speeds similar to ships, allowing them to operate closer to the water. Current MSA operations require HC-130 aircraft to operate at 500 ft. in an iceberg environment. When visibility is poor, these operations become very hazardous. Airships, because of their much lower speed, can perform these operations with safety.

With greater reliance on electronic sensors, such as Side Looking Airborne Radar (SLAR) and Low Light Level TV (LLTV), the advantages of an airborne platform increase. A greater all-weather capability is provided by these sensors to the airborne platforms as compared to sea-going platforms. Yet the controllability of the airship allows it to make close-in visual observations.

PRECIPATATION (ICE OR SNOW)

Ice and snow also interfere with heavier-than-air flight operations. The Coast Guard's fixed-wing aircraft have leading edge and intake de-icers and, therefore, are not greatly restricted. Helicopters, however, do not have de-icers and ice accumulation on the rotors presents a significant hazard.

Because of its large surface area and low speed, one would expect airships to be vulnerable to ice and snow accumulation. However, in the U.S. Navy's

The following minimums apply to IFR departures. Training flights and flights with a first pilot in command shall follow the criteria of subparagraph 3752.

3751 **With Departure Alternate.** Visibility must be one-fourth statute mile or RVR 16 (RVR 12 for helicopters) and departure procedures specified in the IFR Takeoff Minimums and Departure Procedures section of the appropriate approach chart VOLUME or MAN complied with. Departure alternates are selected as follows:

(a) Aircraft must be capable of maintaining MEA to the alternate (less jettisonables) if an engine fails.

(b) Weather at a departure alternate within 30 minutes flying time (based upon one engine inoperative configuration) must be at or better than approach minimums (ceiling and visibility) at takeoff time and forecast to remain so for 1 hour.

(c) Weather at a departure alternate within 1 hour flying time for helicopters and two-engine aircraft, or within 2 hours flying time for four-engine aircraft (based upon one engine inoperative configuration) must have at least an 800-foot ceiling and 2 miles visibility for non-precision approach; a 600-foot ceiling and 2 miles visibility for precision approach and forecast to remain so for 1 hour after ETA at alternate.

3752 **Without Departure Alternate.** Weather must be at or better than the takeoff minimums (ceiling and visibility) for the airport, when published. (Takeoff minimums are established for certain airports to ensure obstruction clearance during climb to MEA. Tabulation of these minimums can be found in the front of the DOD FLIP Terminal Low Altitude Publications.) If specific takeoff minimums are not published, the visibility must be one statute mile or RVR 50 for reciprocating engine, fixed-wing aircraft, with two engines or less; or one-half statute mile or RVR 24 for other fixed-wing aircraft and helicopters.

3753 **Exception.** When the immediate urgency of the mission dictates, the commanding officer of the parent unit or the aircraft commander on detached duty or at a remote location, may [Consideration must be given to equipment ca]pabilities, alternate field availability, and the circumstances justifying the urgent requirement.

3760 *Instrument Approaches*

3761 Instrument approaches will be made only to air facilities for which there is an approved instrument approach procedure.

3762 **Approach and Landing Minimums.** Approach procedures approved by either the FAA or DOD will apply. An approach may be started and flown to minimums when the reported weather is below minimums; however, the pilot will not descend below published MDA/DH, or land, unless he can (1) comply with FAR 91.117 or (2) proceed with a contact approach.

3763 Helicopter Approach Minimums

(a) Helicopters may utilize the category A MDA or DH regardless of weight.

(b) Helicopters may circle to land at the straight-in MDA or DH as long as they can accomplish the maneuver within 500 feet of the runway centerline and remain within the airport boundaries.

3764 *Alternate Airport Minimums.* Published alternate airport minimums apply. (IFR alternate minimums can be found in the front of the DOD FLIP Terminal Low Altitude Publications.) In the absence of published alternate minimums, either because the published minimums do not exist or because the information is not readily available, the following criteria shall apply:

(a) The forecast weather at alternate airport, for the period beginning 1 hour before until 1 hour after alternate ETA, must be at least an 800-foot ceiling and 2 miles visibility for airports served by a non-precision approach; and a 600-foot ceiling and 2 miles visibility for airports served by a precision approach.

(b) *In no case shall* an alternate be selected with forecast weather below circling minimums.

Figure A-1. Existing Flight Regulations.

TABLE A-II
MONTHLY SYNOPTIC WEATHER DATA - ARGENTIA

MONTH	VISIBILITY/ CEILING <½ mi/<300 ft %	VISIBILITY/ CEILING >55 yd, <¼/<150 ft %	WIND SPEED >33 kt %	WIND SPEED >41 kt %	MEAN WIND SPEED
JANUARY	7.7	5.8	10.0	1.2	20.3
FEBRUARY	6.7	5.5	10.2	1.9	21.2
MARCH	8.8	6.9	8.8	1.2	19.5
APRIL	11.5	10.0	4.2	.9	16.6
MAY	17.9	16.5	1.8	0	13.6
JUNE	35.2	23.7	1.0	.2	12.5
JULY	32.9	31.2	.3	.1	11.3
AUGUST	20.6	19.0	.5	.2	12.2
SEPTEMBER	12.2	11.0	2.0	.6	14.1
OCTOBER	7.9	6.9	3.8	.7	16.3
NOVEMBER	9.1	7.5	6.7	2.1	18.0
DECEMBER	7.1	5.8	10.4	.9	19.9

TABLE A-III
MONTHLY SYNOPTIC WEATHER DATA - ADAK

MONTH	VISIBILITY/ CEILING <½ mi/<300 ft %	VISIBILITY/ CEILING >55 yd, <¼/<150 ft %	WIND SPEED >33 kt %	WIND SPEED >41 kt %	MEAN WIND SPEED
JANUARY	8.9	7.8	7.5	1.0	17.8
FEBRUARY	6.1	4.7	10.8	2.2	19.7
MARCH	11.1	8.9	8.1	1.1	18.0
APRIL	9.8	8.1	6.4	1.0	17.0
MAY	12.9	10.9	4.0	.3	15.5
JUNE	14.8	13.5	.6	0	12.4
JULY	29.1	25.3	.7	0	11.9
AUGUST	27.0	13.4	.7	.1	12.6
SEPTEMBER	12.5	9.9	3.1	.8	15.2
OCTOBER	4.0	3.2	7.2	1.2	17.1
NOVEMBER	7.8	7.0	9.3	2.3	19.0
DECEMBER	17.8	7.0	9.5	1.1	17.8

experience, no airship was ever lost or damaged in the air due to snow or ice. This includes winter operations during World War II as well as AEW operations in the late 1950's and early 1960's. Accretion of ice and snow on the envelope of the airship does not occur to the point of endangering safety of flight. Hazardous accumulation can normally be prevented by altitude changes during operations; or, on some occasions, the envelope pressure can be reduced which induces flexure which mechanically de-ices the envelope.

In the mid-1950's the Navy specifically investigated the capability of airships to operate in icing conditions. An airship was instrumented with equipment to measure ice and snow accretion and purposely flown into icing weather. The successful results of this experimental projected are documented in reference [A-3].

The greatest danger of ice and wet snow can occur when the airship is on the ground. This problem can be overcome through mechanical sweeping of the envelope. The primative method of throwing a rope over the envelope and walking it the length of the airship has proven effective in preventing excessive accumulation. More sophisticated methods such as heating the gas could easily be employed.

The VTOL capability of the airship eliminates the expensive and time consuming chore of snow plowing and salting runways.

THUNDERSTORMS AND HURRICANES

Thunderstorms are the nemesis of all aircraft and are avoided if at all possible. This can be accomplished by waiting out, or either flying over or around the storms. The altitude capability of the HU-25 (MRS) permits it to fly over moderate thunderstorms. When penetration is necessary it is usually done at the lowest possible altitude consistent with safe operations. Safest penetration is usually between 4,000 and 6,000 feet.

Again, the long endurance of the airship provides it a large margin of safety when facing a thunderstorm situtation. Isolated thunderstorms can usually be avoided by flying around them. In a squall line, it is best to go around the line, or if this is not possible, to pick the least severe point for penetration. Previous airships with their low maximum speeds were more susceptible to encounters with thunderstorms. The conceptual Coast Guard airship designs with a 90^{+} knot speed capability give greater capability to avoid thunderstorms.

Hurricanes are a severe hazard to all aircraft. These are, however, relatively rare meteorological phenomena, and there is usually a great deal of advanced warning. Since this study assumes that there will not be hangars at the airship bases, airships at the mast would be vulnerable to hurricane force winds. With advanced warning, the airships can be flown to an alternate base or remain in the air at a safe distance from the storm.

HIGH WINDS

Of all of the itemized weather conditions, high winds probably have the greatest impact on airship operations as compared to other aircraft. High winds impact on airships both while in flight and during ground operations. Because of its relatively low speed, an airship's flight operations are affected by high winds. Likewise, because of its large traverse profile, high winds can interfere with ground operations.

Airships, because of aerodynamic factors (i.e., virtual mass), have a greater inertial mass than their gravitational mass (reference [A-4]). Because of their lower speed compared to heavier-than-air craft, high winds will have a greater impact on the slower moving airship. In a previous analysis (reference [A-5]) the effective ground speed of an airship traveling into the wind and returning with a tail wind was analysed. The effective ground speed for this round trip was derived as

$$V_e = \left(1 - \frac{W^2}{V^2}\right) V$$

where

V_e = the effective ground speed
V = the airship speed, and
W = the wind speed.

This turns out to be the worst case. For the general case, where the wind is at an angle θ to the direction of the flight, the effective ground speed is:

$$V_e = \frac{\left(1 - \frac{W^2}{V^2}\right) V}{\sqrt{1 - \frac{W^2}{V^2} \sin^2\theta}}$$

For flights perpendicular to the wind (crosswind), which is the best case, the effective velocity is:

$$V_e = \sqrt{1 - \frac{W^2}{V^2}}\; V$$

Figure A-2 shows the $\frac{Ve}{V}$ (defined as Φ_e in the figure) as a function of the ratio of wind to airship velocity for both head/tail wind, and cross wind cases.

$$\frac{V_e}{V} = 1 - \frac{W^2}{V^2} \text{ for head and tail wind}$$

$$\frac{V_e}{V} = \sqrt{1 - \frac{W^2}{V^2}} \text{ for cross winds}$$

It can be seen from this figure that the difference between these two cases is most significant as the wind speed approaches the airship speed. When the wind speed is one-half the airship speed, for the cross wind case, the average round trip ground speed is almost 90 percent of the airship speed but for the head/tail wind case it is 75 percent. For a 90 kt airship the wind speed must be almost 45 kts before there is a 10 percent loss of effective speed in cross wind conditions. From Table A-I, Synoptic Weather Data, it is seen that a 45 knotwind is a rare occurrence at lower altitudes.

Table A-IV shows the effect of the average wind speed for cross wind and head/tail wind on airship performance for coastal areas consistent with Coast Guard operations. Airship speeds of 50, 60, and 90 kts are considered. The 50 to 60 kt range is the cruising speed range for conceptual Coast Guard airship designs and the 90 kt speed is the maximum operating speed for this airship. Based upon the annual mean wind velocities at the surface for all of these locations there is less than a 10 percent loss of effective speed in all cases for the 50 kt speed and a 2 to 3 percent loss of effective speed for the 90 kt case.

Table A-IV is based upon mean annual wind speeds at ground level. With increasing altitude the mean speeds will increase. There are also significant monthly and diurnal variations for most locations. However, the predominant Coast Guard application for airships is area search. Since the predominant consideration in area search operations is that a specified area be covered, the direction of search is usually not significant. In practice the airships' operations can be tailored to take advantage of the prevailing wind condition. If there is a strong head wind, searches can be conducted in a parallel back and forth crosswind direction. If there is a strong diurnal variation where there are offshore winds at the beginning of the operation and onshore winds at the end, the airship can take advantage of tailwinds in both directions.

The impact of high winds on the effective speed of airships will probably be most significant in Search and Rescue operations (SAR) where there is much less latitude in operations. However, the conceptual airships' speed of 90 kts is not significantly different from that of helicopters. The long endurance, stability, lower vibration levels, and range of the airships should more than compensate for differences in effective speed due to wind for many of the SAR operations currently employing helicopters.

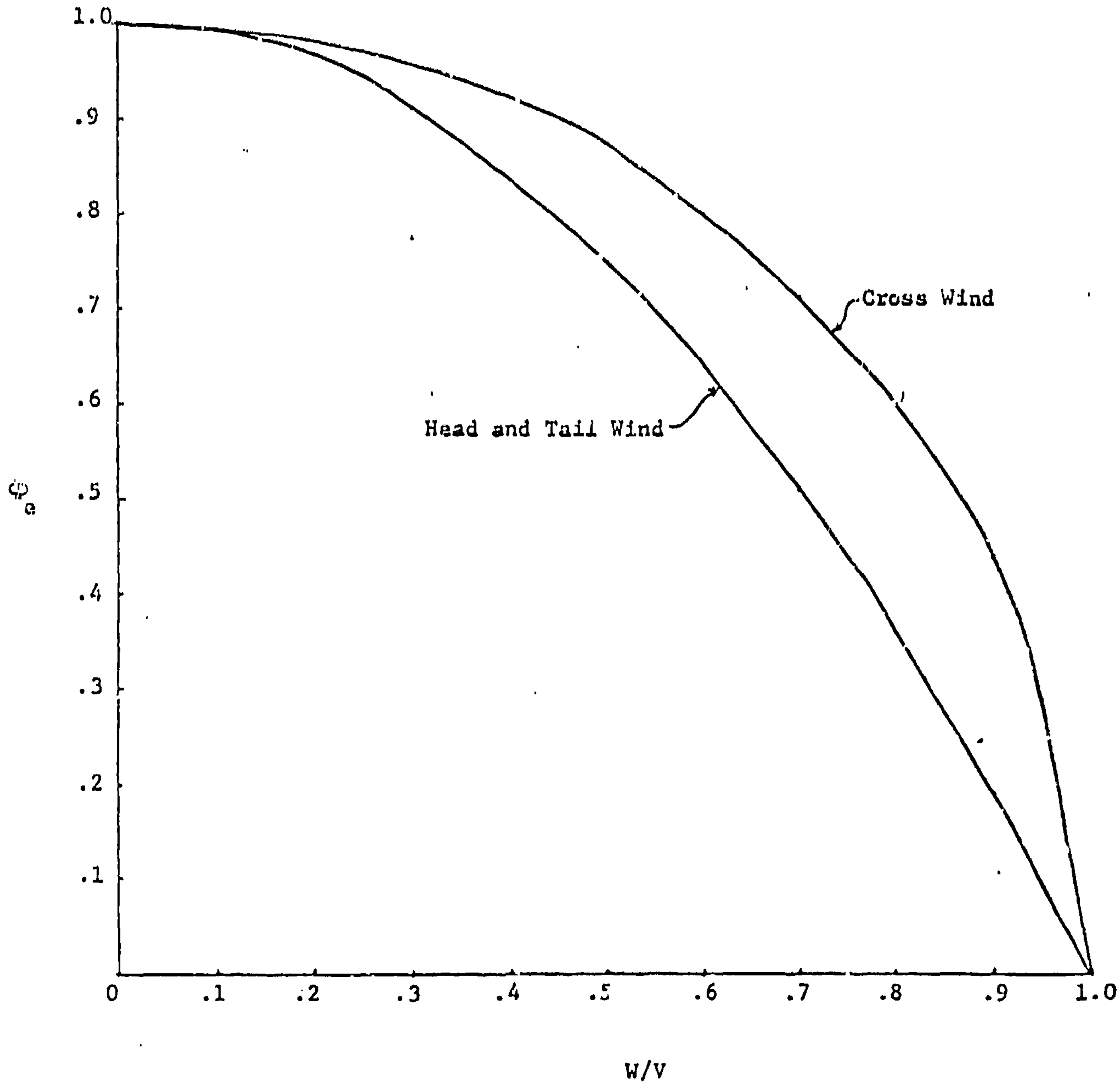

Figure A-2. Effective Velocity Coefficient as a Function of Wind to Air Speed Ratio.

TABLE A-IV
EFFECTIVE SPEED AS A FUNCTION OF MEAN WIND SPEED FOR VARIOUS LOCATIONS

WIND DIRECTION / AIRSHIP SPEED / LOCATION	HEAD/TAIL WIND 50 kt	CROSSWIND 50 kt	HEAD/TAIL WIND 60 kt	CROSSWIND 60 kt	HEAD/TAIL WIND 90 kt	CROSSWIND 90 kt
Argentia	45.0	47.3	55.6	57.8	87.1	88.5
Boston	46.0	47.9	56.6	58.3	87.8	88.9
Kodiak	46.5	48.3	57.2	56.6	88.1	89.1
New York	47.0	48.5	57.5	58.8	88.3	89.2
Adak	45.4	47.6	56.2	58.0	87.4	88.7
Cape Hatteras	45.5	47.7	56.2	58.1	87.5	88.7
Miami	47.2	48.6	57.6	58.8	88.4	89.2
Pensacola	47.3	48.6	57.7	58.8	38.5	89.2
New Orleans	47.2	48.6	57.7	58.8	88.5	89.2
Corpus Christi	46.8	48.4	57.3	58.6	88.2	89.1
San Diego	48.1	49.0	58.4	59.2	89.0	89.5
San Francisco	46.0	47.9	56.6	58.3	87.8	88.9
Astoria	46.6	48.2	57.1	53.6	88.1	89.0
Guantanamo	47.7	48.8	58.1	59.0	88.7	89.3
Eureka	45.4	47.6	56.2	58.0	87.4	88.7

Increasing wind speed with altitude is not expected to severely impact airship effectiveness. Figure A-3 (taken from reference [A-5]) shows that for altitudes of 4,782 ft. and less, the 90th percentile wind speed never exceeds 50 kts for the specified locations. The design altitude for the conceptual airship is 5,000 ft. For most locations the 90th percentile for 1,773 ft. is significantly lower for all seasons. If higher altitude winds are much greater the airship can operate at lower altitudes with little loss of performance. Table A-V provides analysis of airship effectiveness at low altitudes (approximately 1,800 ft.) for selected areas in crosswind conditions and head/tail wind conditions. We again find little loss of performance, especially for crosswind operations.

High winds will also impact on the ground operations of an airship. Traditional airships required dynamic runway takeoffs and large ground crews to maneuver from mast or hangar to the runway. High winds made ground operations hazardous if not impossible. Hangaring an airship in a high crosswind is an extremely difficult job.

With a VTOL-capable airship most of the ground handling crew can be eliminated. Since this study assumes that there are no hangars at the airship bases, hangaring is not a major concern. The exact nature of ground handling of a VTOL airship cannot be determined until experience with a prototype has been obtained. However, based upon experience with traditional airships, ground operations should not be hampered in winds of less than 30 to 40 kts. It is expected that for a VTOL airship, ground operations should be possible in winds up to 60 kts.

For the sake of analysis, based upon the available data base, data for winds of greater than 33 kts and 41 kts for areas of interest have been compiled in Tables A-I, A-II, and A-III. From Table A-I we see that the frequency of occurrence, on an annual basis, of winds greater than 33 kts is less than 6 percent for all locations and less than 2 percent for 41 kts winds. Assuming that 33 kt winds preclude operations because of ground handling problems, we see that for all locations, except Cape Hatteras, the wind restrictions on airship operations are less severe than the visibility restrictions on heavier-than-air craft operations. From Tables A-II and A-III we see that for Argentia and Adak, respectively, for the months of interest (spring and summer), the wind conditions are most favorable while the visibility is the poorest.

SUMMARY

All aircraft are affected by extremes in environment; airships are no exception. Under some conditions they are less severely affected than heavier-than-air craft; under other conditions they are more affected. Because of their low speed controllability, they are less susceptible to poor visibility and low ceilings. The airships' long endurance and range provides safety margins for avoiding severe storms. Icing and snow have traditionally not been a problem during flight operations, but can create problems when the airship is at the mast. High winds have probably the greatest effect on airship operations. They will decrease the effectiveness of flight operations and interfere with ground operations.

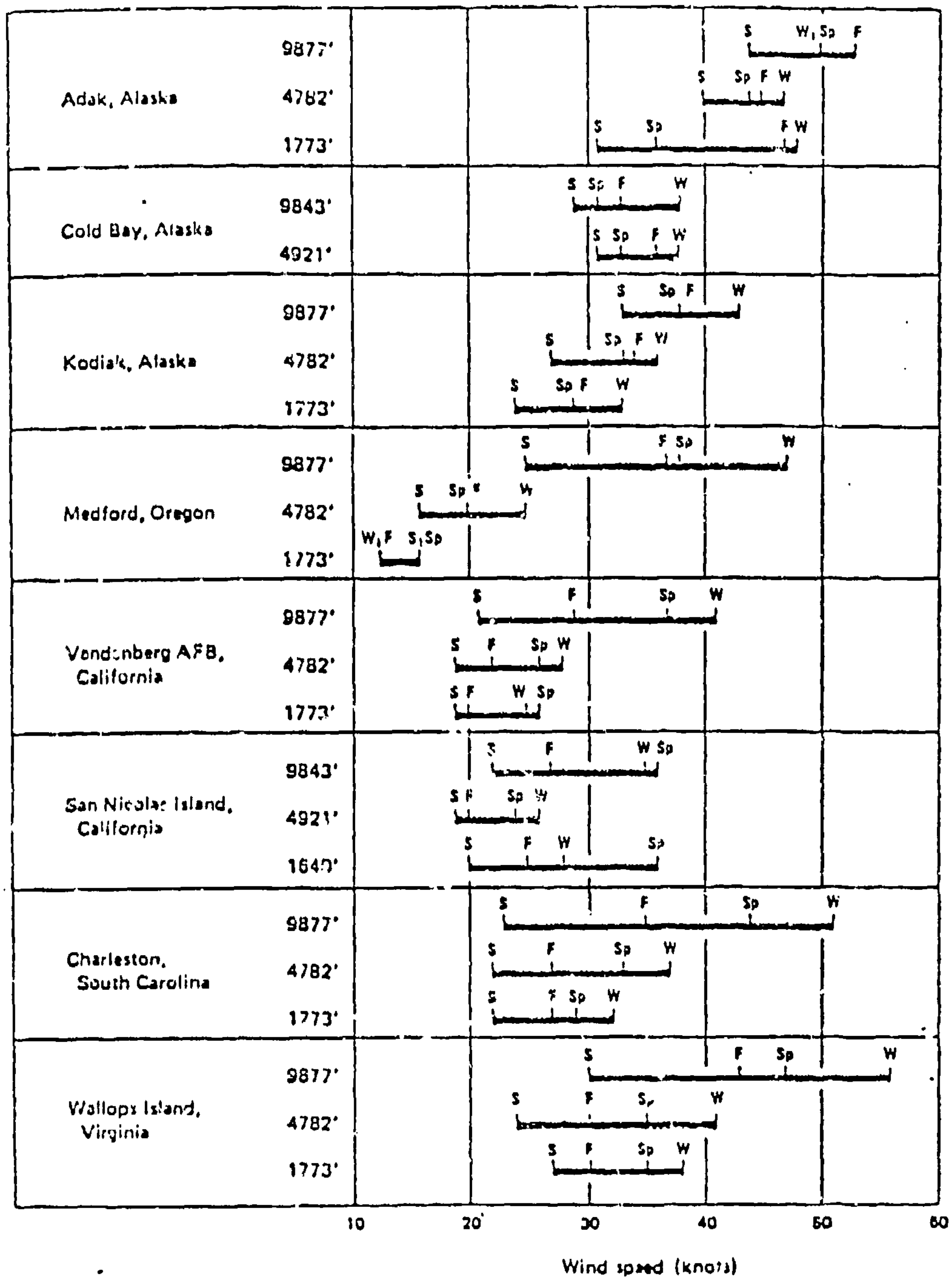

Figure A-3. 90th Percentile Distribution

TABLE A-V
EFFECTIVE SPEED FOR VARIOUS LOCATIONS AT LOW ALTITUDES

Location Altitude	Season	50 Knot Air Speed Head/Tail Wind	50 Knot Air Speed Cross-Wind	60 Knot Air Speed Head/Tail Wind	60 Knot Air Speed Cross-Wind	90 Knot Air Speed Head/Tail Wind	90 Knot Air Speed Cross-Wind
Wallops	S	.89	.94	.92	.96	.97	.98
Island, VA	F	.84	.92	.89	.94	.95	.97
	W	.74	.86	.82	.91	.92	.96
1,773 Feet	Sp	.79	.89	.86	.93	.94	.97
Charleston,	S	.90	.95	.93	.96	.97	.98
SC	F	.87	.92	.91	.95	.96	.98
	W	.82	.91	.87	.93	.94	.97
1,773 Feet	Sp	.84	.92	.89	.94	.95	.97
San Nicolas	S	.92	.96	.94	.97	.97	.98
Island, CA	F	.89	.94	.92	.96	.97	.98
	W	.86	.93	.91	.95	.96	.98
1,640 Feet	Sp	.81	.90	.87	.93	.94	.97
Vandenberg	S	.93	.96	.95	.97	.98	.99
AFB, CA	F	.93	.96	.95	.97	.98	.99
	W	.90	.95	.93	.96	.97	.98
1,773 Feet	Sp	.88	.94	.92	.96	.96	.98
Medford,	S	.96	.98	.97	.98	.99	.99
OR	F	.97	.98	.98	.99	.99	.99
	W	.97	.98	.98	.99	.99	.99
1,773 Feet	Sp	.96	.98	.97	.98	.99	.99
Kodiak,	S	.92	.96	.94	.97	.97	.98
AK	F	.87	.93	.91	.95	.96	.98
	W	.85	.92	.89	.94	.95	.97
1,773 Feet	Sp	.88	.94	92	.96	.96	.96
Adak,	S	.84	.92	.89	.94	.95	.97
AK	F	.76	.87	.84	.92	.93	.96
	W	.76	.87	.84	.92	.93	.96
1,773 Feet	Sp	.79	.89	.85	.92	.93	.95

Flight operations of a 90 kt airship should not be significantly impacted by high winds for the operating areas and conditions of interest. Without operating experience it is difficult to judge the effect of high winds on ground handling requirements of a VTOL airship. Using a conservative estimate that winds of greater than 33 kts will prevent ground handling operations, we find that the frequency of occurrence of winds of greater than 33 kts is less than the frequency of poor visibility/ceiling which will impact on heavier-than-air operations for all locations of interest, except for Cape Hatteras.

Even when considering ship operations significant environmental factors affect operations. In Table A-I the frequency of occurrence of eight foot or greater seas is much greater than the frequency of occurrence of high winds. There is a high correlation between wind speed and sea state. When adverse conditions exist in one medium they usually are adverse in the other. While at-sea operations may not be terminated due to high seas, the efficiency of sea-going platforms in performing their mission is degraded. Figure A-4 (reference [A-6]) shows the degradation of ship speed as a function of significant wave height. For a destroyer escort (DE), which should be comparable to a MEC/HEC, we find for 10 ft. seas there is a 20 percent loss of speed.

CONCLUSIONS

In conclusion we find that airships offer superior performance to heavier-than-air craft in bad visibility/ceiling conditions, and that performance is comparable to propeller driven and rotary wing aircraft in thunderstorms. Airship flight operations are not affected by snow or ice but require snow removal from the envelope when masted. High winds do impact operations, both in the air and on the ground. However, the occurrence of high wind conditions is less than the occurrence of poor visibility (which impacts on heavier-than-air craft operations) or high seas (which impact on ship operations).

In reference [A-7], 24 months of airship operations of the airship Early Warning Squadron-1 (ZW-1) are documented. These operations were conducted during the period of early 1957 through June of 1959. The airships were based at Lakehurst, New Jersey, with operations conducted 180 nmi southeast of Lakehurst. During this period there was one hurricane (Carrie, September 1957) and a severe winter that included a record snow storm that closed the runway for five days. Yet, despite these adverse conditions, no operations were lost due to the hurricane, and excepc for the period in which the runway was closed, the flight schedule goals of 288 sensor hours on stations per month were met. Most flights were greater than 24 hours duration with the premature termination of flights usually due to equipment failures (normally mission oriented electronic equipment). A VTOL-capable airship would not have lost the five days of operation due to snow on the runway.

An additional substantiation of airship all-weather flight experience is contained in a quotation by the Assistant Secretary of the Navy for Air in January 1957:

> "On the 14th of January — 11 days ago — we placed one of our latest airships — a ZPG — on patrol in the North Atlantic,

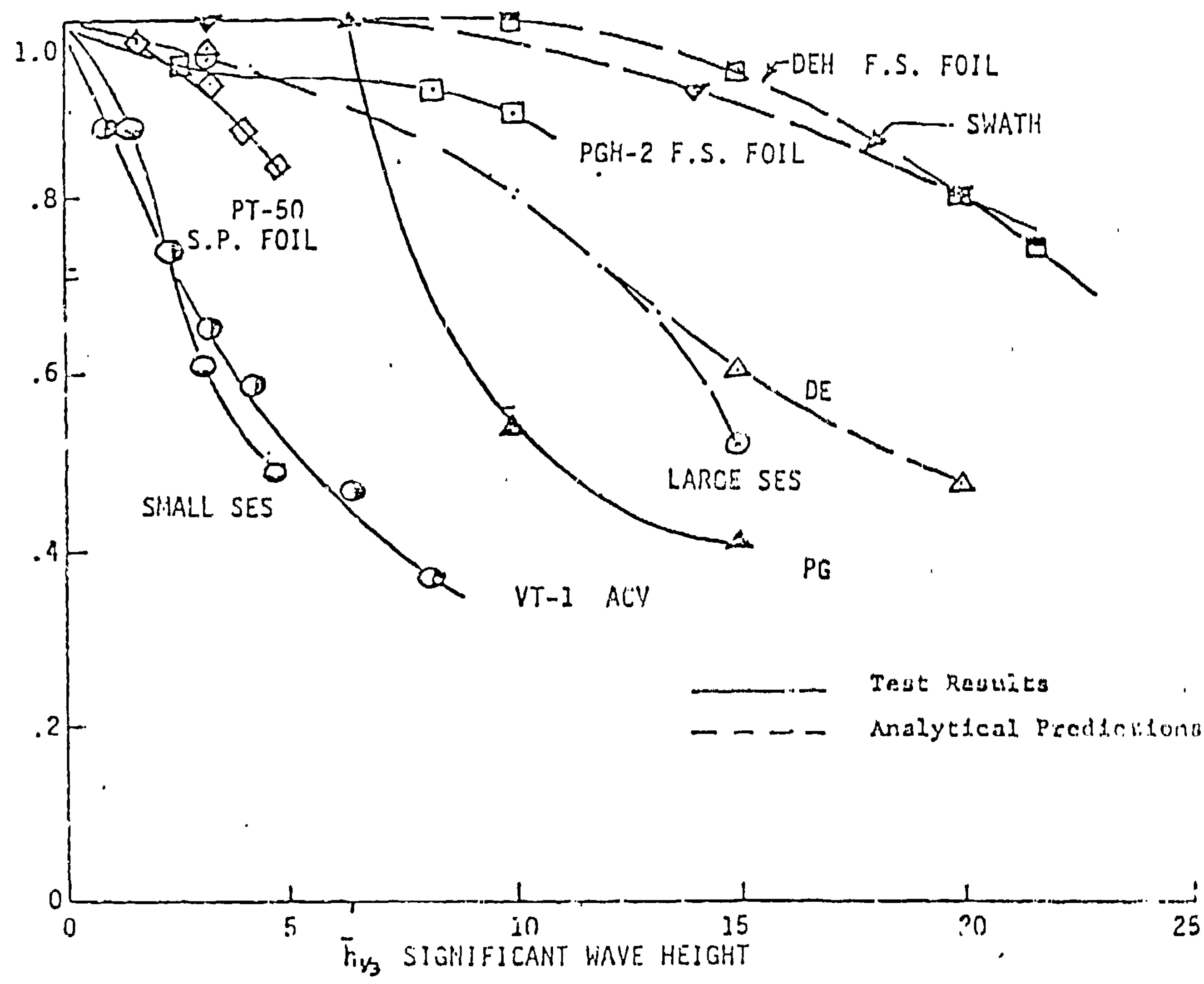

Figure A-4. Degradation of Speed Vs. Significant Wave Height.

about 200 miles off the East Coast. Twenty-four hours later a sister ship relieved her on station. This turn-over was repeated at long intervals. The watch was maintained continuously through some of the worst weather the East Coast has experienced in 35 years. These airships flew through extremes of snow, freezing rain, winds of 60 miles per hour, and extreme turbulence -- conditions which at times kept all planes grounded. One airship flew in icing conditions for 32 hours on a 40 hour flight. Another was airborne for over 56 hours. At 9:20 this morning the last flight landed at NAS South Weymouth, Massachusetts, successfully completing an all weather evaluation which provided a continuous airborne alert of over ten days."

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A-2 Coast Guard Air Operations Manual, Department of Transportation, September 14, 1976, CG No. 333.

A-3 Second Partial Report on Project NDSW/ONR-46101, Evaluation of the All Weather Capabilities of Airships, Naval Air Development Unit, South Weymouth, March 1, 1957.

A-4 Airship Stresses Due to Vertical Velocity Gradients and Atmospheric Turbulence, Duncan Sheldon, Proceedings of the Interagency Workshop on Lighter-Than-Air Vehicles, Ed. Joseph F. Vittek, Jr., MIT Flight Transportation Laboratory, FLT Report R75-2, January 1975, Pg. 158.

A-5 Assessment of Selected Lighter-Than-Air Vehicles for Mission Tasks of the U. S. Coast Guard, Ralph E. Beatty, Jr., Richard D. Linnel, Department of Transportation, United States Coast Guard, Office of Research and Development, May 1978, Washington, DC, CG D-39-78.

A-6 Performance Characteristics of High Performance and Advanced Marine (HIPAM) Surface Vehicles, Jon Buck, Colen G. Kennell, Nathan R. Fuller, presented at the Chesapeake Section, Society of Naval Architects and Marine Engineers, October 9, 1974.

A-7 An Operational Evaluation of Airship Early Warning Squadron One (ZW-L), Goodyear Aircraft Corporation, December 2, 1957, May 14, 1958, September 26, 1958, May 6, 1959, Akron, Ohio, GER 8438 S/1, GER 8439 S/2.

APPENDIX B

DOCUMENTATION OF RADAR SWEEP-RATE PARAMETERS

This discussion presents values and assumptions used in the Maritime Patrol Airship Study for radar sweep-rate. The analysis is based upon the HU-25 (MRS) equipment performance specified in reference [B-1]. The assumptions made and final choice of parameters are consistant with reference [B-2].

It was assumed that for search for surface vessels the APS-127 Forward-Looking Radar will be used. For detection of pollution the APS-94 Side-Looking Radar will be used. The performance curves for these radars are taken from reference [B-1] and are given in Figures B-1 and B-2 respectively.

The performance curves given in Figure B-1 is a .5 probability of detection on a single scan. Reference B-1 assumes, due to multiple scans on the same target, that for the MRS this is equivalent to a .9 probability of detection. In reference [B-2] it is assumed that, since an airship sweeps at a lower speed than the MRS (approximately 50 kts versus approximately 250 kts) it will have more opportunities to detect and, therefore, can detect a large target at a 20 percent greater range than the MRS. For a small target an airship is assumed to have a 50 percent greater detection range.

Since the APS-127 has a 120° sector scan, a 60 nmi sweep width equivalent to a 30 nmi lateral range, requires an approximate detection range of 35 nmi (reference [B-3]). Using the 20 percent enhancement factor (reference [B-2]), a 29 nmi detection range is required. From Figure B-1, this is equivalent to the detection range for a 150 M^2 target reflectivity or a 175 foot steel boat. To obtain a 35 nmi horizon an approximate altitude of 850 feet is required and a 2° depression of the radar.

From Figure B-1 it is seen that the radar is sea state limited for Sea State 3 at approximately 25 M^2 target reflectivity which is equivalent to a 80' wood boat. This corresponds to a 20 nmi detection range. Correcting for geometry and the 50 percent enhancement factor this equates to an approximate 50 nmi sweep width.

For oil slicks, based upon the performance of the APS-94 radar given in Figure B-2 (reference [B-1]) the 50 percent enhancement factor and the Sea State limit, an approximate 30 nmi sweep width can be expected.

These results can be summarized as follows:

Target	Sweep Width	Target Reflectivity
Large Target	60 nmi	150 M^2
Small Target	50 nmi	25 M^2 (Sea State 3 limit)
Oil Slick	30 nmi	20 M^2 (Sea State 3 limit)

REFERENCES

B-1 U.S. Coast Guard MRS Sensor System Cost Benefits, CG-D-105-76, Naval Air Development Center, K. T. McOueen and J. A. Monastra, October, 1976.

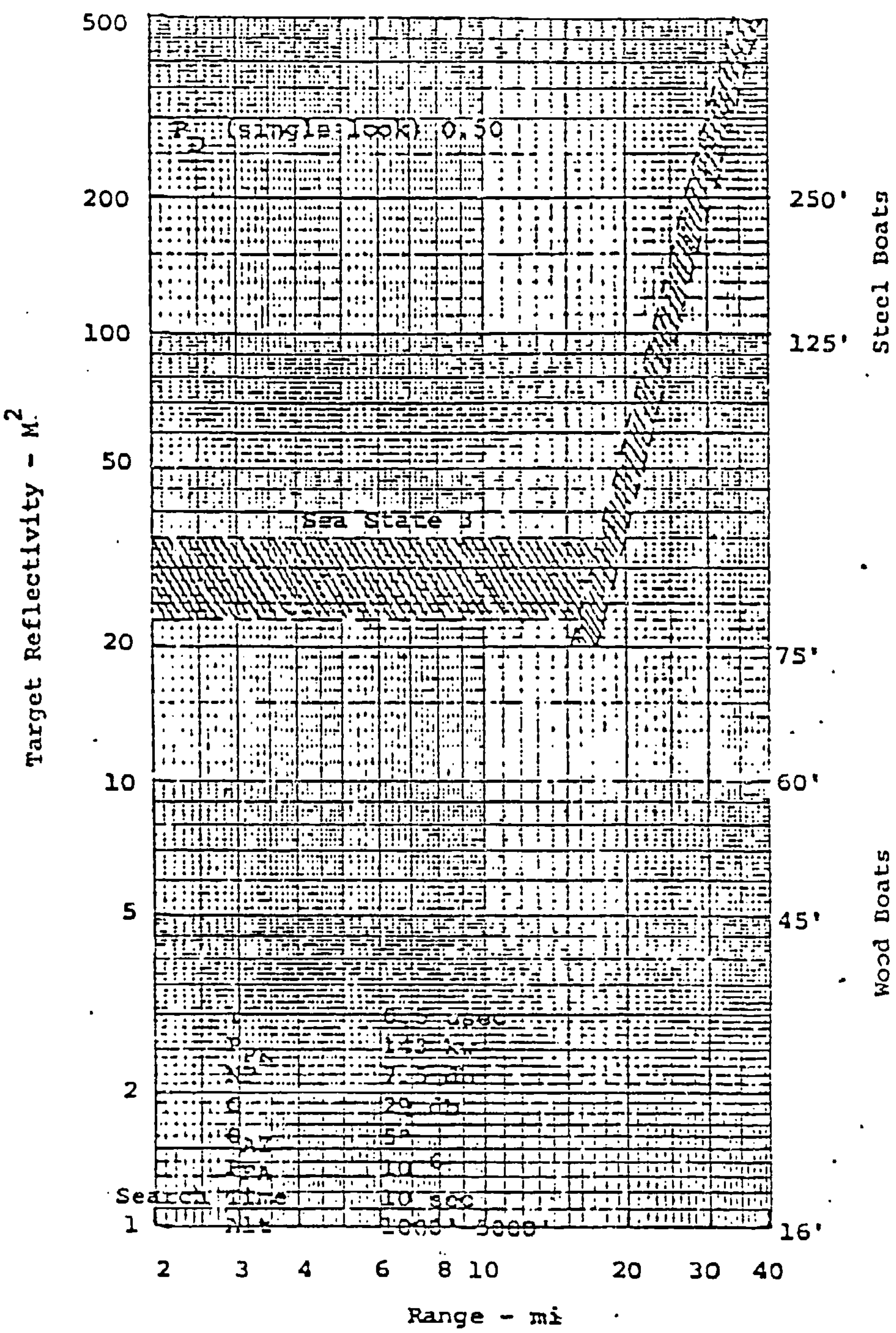

Figure B-1. APS-127 Forward-Looking Radar Detection Performance.

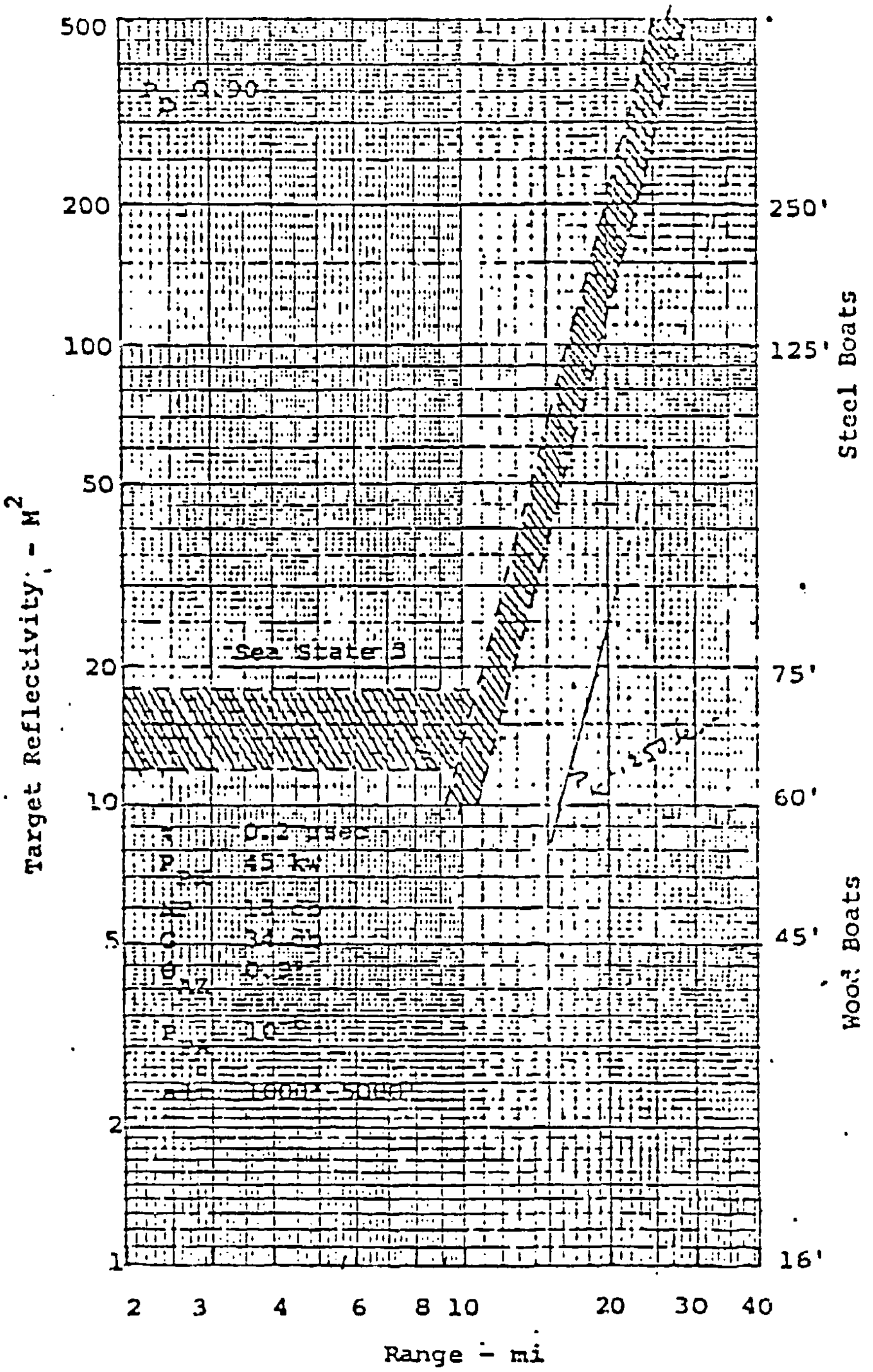

Figure B-2. APS-92 Side-Looking Radar Detection Performance.

B-2 Assessment of Selected Lighter-Than-Air Vehicles for Mission Tasks of the U.S. Coast Guard, CG-D-39-78, R. E. Beatty, Jr., and R. D. Linnel, Center for Naval Analyses, May, 1978.

B-3 AN/APS-127 Airborne Radar System Evaluation, O. Kessler and S. R. Swyers, Naval Air Development Center Report NADC-77283-20, September, 1977.

APPENDIX C

NAVAL AIRSHIP PROGRAM FOR SIZING AND PERFORMANCE (NAPSAP)

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NAPSAP was developed for general in-house use in sizing airships via a parametric approach and in conducting missions based on predicted performance and mission requirements (reference [C-1]). NAPSAP is the result of four basic objectives in generating a useful analytical tool. These were: (1) the program must be easy to use and require an absolute minimum of input data; (2) the program must provide easy parametric analysis of the influence of all major design and performance variables; (3) the program must be capable of evaluating vehicle performance capability over the complex mission profiles and (4) the program architecture must be capable of easy modification for future add-on program sections.

The program has been designed to operate on a minimum of input data (only five cards are necessary), but has the capability to evaluate the influence of over 40 key parameters. NAPSAP provides easy parametric analysis for several optional levels of detail. Once the design section of NAPSAP converges on a vehicle which meets the input requirements, this vehicle can then be evaluated against a specified mission profile with all key parameters monitored at preselected time intervals.

PROGRAM APPLICATION OVERVIEW

There are two major applications of the current NAPSAP program. The first ("Basic Case") allows a vehicle to be sized in terms of a simplified set of input data and its performance to be evaluated in terms of payload as a function of range at the input design speed. The second major application allows the performance of the "Basic Case" vehicle to be evaluated over multi-segment mission profiles. Several options may be exercised for parametric analyses and sensitivity studies of these two basic program applications.

NAPSAP currently can analyze two types of LTA vehicles: rigid airships of conventional, Zeppelin-type construction (e.g., wire braced main frames, longitudinal girders with cruciform empennage), and non-rigid airships similar to the type most recently operated by the U.S. Navy (see reference [C-2]). Either type of vehicle can be analyzed at a range of gross weights, including those greater than the total static lift (i.e., in a "heavy" condition).

The propulsion system may be sized for either a conventional take off using a ground run to develop aerodynamic lift or for vertical take off at maximum gross weight. Three types of engines may be utilized: gas turbines, diesels, or spark ignition reciprocating engines ("recip's"). Rotors or propellers may be analyzed on a point design basis by utilizing dedicated subroutines.

BASIC PROGRAM OVERVIEW

The basis NAPSAP program methodology is illustrated in the top level flow chart of Figure C-1.

Input data is read in and program initilizations are performed. The Basic Case vehicle evaluation requires only five input data cards. Vehicle input characteristics are used to size the vehicle and determine its overall physical

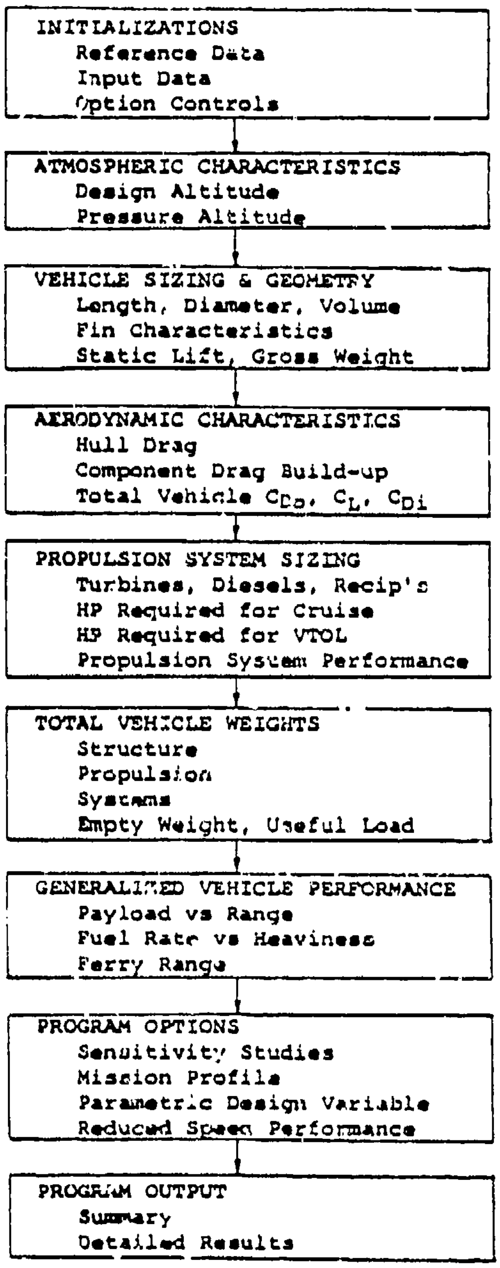

Figure C-1. Basic NAPSAP Program Top Level Flow Chart.

and geometric characteristics. Vehicle sizing is based on an input value of volume or gross weight, and static lift to gross weight ratio (Beta), length to diameter ratio, prismatic coefficient, design altitude, and unit lift of the lifting gas at sea level standard conditions.

The aerodynamic characteristics are calculated for zero angle of attack and the angle of attack required for cruise at maximum gross weight. Total vehicle drag coefficient at zero angle of attack is estimated on a simplified component build up approach based on drag breakdown of prior Navy non-rigid airships. Induced drag is based on the expression used by previous Navy airship design methods. The drag at the input design conditions (gross weight, speed, and altitude) is used to determine the horsepower required for cruise. If vertical take off (VTO) is required, the horsepower requirements for VTO at maximum gross weight are also calculated. The largest required horsepower sizes the propulsion system.

All propulsion calculations are based on "rubberized" engines and conventional propellers or rotors which are tilted for vertical take off, landing, and hover. Propellers are sized by an approximation of Hamilton Standard propeller performance (reference [C-3]). Propeller efficiency as a function of velocity is based on the data presented in references [C-4] and [C-5] (separate subroutines have been developed for detailed point design analysis of rotors and propellers). Bare engine weight per horsepower and specific fuel consumption (SFC) as a functon of horsepower are based on the data of reference [C-6]. Fuel consumption for each engine cycle is corrected for airspeed, altitude, and throttle effects based on the data presented in references [C-6] and [C-7].

Next, the vehicle weight characteristics are calculated. These include the non-propulsive structure weight, the total propulsion system weight; the vehicle systems weight, the total vehicle empty weight, and useful load.

Non-rigid airship weights are estimated by simplified weight estimating relationships (WER's) developed from an analysis of previous Navy weight reports and recent studies (references [C-4] and [C-8]). Rigid airship structural weight is based on the WER's utilized in the NASA Ames Research Center version of the Boeing CASCOMP (reference [C-9]) program. Advanced state-of-the-art materials effects can be applied to the rigid airship WER's using the results presented in reference [C-5] study (Appendix A). Propulsion system weights are based on the data of references [C-5], [C-9], [C-10], and [C-11]. System weights are based on a combination of prior vehicle actuals and generalized WER's from reference [C-8]. The subsystem weights are summed to obtain the total vehicle empty weight, and the useful load is calculated.

The "generalized performance" is calculated for the vehicle sized above. This calculation consists of calculating the payload as a function of range for the vehicle flying at input (design) airspeed and altitude. Once neutral buoyancy is reached, the remainder of evaluation assumes zero angle of attack flight. Calculations proceed to the point where the total vehicle useful load has been consumed as fuel and fuel reserves.

The program calculations may be terminated at this point or any of the several program options may be exercised. These options include evaluation of the vehicles mission profile performance, sensitivity studies via a perturbation factor option, parametric studies via the change design variable option, or evaluation of the basic vehicle generalized performance at cruise speeds below the design speed. These options are illustrated in Figure C-2.

MISSION PROFILE SUBROUTINE OVERVIEW

The mission profile subroutine (MISPFL) may have up to 100 segments, each defined by a set of performance characteristics which may include the following: airspeed. altitude, duration, range, expendables rate, auxiliary power requirements, tow drag, fuel weight to be picked up, and payload to be picked up or off loaded. A simplified overview of the mission profile subroutine is presented in Figure C-3. MISPFL currently has the capability to evaluate vehicle performance for five different types of segments: (1) cruise for a fixed range; (2) cruise for a fixed duration; (3) hover for a fixed duration; (4) pick up or off load payload; and (5) refuel.

The mission profile subroutine calculates the following variables on a per segment and cumulative basis over the total mission: mission time, range, fuel consumed, fuel reserves, time on station, expendables weight, weight consumed for auxiliary power generation, ballast required, change in heaviness on the segment, and weight transfered on the segment. In addition, the program stores for output the initial and final values of each of the following variables on each segment: static lift to gross weight ratio (Beta), heaviness in pounds, number of engines required, throttle setting per engine, fuel rate, total horsepower required, and ballast. A graphic output routine is under development which will allow any of the above variables to be plotted as a function of mission time, range flown, or by mission segment number.

The evaluation of a vehicle's capability to satisfy the input mission profile is analyzed in a "rubberized" fashion; i.e., the vehicle never runs out of fuel. The MISPFL subroutine "flys" the vehicle over the input mission profile and keeps track of the total consumables weight (TOTDWT) required to satisfy the mission. TOTDWT is the main control variable in the mission profile evaluation and any iterations through MISPFL commanded by the main NAPSAP control program. This parameter is the sum of all fuel consumed, fuel reserves, expendables weight, weight consumed for auxiliary power generation, any payload off loaded minus any fuel picked up during the mission profile.

TOTDWT may be greater than or less than the total vehicle useful load. The value of TOTDWT is used to determine the actual payload for the input vehicle and to estimate the vehicle performance capability. Two different estimates are made based on the rubberized mission profile evaluation: (1) the actual vehicle volume required to satisfy the input mission profile, and (2) the time on station that the input vehicle could achieve at the specified range to station if each mission segment duration were scaled upward or downward. These performance estimates are useful in determining the performance capability of a vehicle sized for one mission in other mission applications.

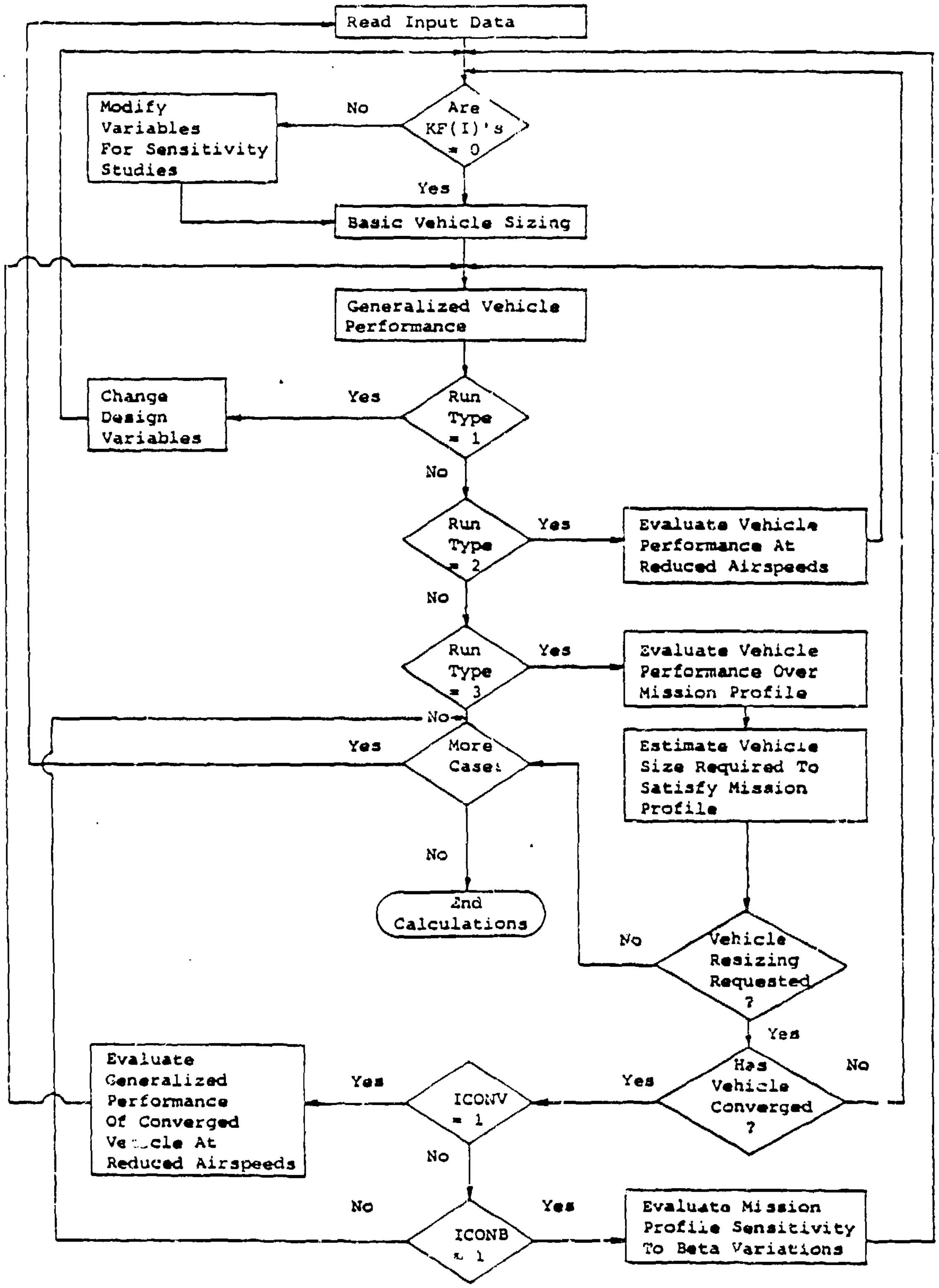

Figure C-2. NAPSAP Program Calculation Options.

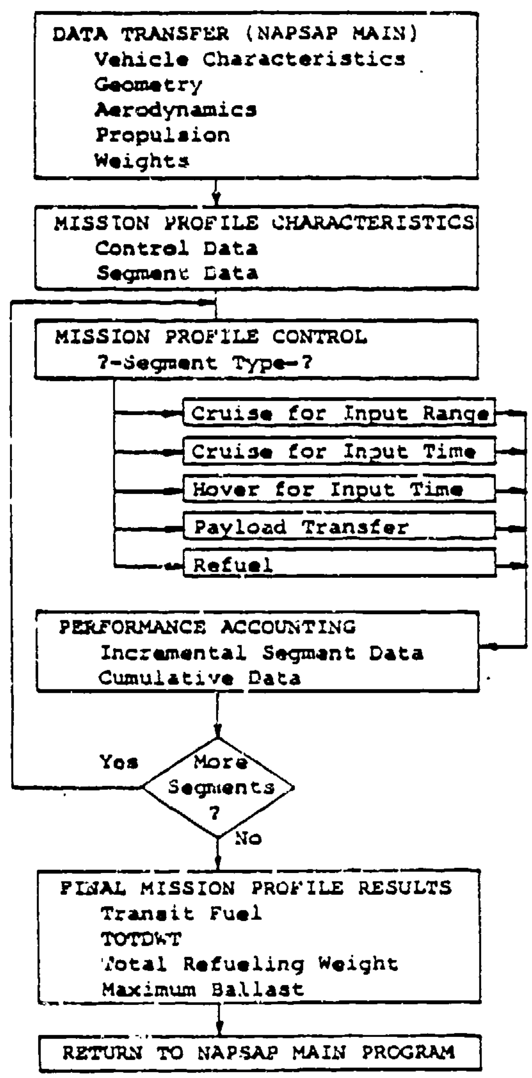

Figure C-3. Mission Profile Subroutine Top Level Flow Chart.

MISSION PROFILE VEHICLE RESIZING OPTION

One of the important features of the NAPSAP program is the capability to perform multiple iterations through the basic sizing program and the mission profile subroutine to determine the vehicle volume required to "exactly" satisfy an input mission profile (Figure C-2). The parameter TOTDWT is used as the control variable to determine whether the vehicle volume required is larger or smaller than the input vehicle. A new hull volume is defined and the entire sizing and performance re-evaluated until vehicle size exactly matches the mission profile requirements.

OTHER PROGRAM OPTIONS

The perturbation factor (KF(i)) option can be exercised with any other program option (see Figure C-2). This feature allows sensitivity studies to be made of the effects of several key design or performance variables. These include: induced drag, total drag, propulsion efficiency, total propulsion weight, envelope weight, car weight, total non-propulsive weight, and auxiliary gear weight. Growth for additional variables has been provided.

The parametric design variable option allows any one or more of the following input variables to be changed with a single input card: hull volume, gross weight, Beta, design speed, design altitude, number of engines, and hull fineness ratio. The change is made to the basic case input data and the entire program is rerun. Multiple cases may be run with the single input card.

The Off-Design Speed option allows the generalized performance of a vehicle sized for the input design speed to be evaluated at lower airspeeds.

OTHER PROGRAM CAPABILITIES AND SAMPLE RESULTS

NAPSAP can analyze three different types of propulsion systems; gas turbines, diesels, and spark ignition reciprocating engines. Each engine type has its own characteristics in terms of performance variations with airspeed, altitude, and specific fuel consumption variation with throttle setting. All of these factors are important in complex mission profiles where much time is spent at low speeds.

EFFECTS OF HEAVINESS

The vehicle volume sensitivity to take off heaviness (Beta) can be analyzed. The "optimum" Beta is a strongly mission dependent variable. Missions which have the majority of time at high speeds will tend to 'optimize" at low Betas. Missions which have large percentages of time at low speed or hover tend to optimize at higher Betas, depending on the range to station (hence, fuel consumed in transit).

SUMMARY AND CONCLUSIONS

The Naval Airship Program for Sizing and Performance, NAPSAP, has been developed to assist the U.S. Navy's LTA Project Office at the Naval Air Development Center in their continued analysis of the technical and operational feasibility of modern LTA vehicles. NAPSAP can perform preliminary design and parametric performance analysis of rigid or non-rigid LTA vehicles in conventional take off or VTOL operations with various types of propulsion. Program capabilities include the following:

1. Point design vehicle sizing and performance evaluation at constant speed and altitude.

2. Performance evaluation of the Point Design vehicle at speeds below the design speed.

3. Parametric analysis of a Point Design vehicle sizing and performance as a function of the perturbation of key design or operational parameters.

4. Performance evaluation of a Point Design vehicle over complex mission profiles of up to 100 segments. Segments may consist of cruise, hover, payload pick up or off load, and refueling, and may include the effects of mission dependant expendables, auxiliary power, towing forces, and ballast requirements.

5. Multiple iterations of the vehicle sizing and mission profile performance evaluations to determine the minimum vehicle volume required to satisfy the input mission profile.

NAPSAP is a valuable analytical tool for preliminary design and parametric evaluation of the technical and operational feasibility of modern LTA vehicles.

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APPENDIX D

REPRESENTATIVE MISSION PROFILES

REPRESENTATIVE PROFILE

ELT: Search and board		(27.5 Hrs)
1.	Warm-up, take-off @ S.L. TOGW Standard Day (T-59°F)	0.25 HRS
2.	Climb to alt - 5,000 FT	0
3.	Cruise 250 NM @ 50 KN	5.0
4.	Sweep @ 50 KN for 5 HRS	5.0
5.	Dash @ 90 KN for 0.5 KN	.5
6.	Descend to alt - 50 FT	0
7.	Hover for 0.25 HRS	.25
8.	Loiter @ 30 KN for 1 HR	1.0
9.	Hover for 0.25 HRS	.25
10.	Climb to alt 5,000 FT	0
11.	Sweep @ 50 KN for 4 HRS	4.0
12.	Repeat Steps #5-11 once	6.0
13.	Cruise 250 NM @ 50 KN	5.0
14.	Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS   Crew: 11

MISSION PAYLOAD: 3,249

TOTAL PAYLOAD: 7,669 LBS

ELT: Mission Payload

1.	Crew of 11 (@ 200 #/man)	2,200
2.	Provisions, General Store, and Potable Water (@25 #/man-day)	315
3.	Inflatable boat w/motor and fuel	411
4.	Rescue Equipment	81
5.	Dewatering Pumps	110
6.	Firefighting equipment Set	90
7.	Smoke and Light Floats (@ 6 each)	42
		3,249 LBS

REPRESENTATIVE PROFILE

MEP: Initial Clean-up, C^3	(12.5 HRS)
1. Warm-up, take-off @ S.L. TOGW Standard Day (T-59°)	.25 HRS
2. Climb to alt - 5,000 FT	0
3. Cruise 50 NM @ 50 KN	1.0
4. Descend to alt - 100 FT	0
5. Hover (Pick-up mission payload)	.5
6. Climb to alt - 1,000 FT	0
7. Cruise 25 NM @ 50 KN	.5
8. Off-load payload - Hover .5 HR	.5
9. Cruise back 25 NM @ 50 KN	.5
10. Repeat Steps #4-9 two times	4.0
11. Climb to alt - 5,000 FT	0
12. Loiter @ 30 KN for 3.5 HRS	3.5
13. Cruise 75 NM @ 50 KN	1.5
14. Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS — Crew: 6

MISSION PAYLOAD: 17,952

TOTAL PAYLOAD: 22,372 LBS

MEP: Mission Payload

1.	Crew of 6 (@ 200 #/man)	1,200
2.	Provisions, General Stores, and Potable Water (@ 25 #/man-day)	78
3.	Inflatable boat w/motor and fuel	411
4.	Rescue Equipment	81
5.	Pump	110
6.	Firefighting Equipment Set	90
7.	Smoke and Light Floats (@ 6 each)	42
8.	Chemicals for Spill	500
9.	Harbor Oil Boom (one @ 2 #/FT)	440
10.	Oil Recovery Devices	15,000
	TOTAL	17,952

REPRESENTATIVE PROFILE

MO/MP: Towed Array ASW, Attack		(26.5 HRS)
1.	Warm-up, take-off @ S.L. TOGW Standard Day (T-59°F)	.25 HRS
2.	Climb to alt - 5,000 FT	0
3.	Cruise 300 NM @ 40 KN	7.5
4.	Descend to alt - 300 FT	0
5.	Tow away @ 10 KN for .5 HR	.5
6.	Cruise 15 NM @ 30 KN	.5
7.	Repeat Steps #5-6 fourteen times	14.0
8.	Dash @ 90 KN for 1 HR	1.0
9.	Attack (deploy weapons)	0
10.	Cruise 100 NM @ 40 KN	2.5
11.	Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS   Crew: 11

MISSION PAYLOAD: 6,520

TOTAL PAYLOAD: 10,940 LBS

MO/MP: Mission Payload

1.	Crew of 11 (@ 200 #/man)	2,200
2.	Provisions, General Stores, and Potable Water (@ 25 #/man-day)	315
3.	Rescue Equipment	81
4.	Towed Array System (including processor)	1,500
5.	MK-46NT (3)	1,524
6.	VLA/DIFAR (Dwarf) (20)	200
7.	Marker, BT, AN	300
8.	MAD Gear	400
	TOTAL	6,520 LBS

REPRESENTATIVE PROFILE

PSS: Hazardous Vessel Escort (8.35 HRS)

1.	Warm-up, take-off @ S.L. TOGW Standard Day (T-59°F)	.25 HRS
2.	Climb to alt - 5,000 FT	
3.	Cruise 50 NM @ 40 KN.	1.25
4.	Loiter @ 30 KN for 6 HRS	6.0
5.	Descend to alt - 1,000 FT	0
6.	Cruise 25 NM @ 40 KN	.6
7.	Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS Crew: 6

MISSION PAYLOAD: 1,817

TOTAL PAYLOAD: 6,237

PSS: Mission Payload

1.	Crew of 6 (@ 200 #/man)	1,200
2.	Provisions, General Stores, and Potable Water (@ 25 #/man-day)	52
3.	Rescue Equipment	81
4.	Dewatering Pump (2)	220
5.	Firefighting Equipment Set (2)	180
6.	Smoke and Light Floats (@ 12 each)	84
	TOTAL	1,817 LBS

REPRESENTATIVE PROFILE

SAR: Search, Board, Tow (13.6 HRS)

1.	Warm-up, take-off @ S.L. TOGW Standard Day (T-59°F)	.25 HRS
2.	Climb to alt - 5,000 FT	0
3.	Cruise 25 NM @ 90 KN	.3
4.	Search for 1.5 HRS @ 60 KN	1.5
5.	Descend to alt - 100 FT	0
6.	Hover for .5 HRS	.5
7.	Loiter @ 30 KN for 2 HRS	2.0
8.	Hover for .5 HRS	.5
9.	Tow @ 6 KN for 50 NM	8.3
10.	Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS   Crew: 8

MISSION PAYLOAD: 2,490

TOTAL PAYLOAD: 7,910

SAR: Mission Payload

1.	Crew of 8 (@ 200 #/man)	1,600
2.	Provisions, General Stores, and Potable Water (@ 25 #/man-day)	114
3.	Inflatable boat w/motor and fuel	411
4.	Rescue Equipment	81
5.	Dewatering Pump	110
6.	Firefighting Equipment	90
7.	Smoke and Light Floats	84
	TOTAL	2,490 LBS

REPRESENTATIVE PROFILE

A/N: Buoy Maintenance		(17.0 HRS)
1.	Warm-up, take-off @ S.L. TOGW Standard Day (T-59°F)	.25 HRS
2.	Climb to alt - 1,000 FT	0
3.	Cruise 150 NM @ 50 KN	3.0
4.	Descend to alt - 100 FT	
5.	Hover for 0.5 HRS	.5
6.	Climb to alt - 500 FT	0
7.	Cruise 80 NM @ 50 KN	1.6
8.	Repeat Steps #4-7 four times	8.4
9.	Climb to alt - 1,000 FT	0
10.	Cruise 150 NM @ 50 KN	3.0
11.	Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS   Crew: 8

MISSION PAYLOAD: 2,976

TOTAL PAYLOAD: 7,419

A/N: Mission Payload

1.	Crew of 8 (@ 200 #/man)	1,600
2.	Provisions, General Stores, and Potable Water (@ 25 #/man-day)	142
3.	Inflatable boat w/motor and fuel	411
4.	Rescue Equipment	81
5.	Dewatering Pump	110
6.	Firefighting Equipment	90
7.	Smoke and Light Floats (@ 6 each)	42
8.	Buoy Maintenance Kit	500
	TOTAL	2,976 LBS

REPRESENTATIVE PROFILE

MSA: Ice Patrol (St. Johns)		(35.5 HRS)
1.	Warm-up, take-off @ S.L. TOGW Standard Day (T-59°F)	.25 HRS
2.	Climb to alt - 5,000 FT	0
3.	Cruise 100 NM @ 40 KN	2.5
4.	Sweep @ 60 KN for 30 HRS	30.0
5.	Cruise 100 NM @ 40 KN	2.5
6.	Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS   Crew: 11

MISSION PAYLOAD: 3,341

TOTAL PAYLOAD: 7,761 LBS

MSA: Mission Payload

1.	Crew of 11 (@ 200 #/man)	2,200
2.	Provisions, General Stores, and Potable Water (@ 25 #/man-day)	407
3.	Inflatable boat w/motor and fuel	411
4.	Rescue Equipment	81
5.	Dewatering Pump	110
6.	Firefighting Equipment	90
7.	Smoke and Light Floats (@ 6 each)	42
	TOTAL	3,341

REPRESENTATIVE PROFILE

IO:	Ice Mapping (Great Lakes)	(20.5 HRS)
1.	Warm-up, take-off @ S.L. TOGW Standard Day (T-59°F)	.25 HRS
2.	Climb to alt - 5,000 FT	
3.	Map @ 60 KN for 20 HRS	20.0
4.	Descend and land @ S.L. with 10 percent fuel remaining	.25

FIXED PAYLOAD: 4,420 LBS — Crew: 6

MISSION PAYLOAD: 3,000

TOTAL PAYLOAD: 7,420

10: Mission Payload

1.	Crew of 6 (@ 200 #/man)	1,200
2.	Provisions, General Stores, and Potable Water (@ 25 #/man-day)	66
3.	Inflatable boat w/motor and fuel	411
4.	Rescue Equipment	81
5.	Dewatering Pump	110
6.	Firefighting Equipment	90
7.	Smoke and Light Floats (@ 6 each)	42
8.	Scientific Instruments	1,000
	TOTAL	3,000 LBS

APPENDIX E

VEHICLE SENSITIVITY ANALYSIS

Since the vehicle designs (both in-house and contracted) described in Chapters V and VII were intended to be only of a conceptual nature, some questions could be raised at the legitimacy of performing sensitivity studies. However, it was felt that at least the trends of these analyses should be accurate if not the discrete data. For that reason a series of key parameter variations was examined.

To study the effects of variation of key parameters, certain variables were fixed to simplify the analyses. First, the representative mission profile for ELT was chosen as portraying a wide spectrum of all Coast Guard missions (note that the ZP-X design sized for MEP is oversized for this mission resulting in a performance bonus in endurance and/or payload for ELT); and second, as mentioned above, the MPAS design vehicle, the ZP-X, was established as the baseline (this fixes the gross weight) along with the design performance requirements such as 90 knot dash speed and 5,000 foot altitude. Following are the resulting data as four primary variables are varied. These four are Design Dash Speed, Design Altitude, Structural Weight, and Total Drag Coefficient. In addition to graphical data of a portion of the results, tabular data also included can be used to explore effects on other parameters.

Figure E-1, "Effect of Design Dash Speed Variation," displays the very strong influence the choice of design dash speed on vehicle hull size and horsepower required. Table E-I, presents on a percentage basis the results of sensitivity changes to the maximum speed.

Figure E-2, "Effect of Design Altitude," illustrates the fact that buoyant vehicles must grow larger where the surrounding medium is less dense. Also in this environment power requirements diminish since lower density implies less drag on the vehicle. Table E-II provides additional information.

Figure E-3, "Effect of Structural Weight Variation," shows how even fairly small weight savings (as might be expected from modern materials such as composites) result in either a smaller vehicle or extended mission endurance. Table E-III provides the percentage effects on other parameters as structural weight is varied.

Figure E-4, "Effect of Drag Coefficient Variation," presents the story of drag. By their large ellipsoidal nature, airships are a drag intensive shape - primarily skin friction in the usual speed range of 100 knots or less. Since horsepower requirements are largely dictated by power necessary to overcome drag, the effect of drag changes are very significant. Other effects of drag variation are shown in Table E-IV.

These sensitivity analyses serve to point out the conceptual nature of the MPAS point designs. Slight changes in key parameters can have large effects. Overstating requirements such as dash speed can result in a larger and more costly vehicle. The vehicles presented are valid in a representative sense but a closer look should be made at actual Coast Guard requirements followed by an in-depth point design study.

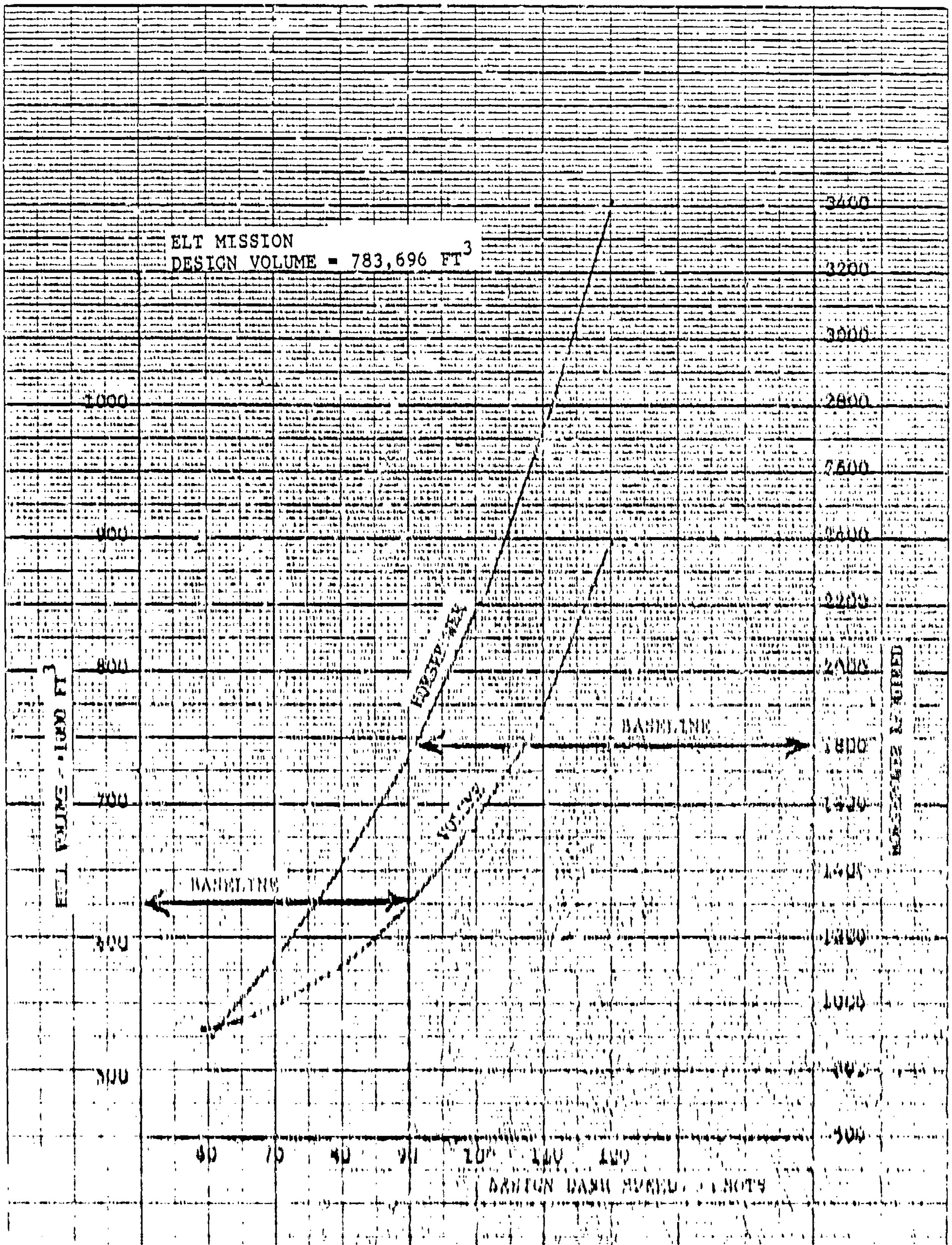

Figure V-1. Effect of Design Dash Speed Variation.

TABLE E-1
PERCENT CHANGE IN DESIGN DASH SPEED

PERCENT CHANGE IN DESIGN DASH SPEED	EFFECTS ON KEY PARAMETERS - PERCENT				
	HULL VOLUME	TOTAL MISSION TIME	EMPTY WEIGHT	USEFUL LOAD	HORSEPOWER REQUIRED
-20	-12.9	+22.8	-6.7	- 6.3	-48.0
-10	- 7.5	+11.7	-3.7	- 3.5	-23.4
0	0	0	0	0	0
+10	+ 7.8	-12.9	+4.3	+ 4.4	+19.6
+20	+20.5	-30.5	+9.9	+10.9	+44.9

VDESIGN = 90 Knots
GROSS WEIGHT = 54554

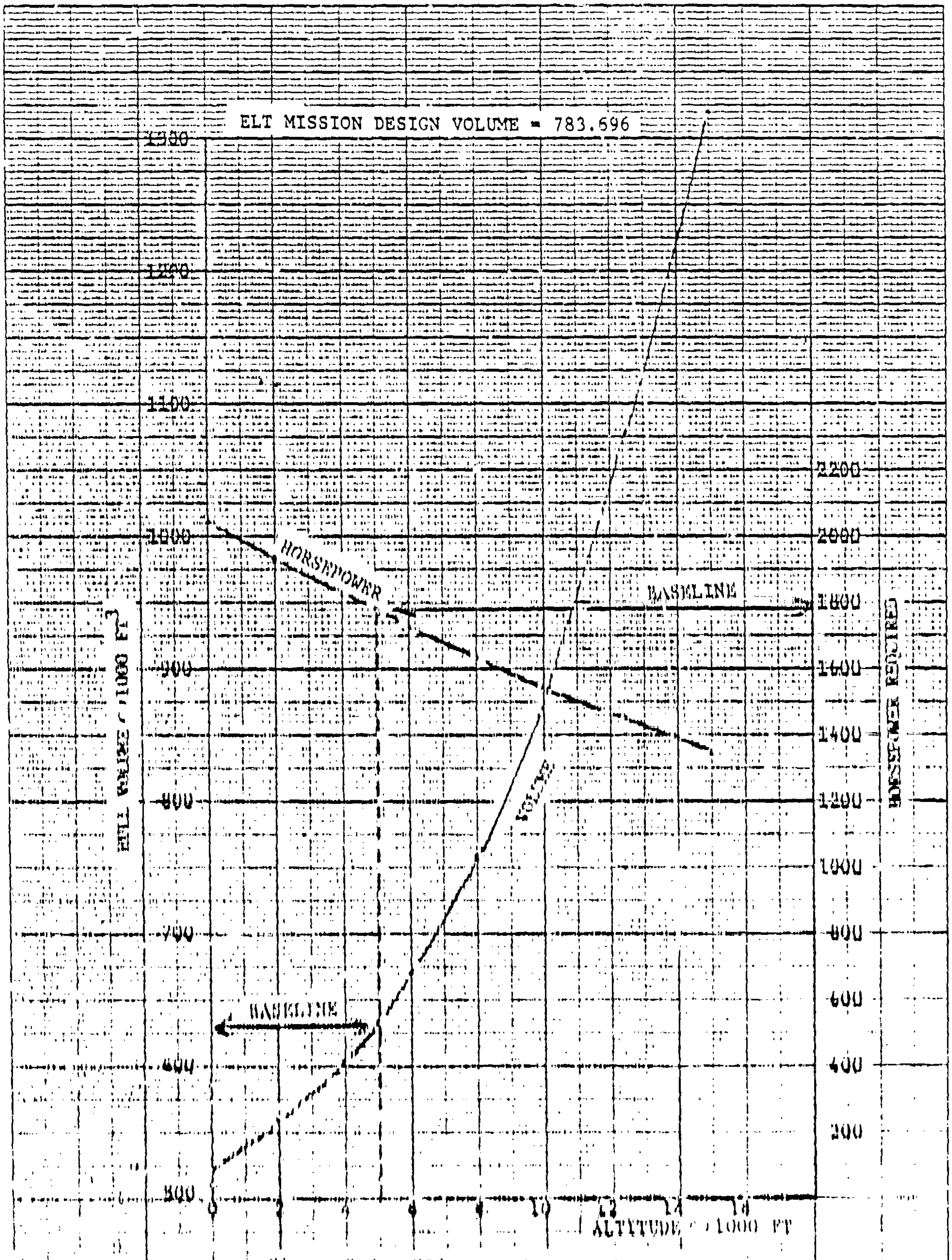

Figure E-2. Effect of Design Altitude Variation.

TABLE E-II
PERCENT CHANGE IN DESIGN ALTITUDE

PERCENT CHANGE IN DESIGN ALTITUDE	EFFECTS ON KEY PARAMETERS - PERCENT				
	HULL VOLUME	TOTAL MISSION TIME	EMPTY WEIGHT	USEFUL LOAD	HORSEPOWER REQUIRED
-20	-4.3	+6.6	+1.0	+0.6	+2.8
-10	-2.1	+2.3	+0.3	+0.3	+1.5
0	0	0	0	0	0
+10	+3.4	-5.3	-0.3	-0.3	-1.3
+20	+6.1	-9.7	-0.6	-0.6	-2.7

GROSS WEIGHT = 54554
DESIGN ALTITUDE = 5000 FT

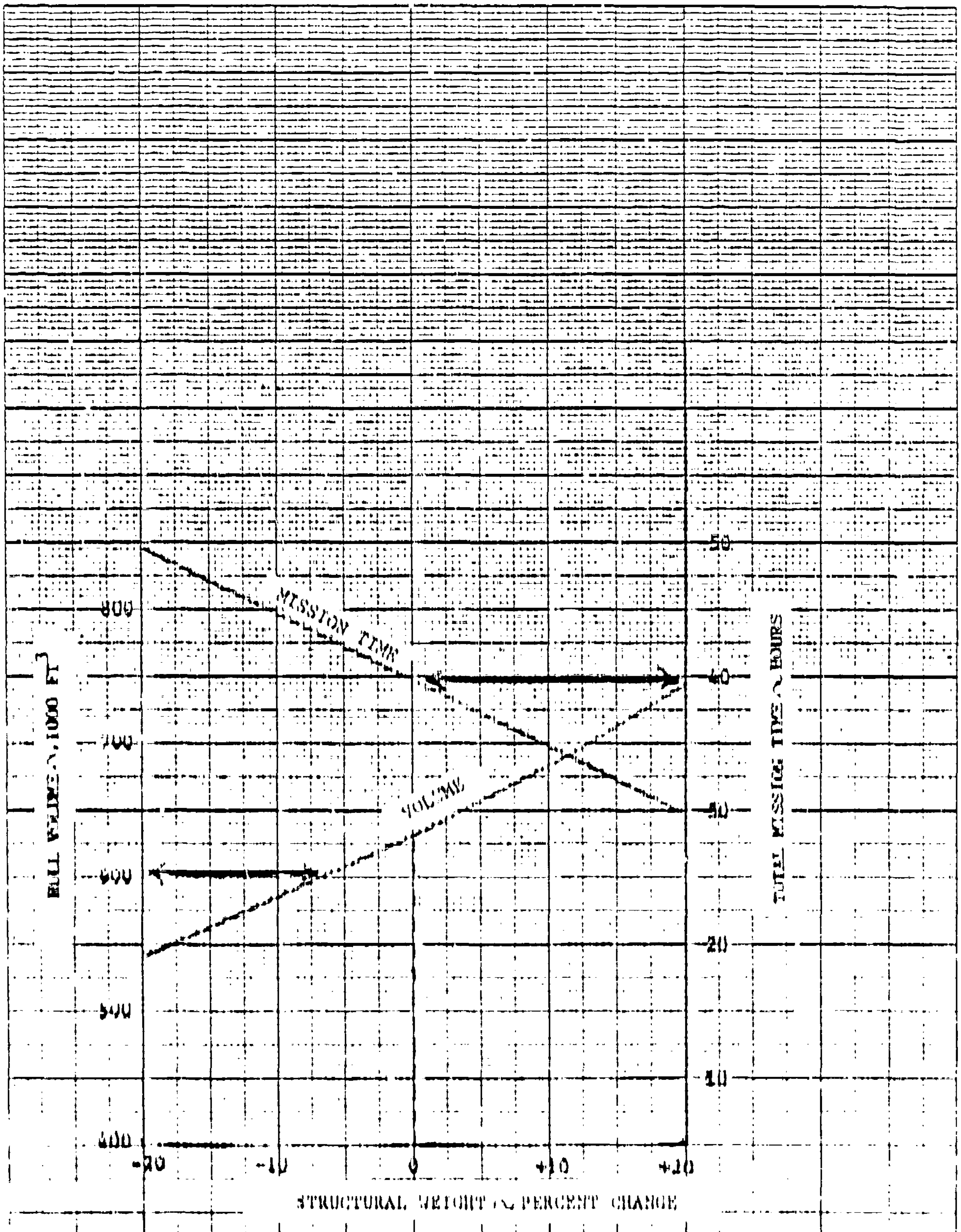

Figure E-1. Effect of Structural Weight Variation.

TABLE E-III
PERCENT CHANGE IN STRUCTURAL WEIGHT

PERCENT CHANGE IN STRUCTURAL WEIGHT	EFFECTS ON KEY PARAMETERS - PERCENT			
	HULL VOLUME	TOTAL MISSION TIME	EMPTY WEIGHT	USEFUL LOAD
-20	-14.[illegible]	+24.6	-13.9	-12.4
-10	- 6.9	+12.4	- 7.5	- 6.0
0	0 (baseline)	0	0	0
+10	+ 6.5	-13.8	+ 6.5	+ 6.7
+20	+12.9	-32.7	+12.9	+14.7

GROSS WEIGHT = 54554

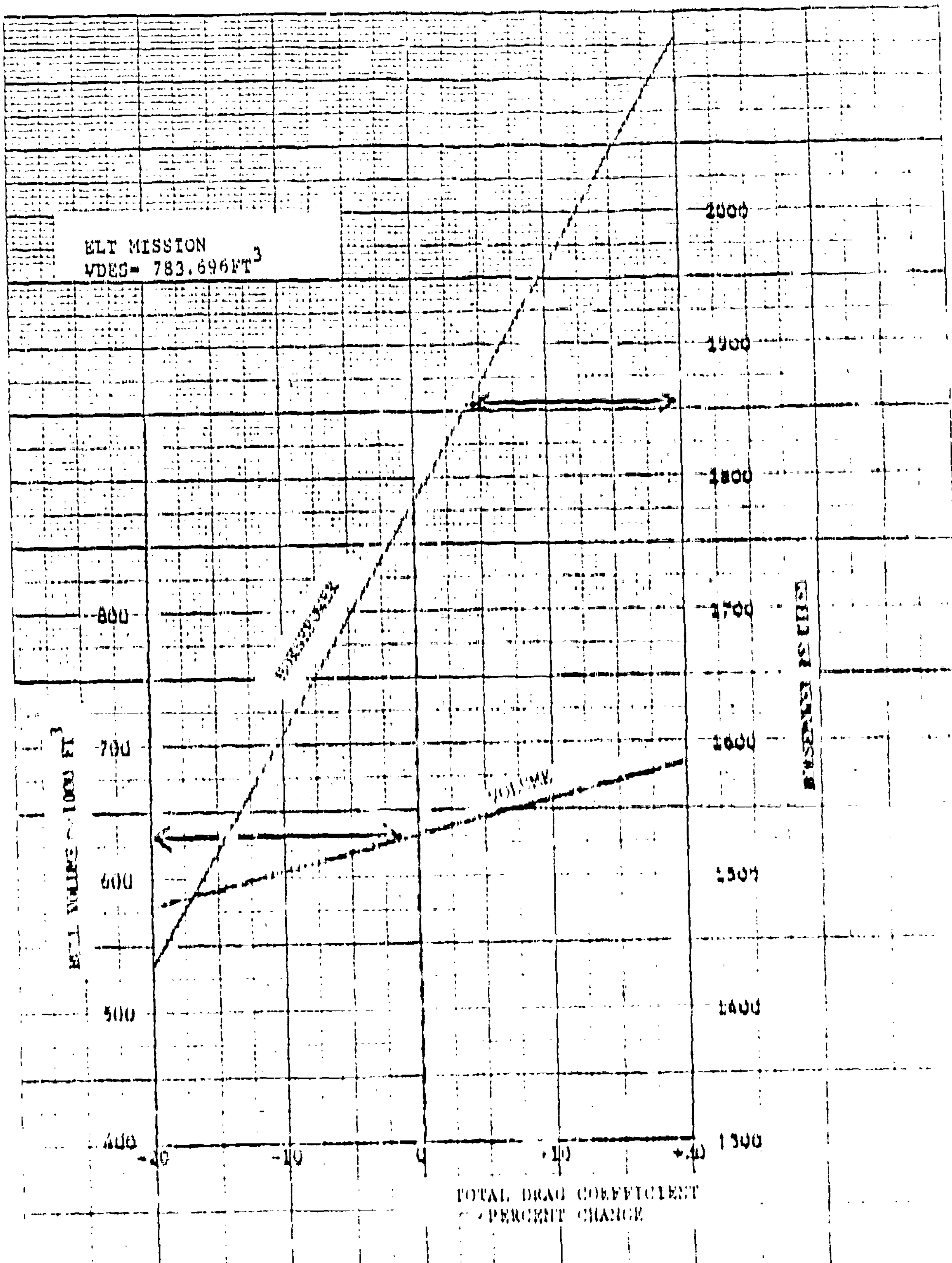

Figure E-4. Effect of Drag Coefficient Variation.

TABLE E-IV
PERCENT CHANGE IN TOTAL DRAG COEFFICIENT

PERCENT CHANGE IN TOTAL DRAG COEFFICIENT	EFFECTS ON KEY PARAMETERS - PERCENT				
	HULL VOLUME	TOTAL MISSION TIME	EMPTY WEIGHT	USEFUL LOAD	HORSEPOWER REQUIRED
-20	-2.0	- 2.7	-4.8	-4.4	-25.0
-10	-4.8	- 7.7	-2.4	-3.3	-11.1
0	0	0	0	0	0
+10	+4.2	+ 7.7	+2.5	+2.5	+10.0
+20	+8.5	+15.5	+5.1	+5.3	+20.0

GROSS WEIGHT = 54554

APPENDIX F

COAST GUARD MPAS PROGRAM HISTOGRAM ANALYSIS

As described in Chapter VIII, the missions of the Coast Guard are examined on a histogram basis from several perspectives. In Chapter VIII, the overall picture is presented with all eight programs compiled together. This appendix addresses each program separately.

A series of three histograms (with the exception of MO/MP for which operational data was not available) are presented for each Coast Guard program:

1. Flight Hour Requirement as a Function of Mission Duration;

2. Number of Missions as a Function of Mission Duration; and

3. Number of Profiles as a Function of Mission Duration.

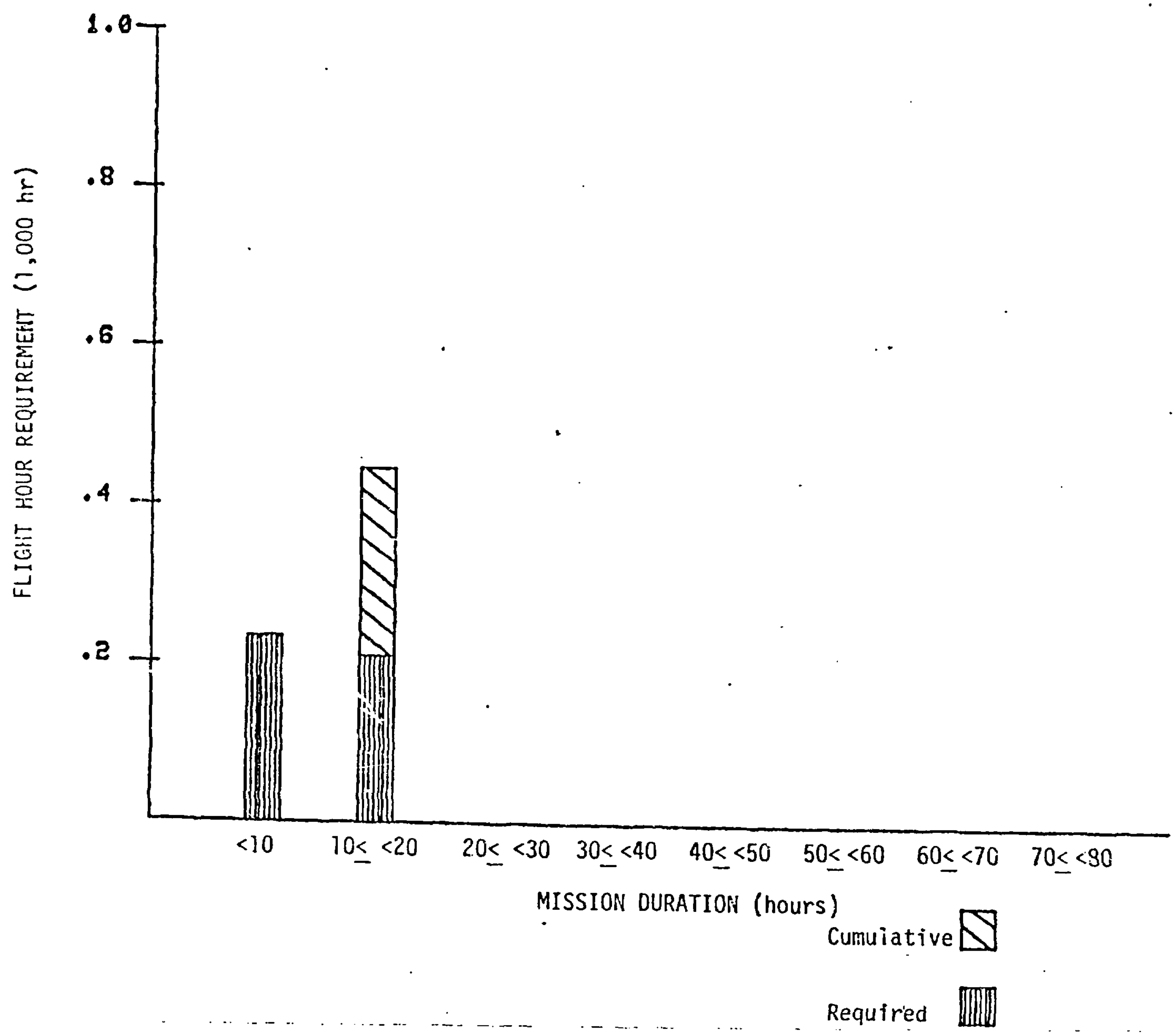

Figure F-1. Flight Hour Requirement for Short Range Aids to Navigation.

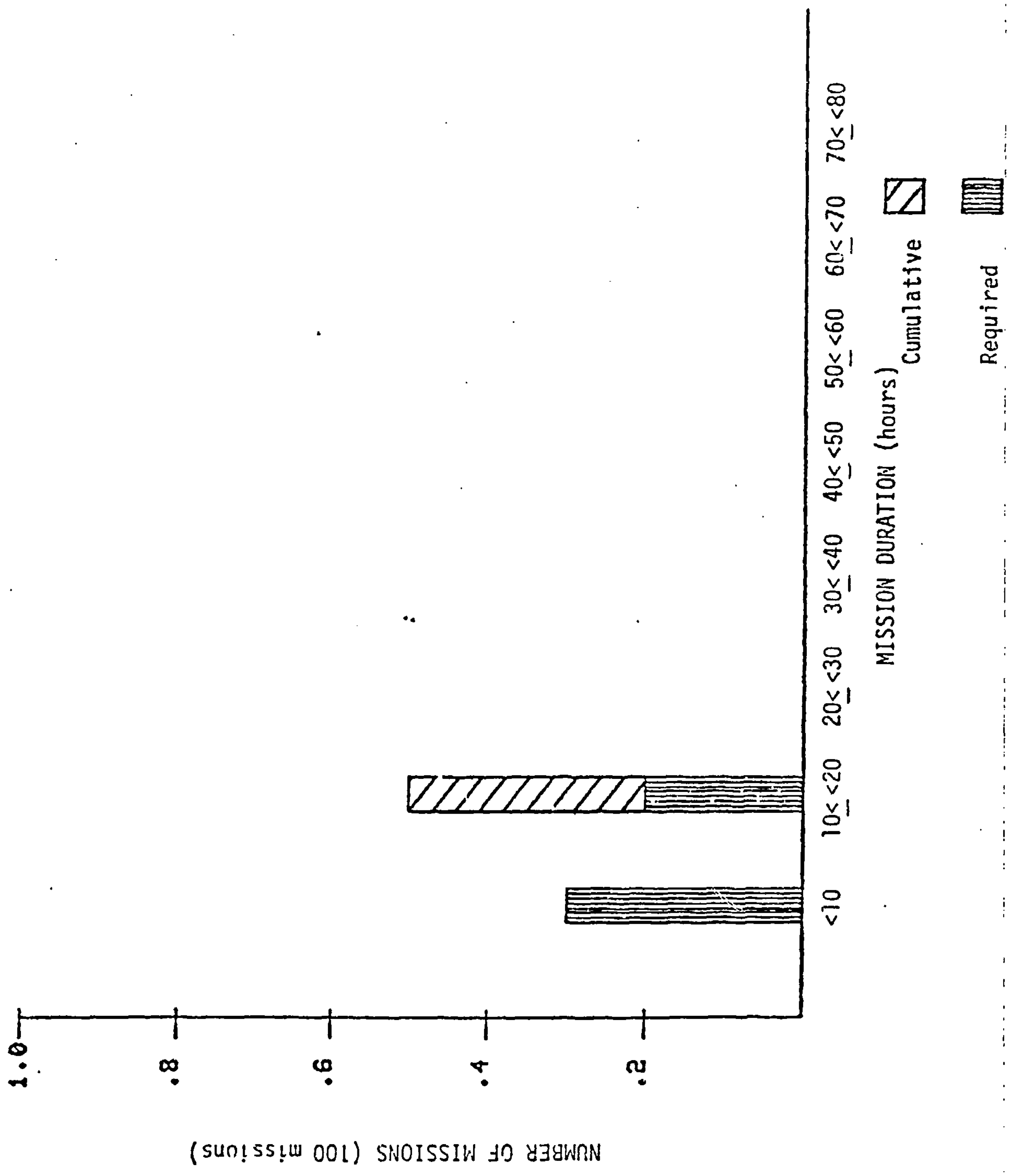

Figure F-2. Number of Missions for Short Range Aids to Navigation.

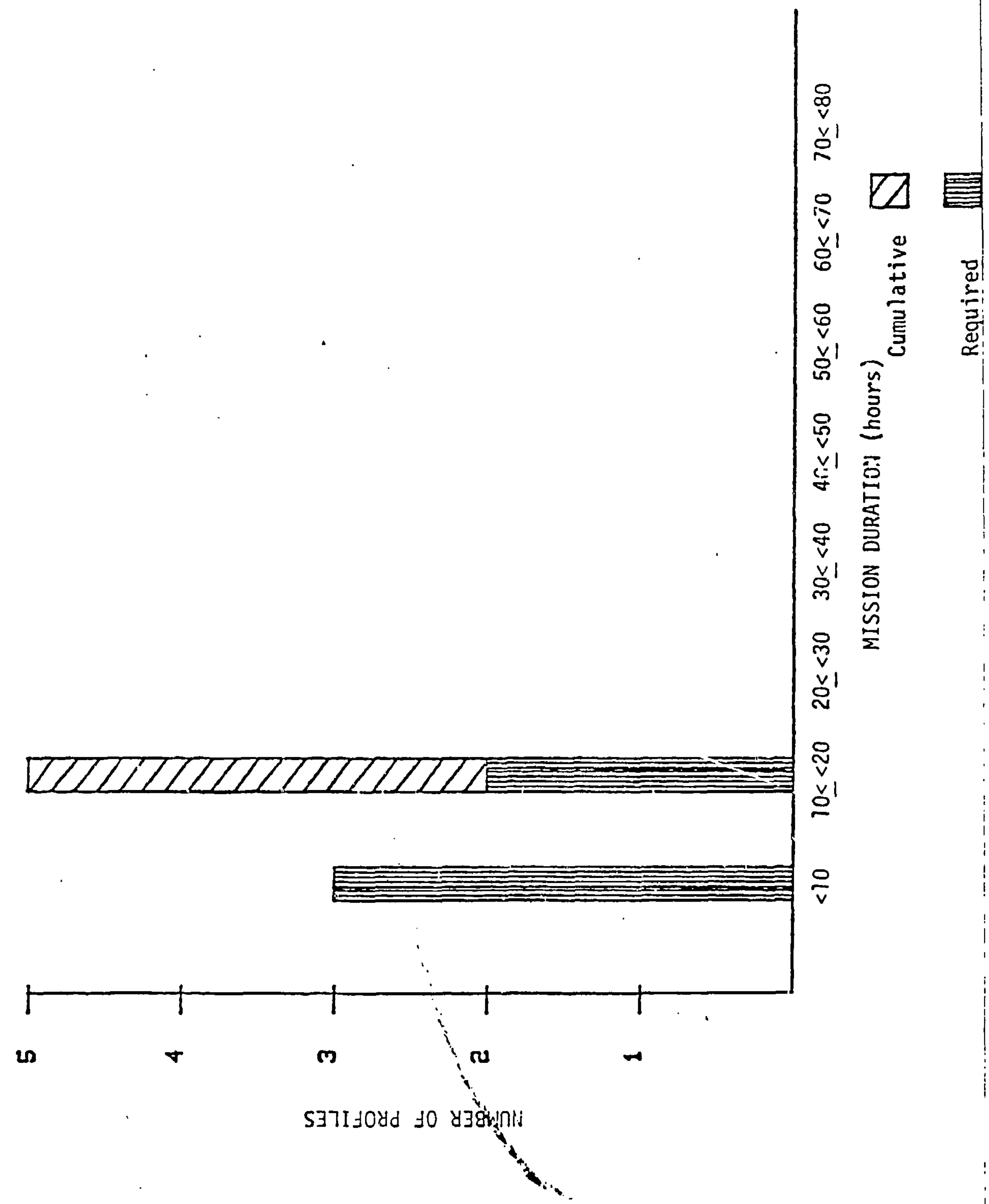

Figure F-3. Number of Profiles for Short Range Aids to Navigation.

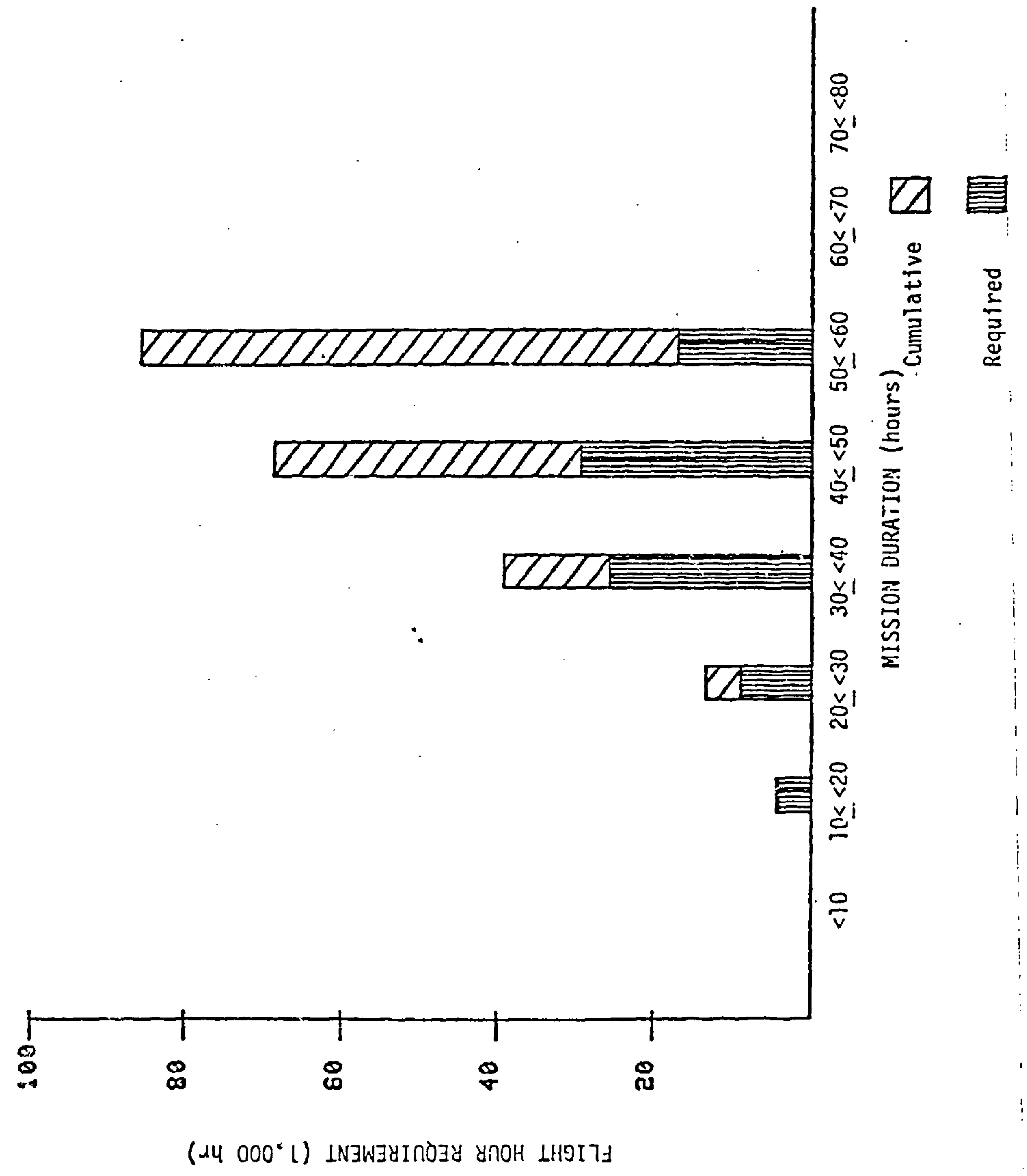

Figure F-4. Flight Hour Requirement for Enforcement of Laws and Treaties.

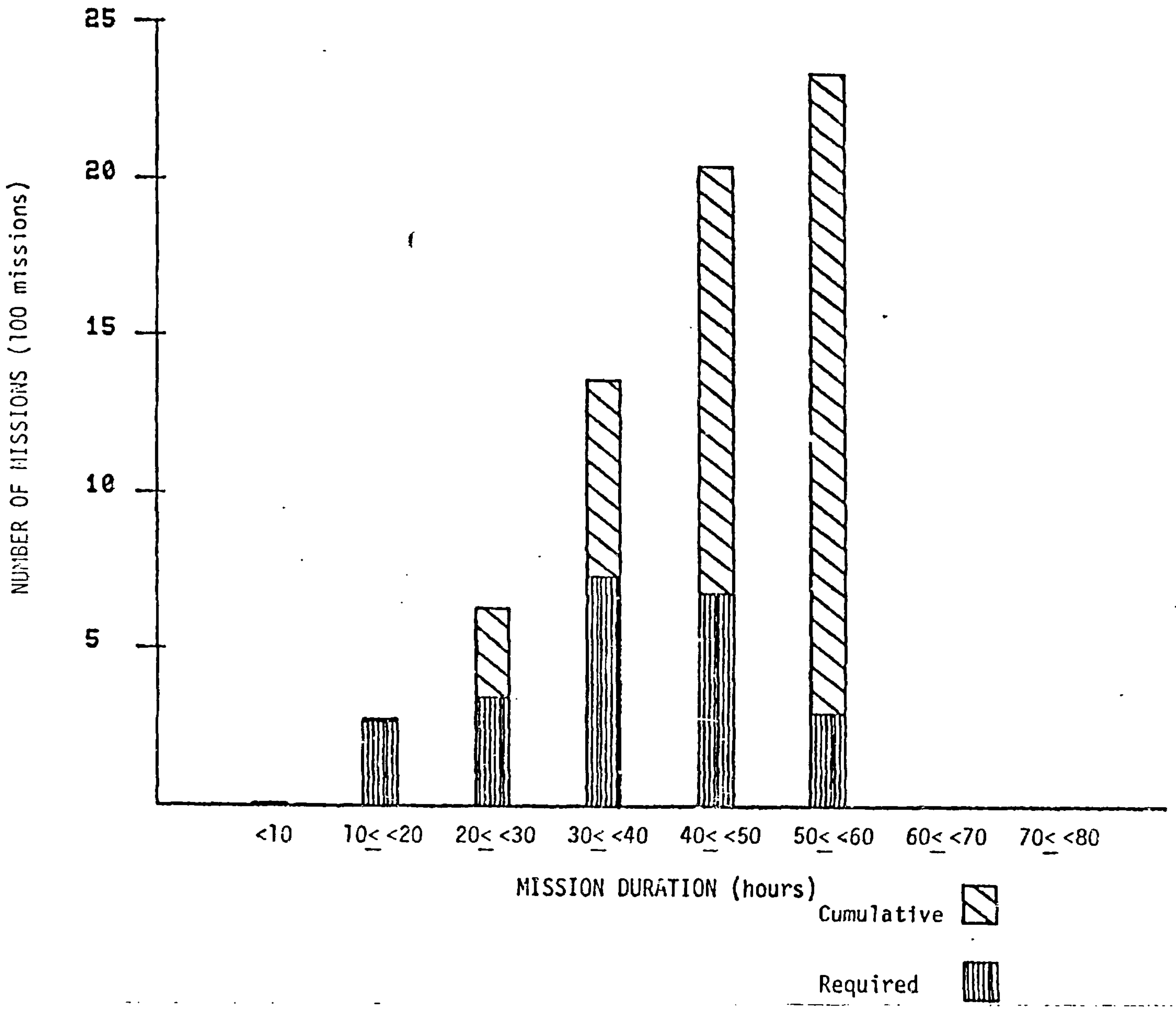

Figure F-5. Number of Missions for Enforcement of Laws and Treaties.

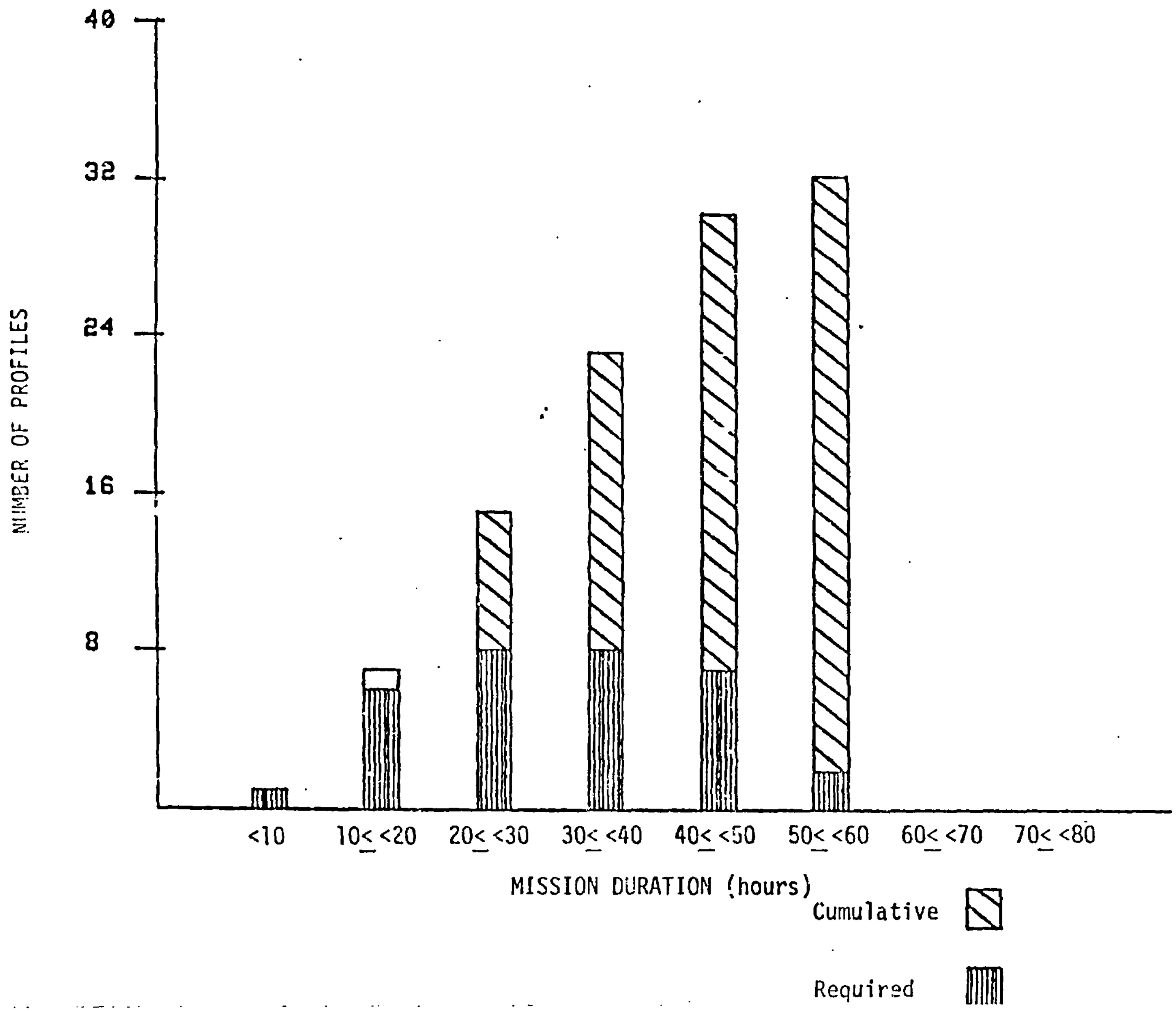

Figure F-6. Number of Profiles for Enforcement of Laws and Treaties.

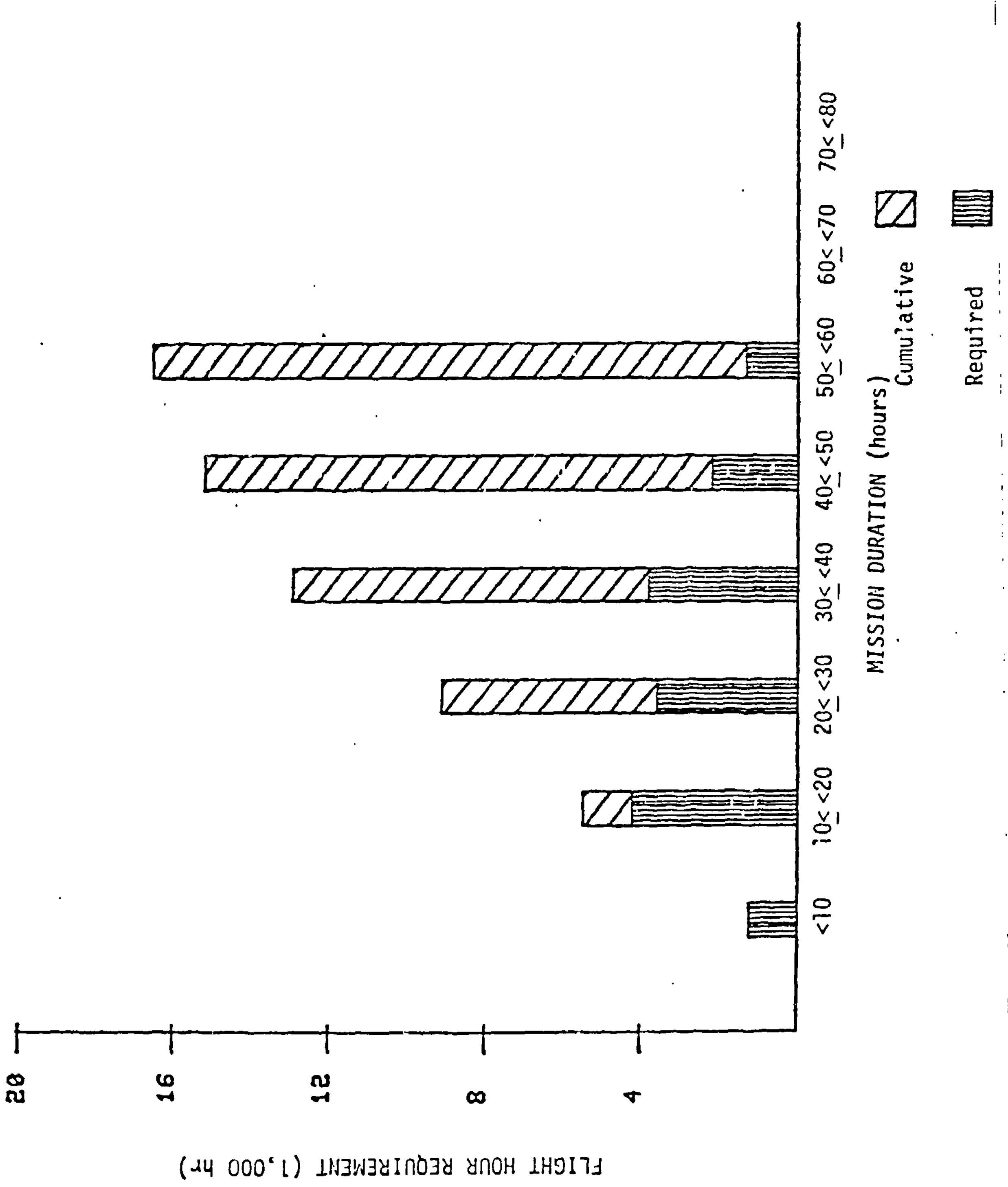

Figure F-7. Flight Hour Requirement for Marine Environmental Protection.

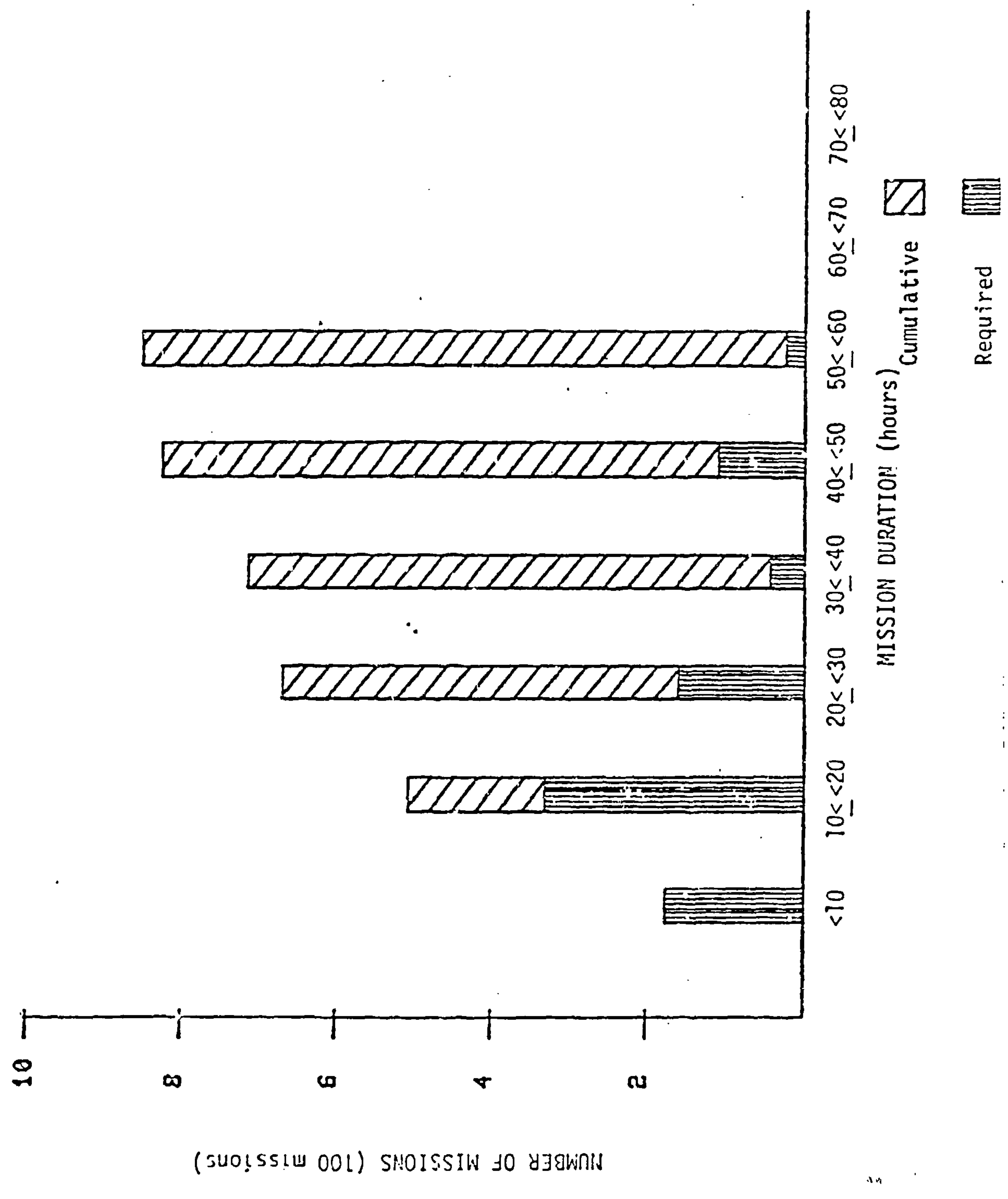

Figure F-8. Number of Missions for Marine Environmental Protection.

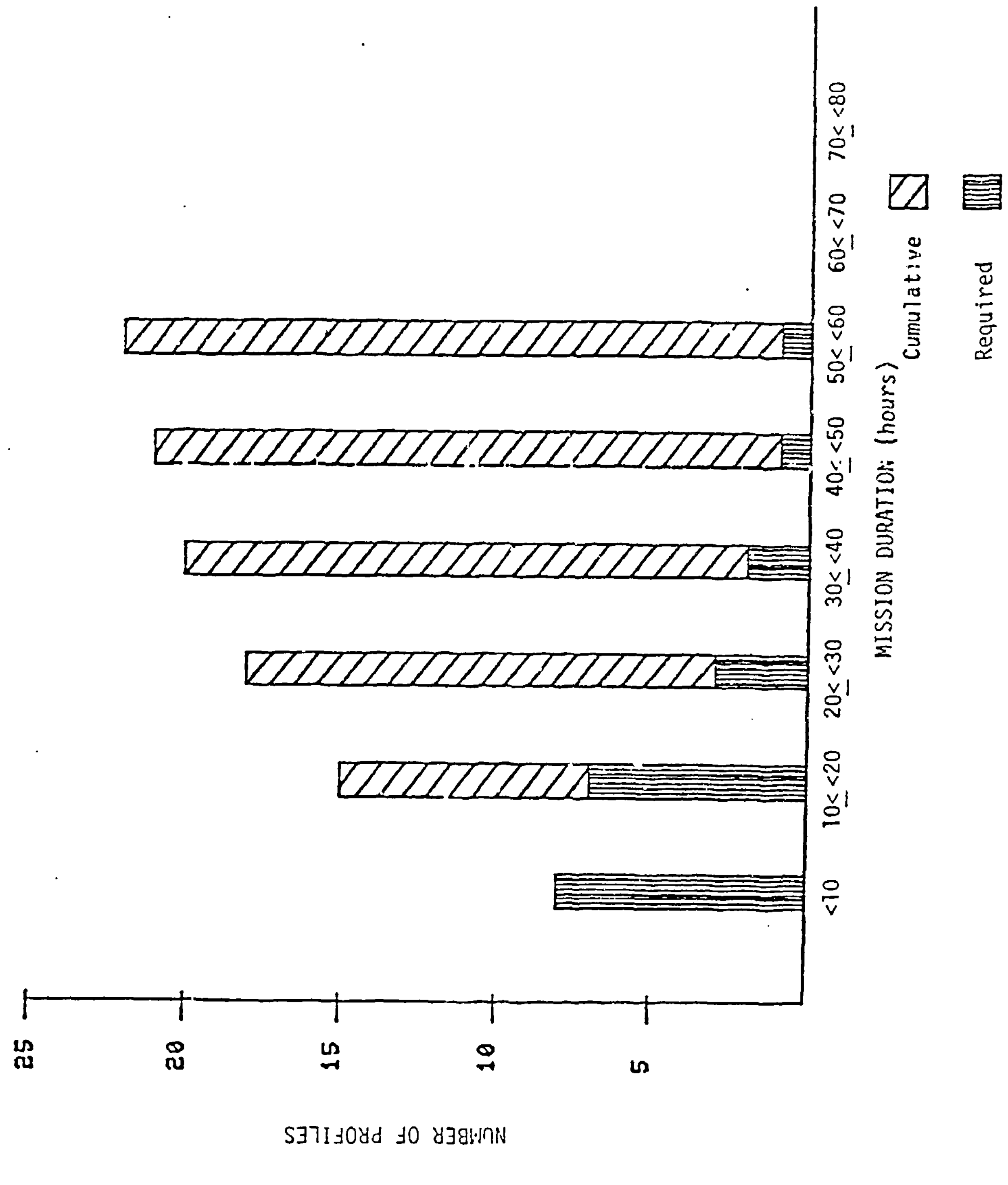

Figure F-9. Number of Profiles for Marine Environmental Protection.

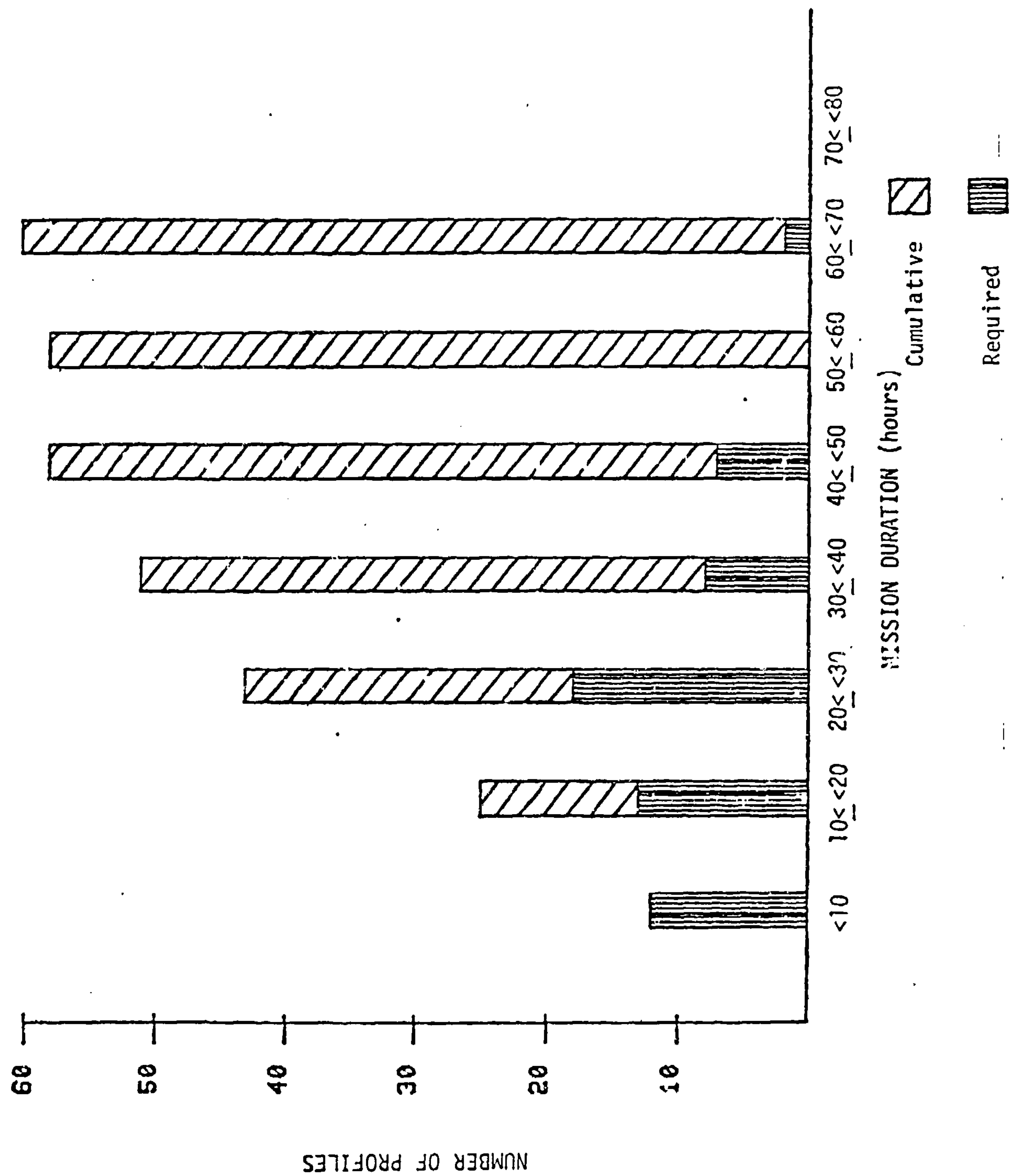

Figure F-10. Number of Profiles for Military Operations/Military Preparedness.

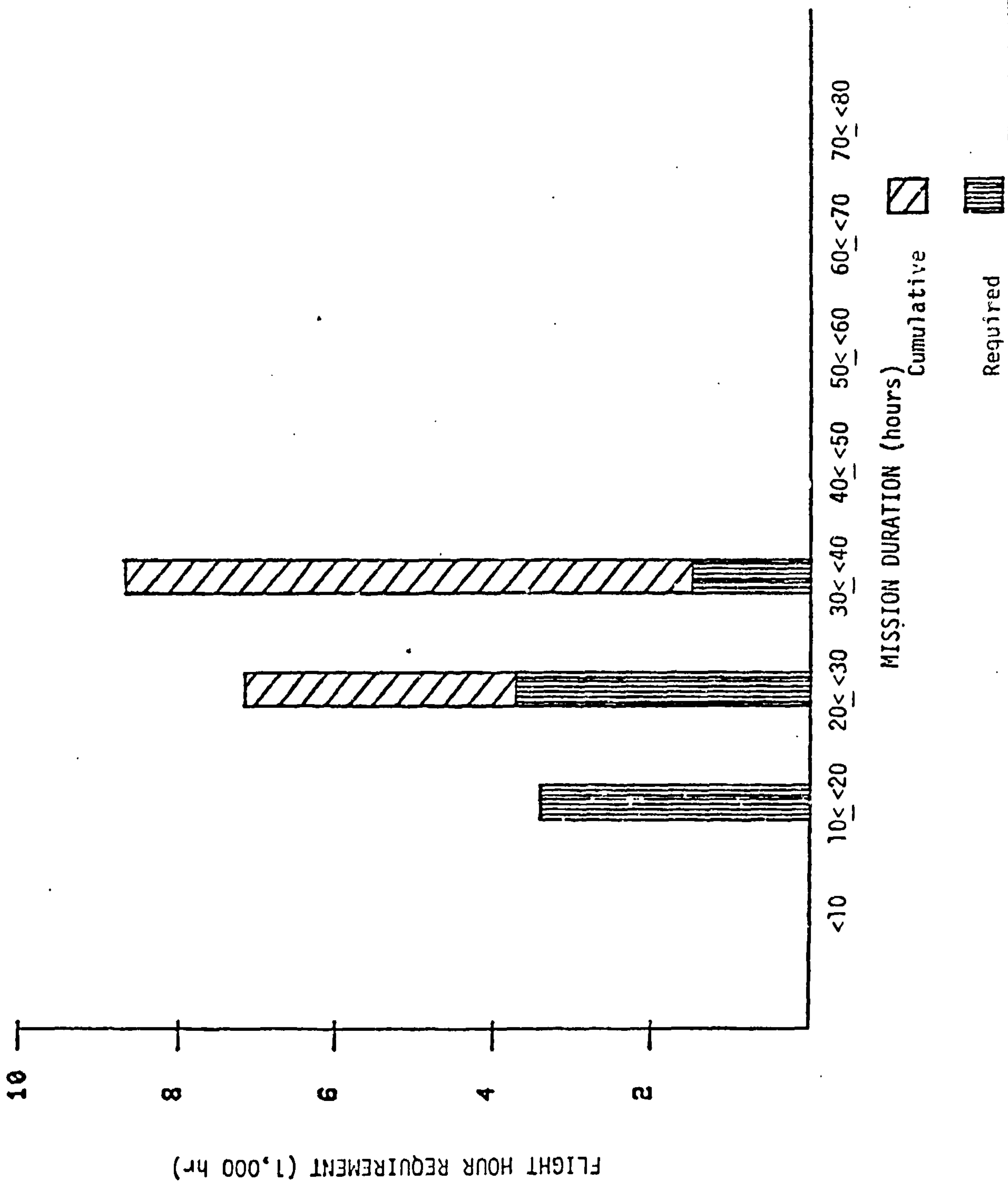

Figure F-11. Flight Hour Requirement for Marine Science Activity.

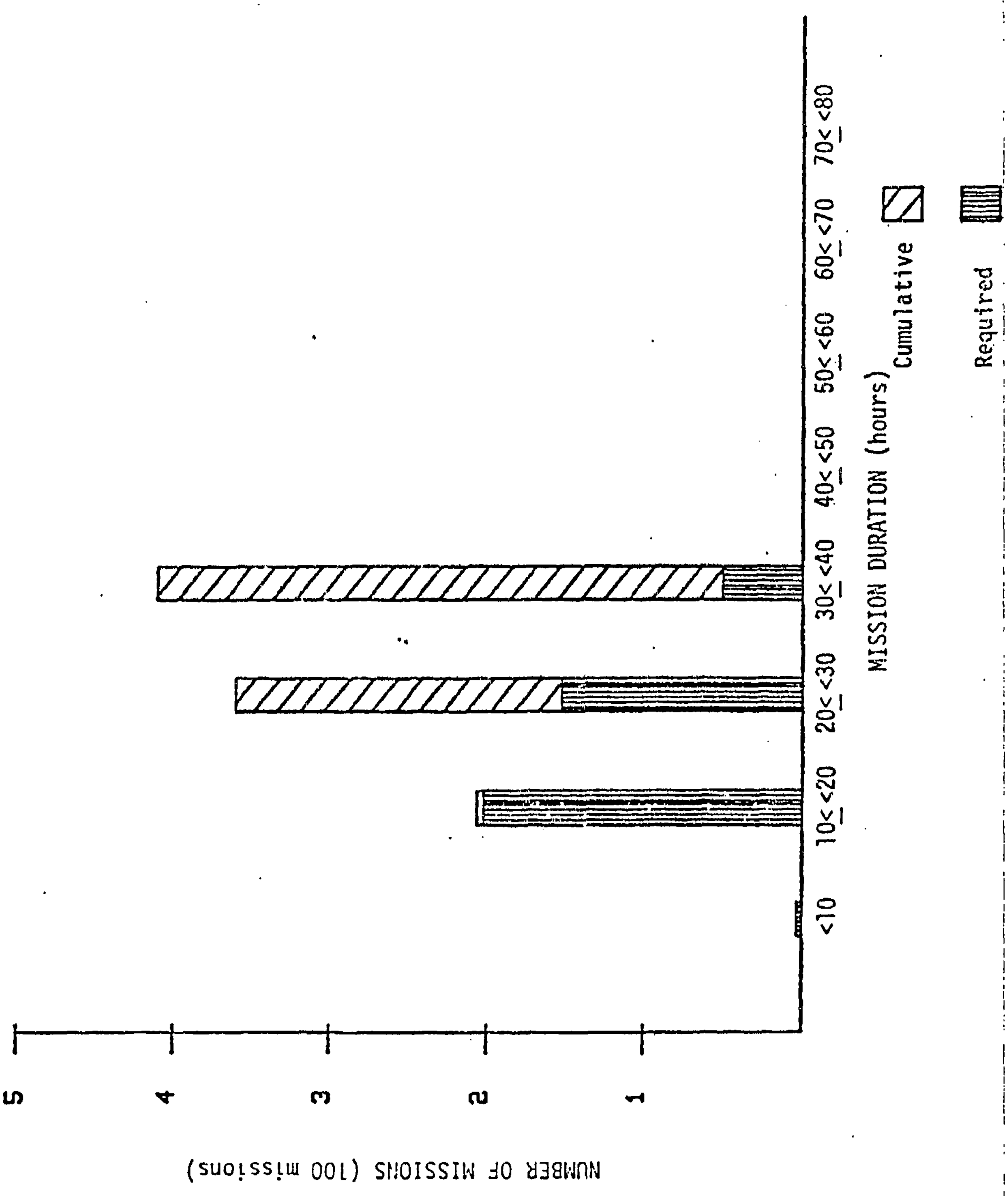

Figure F-12. Number of Missions for Marine Science Activity.

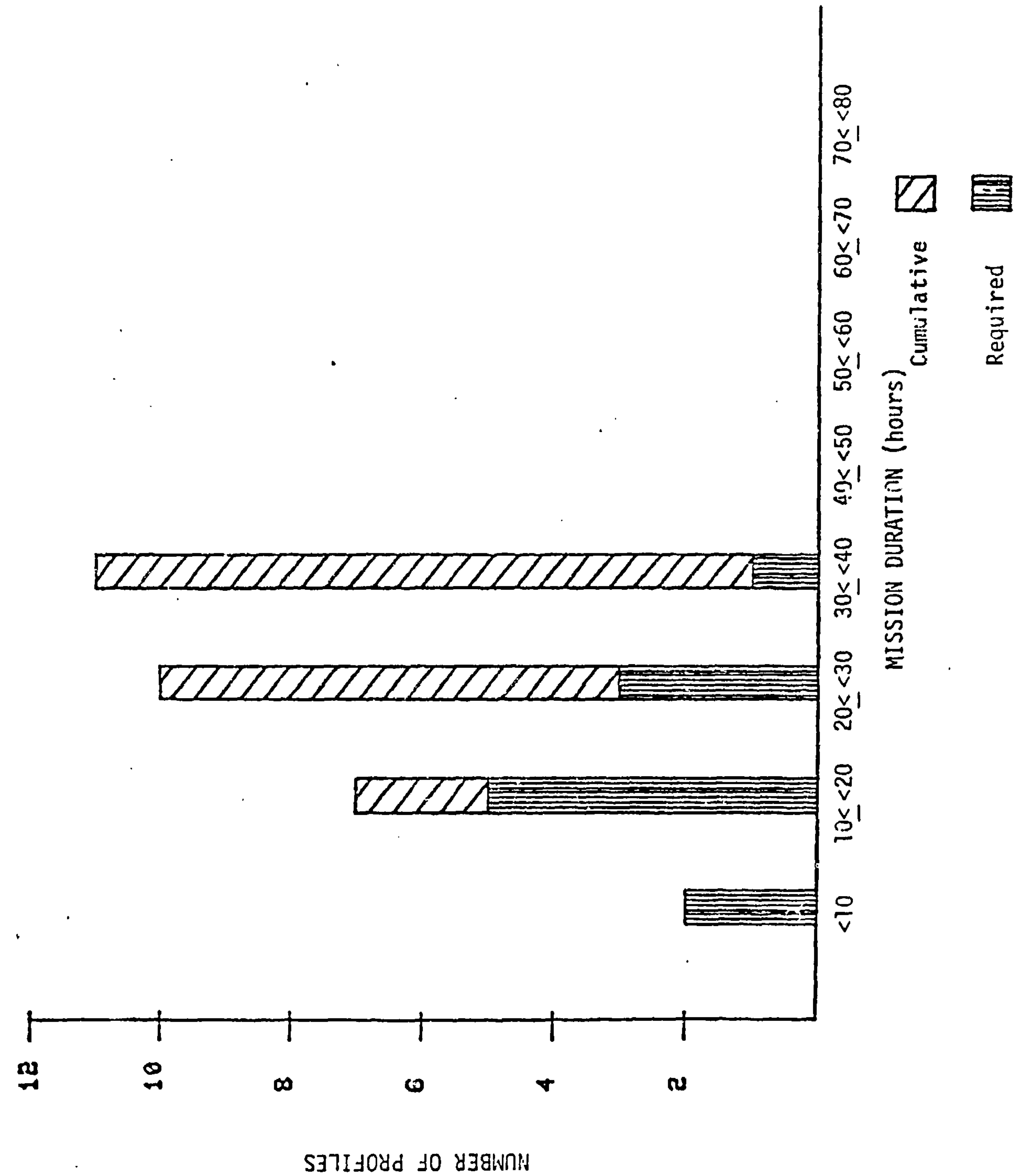

Figure F-13. Number of Profiles for Marine Science Activity.

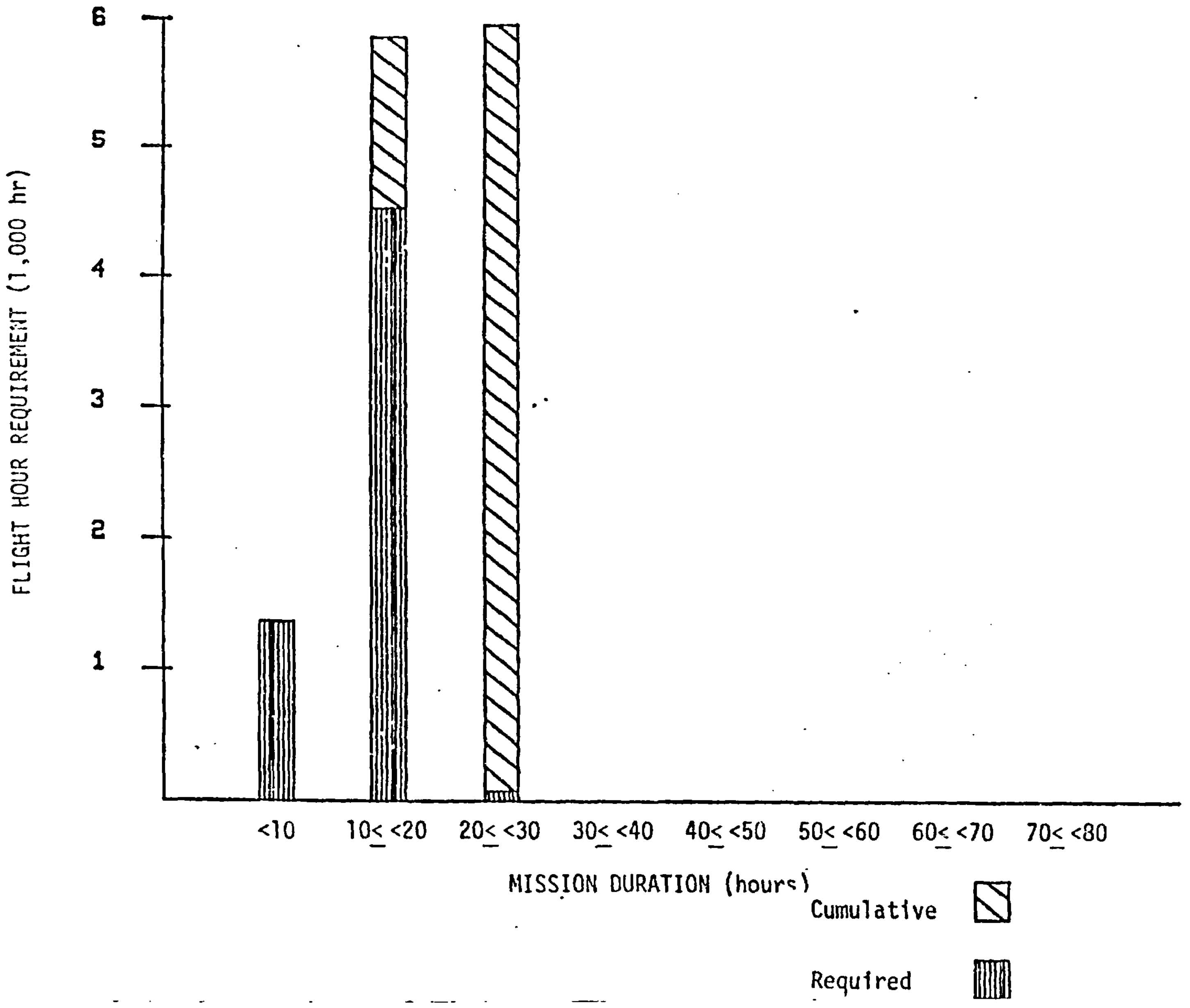

Figure F-14. Flight Hour Requirement for Port Safety and Security.

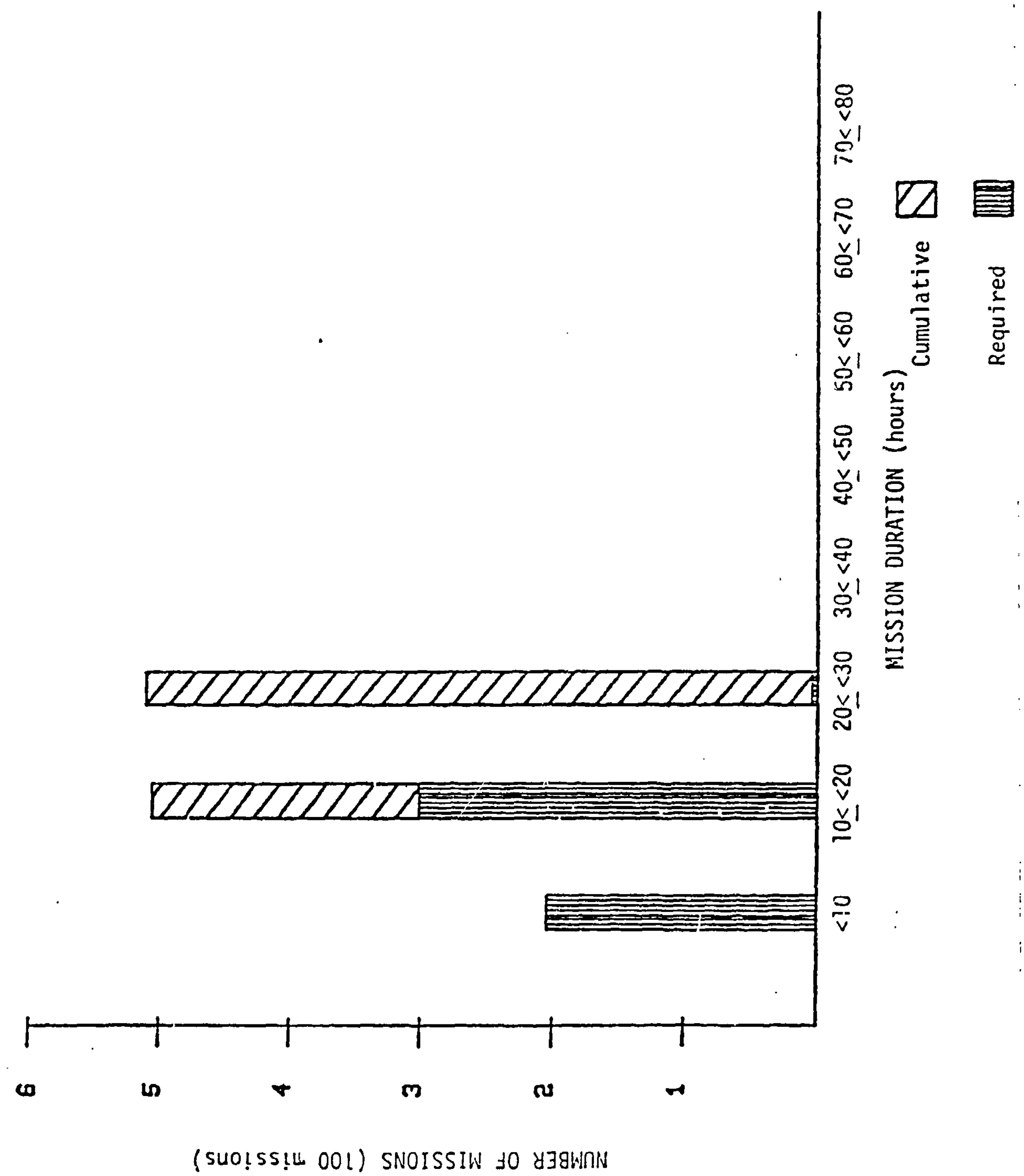

Figure F-15. Number of Missions for Port Safety and Security.

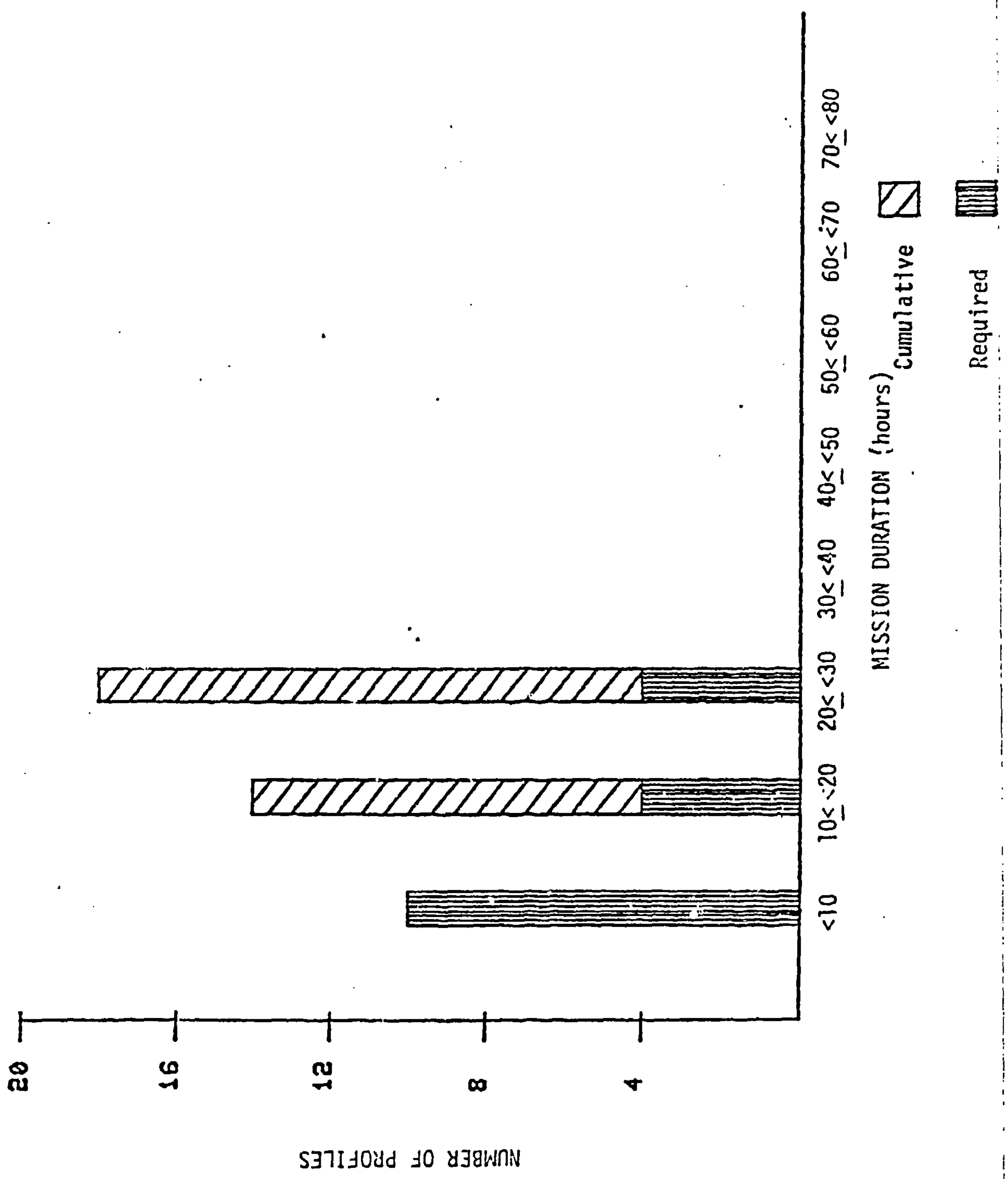

Figure F-15. Number of Profiles for Port Safety and Security.

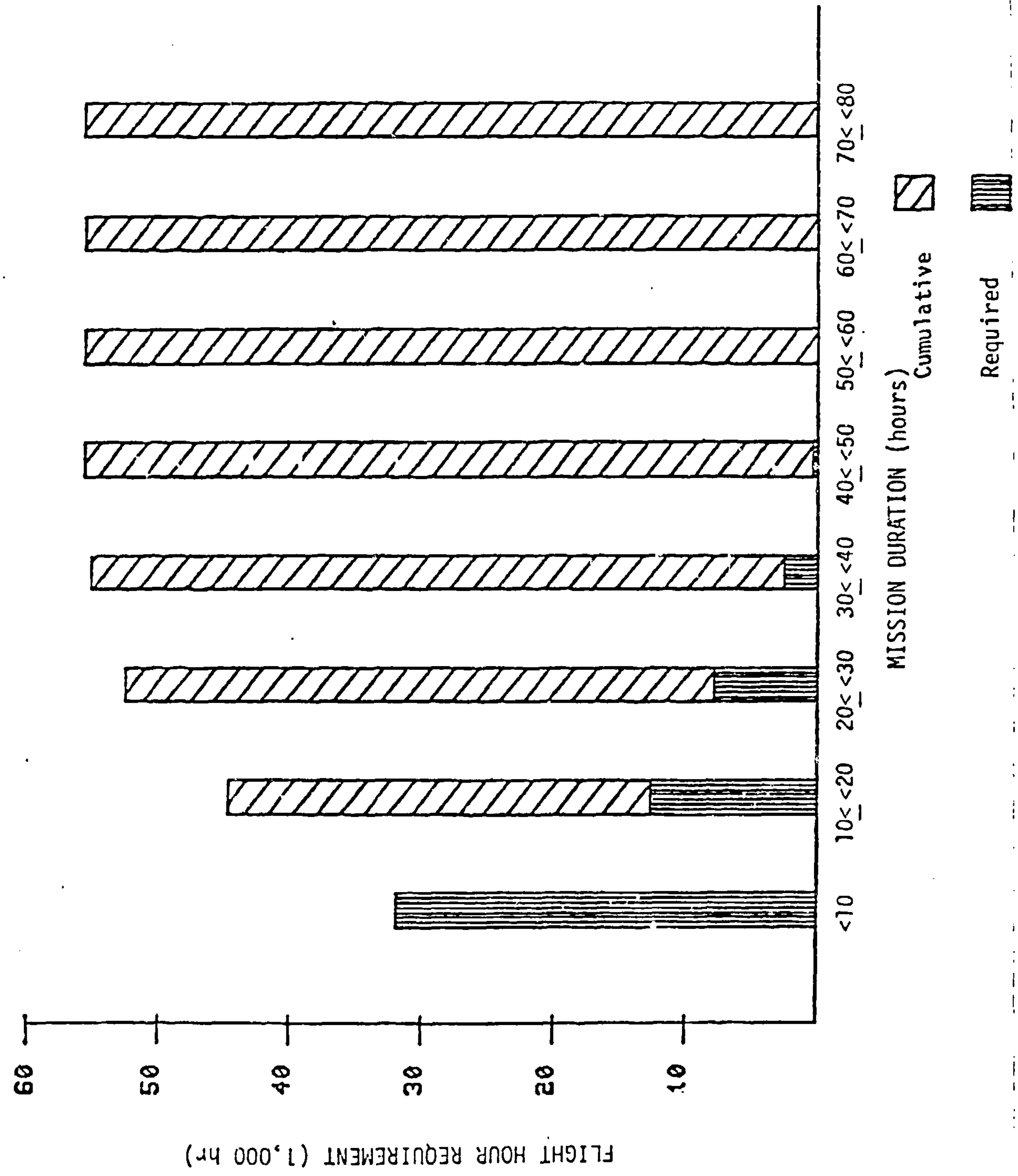

Figure F-17. Flight Hour Requirement for Search and Rescue.

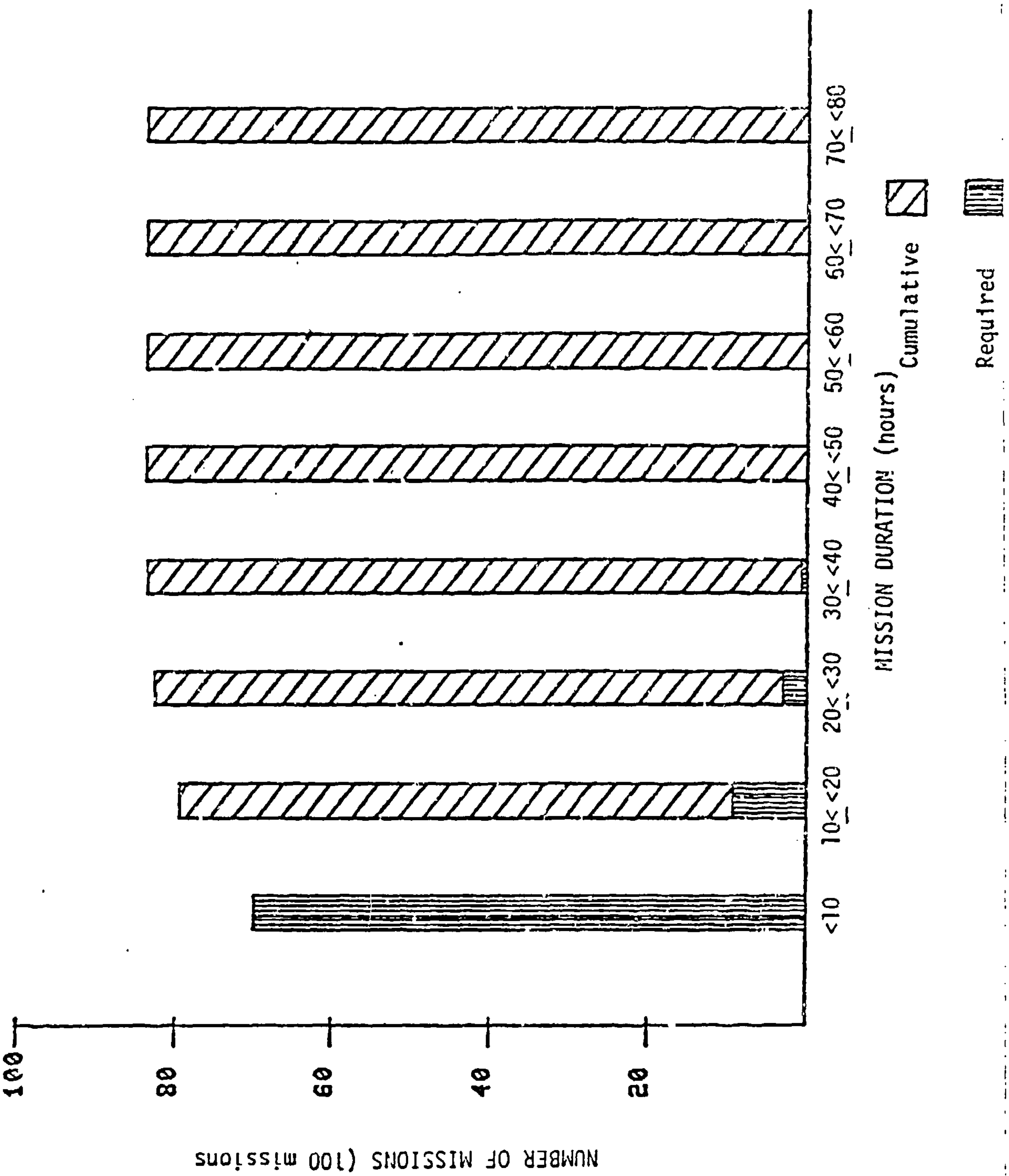

Figure F-18. Number of Missions for Search and Rescue.

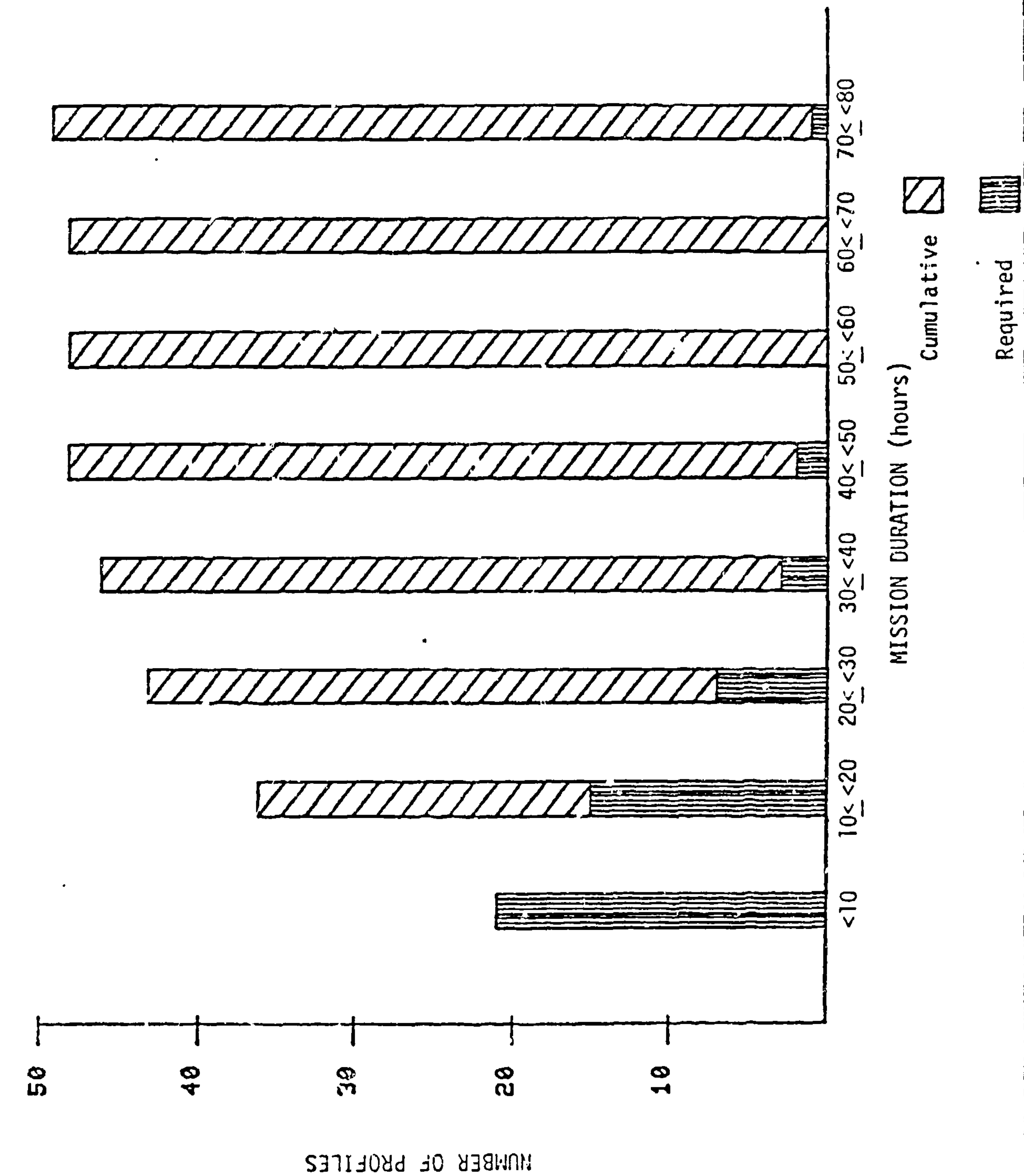

Figure F-19. Number of Profiles for Search and Rescue.

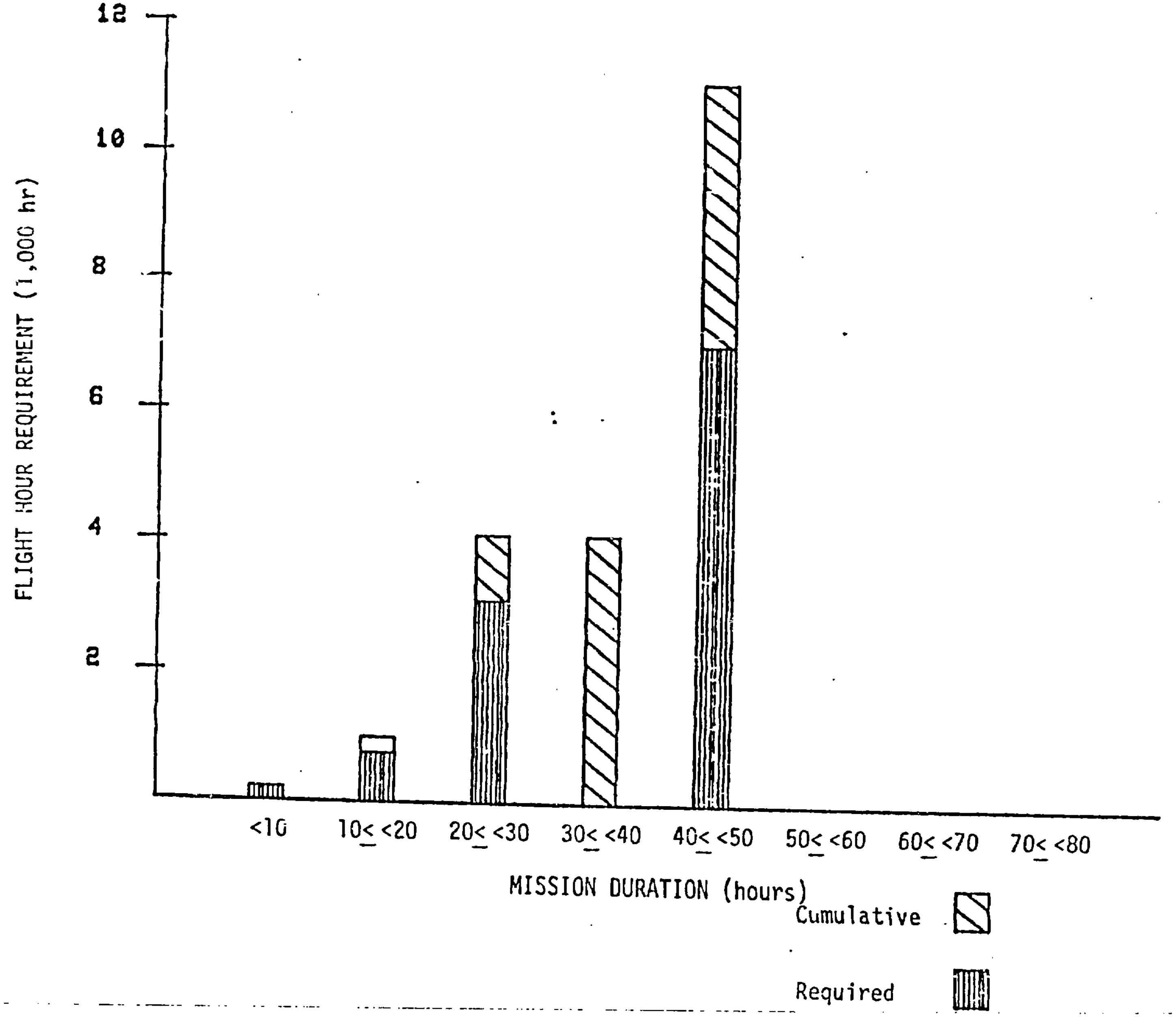

Figure F-20. Flight Hour Requirement for Ice Operations.

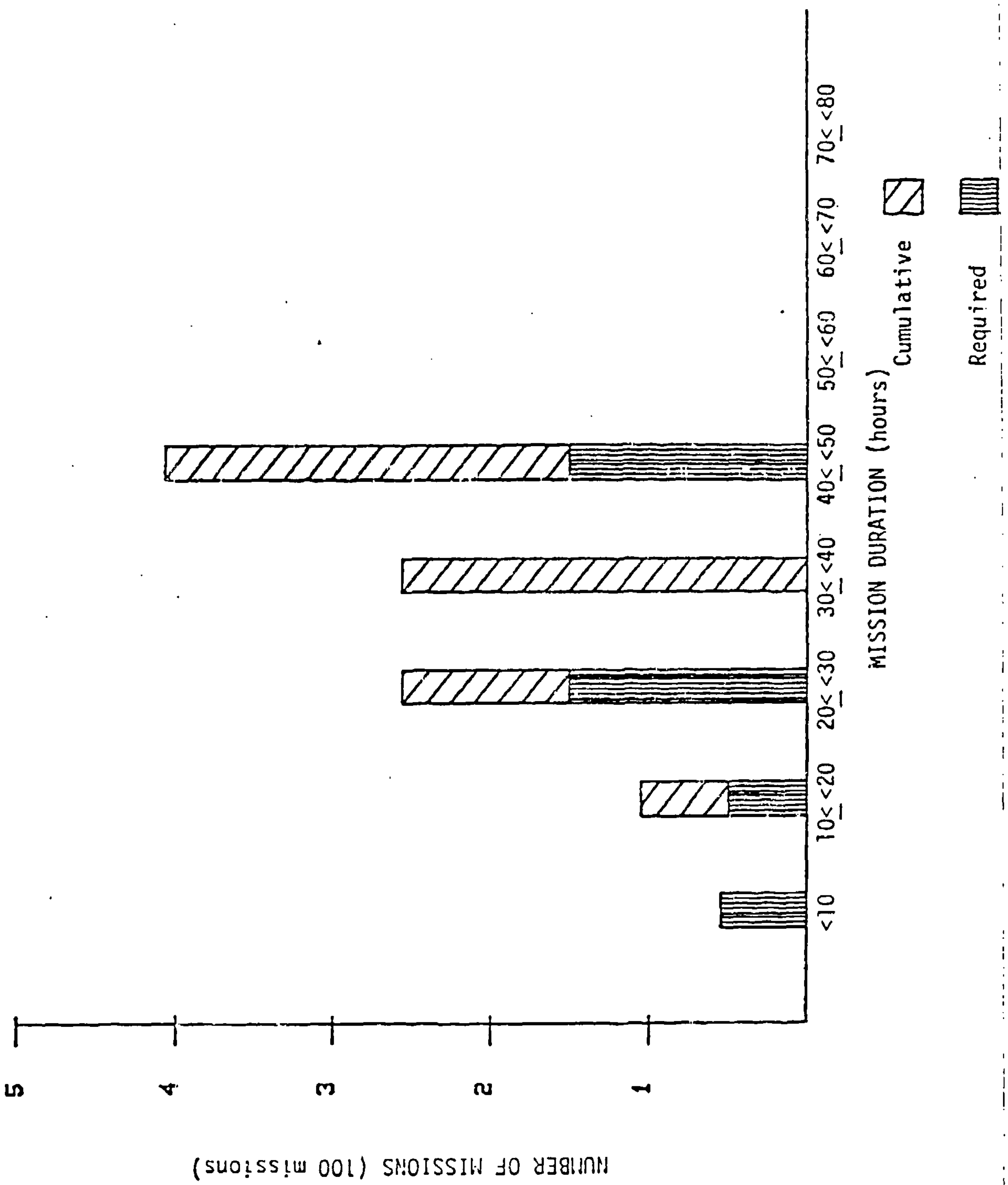

Figure F-21. Number of Missions for Ice Oerations.

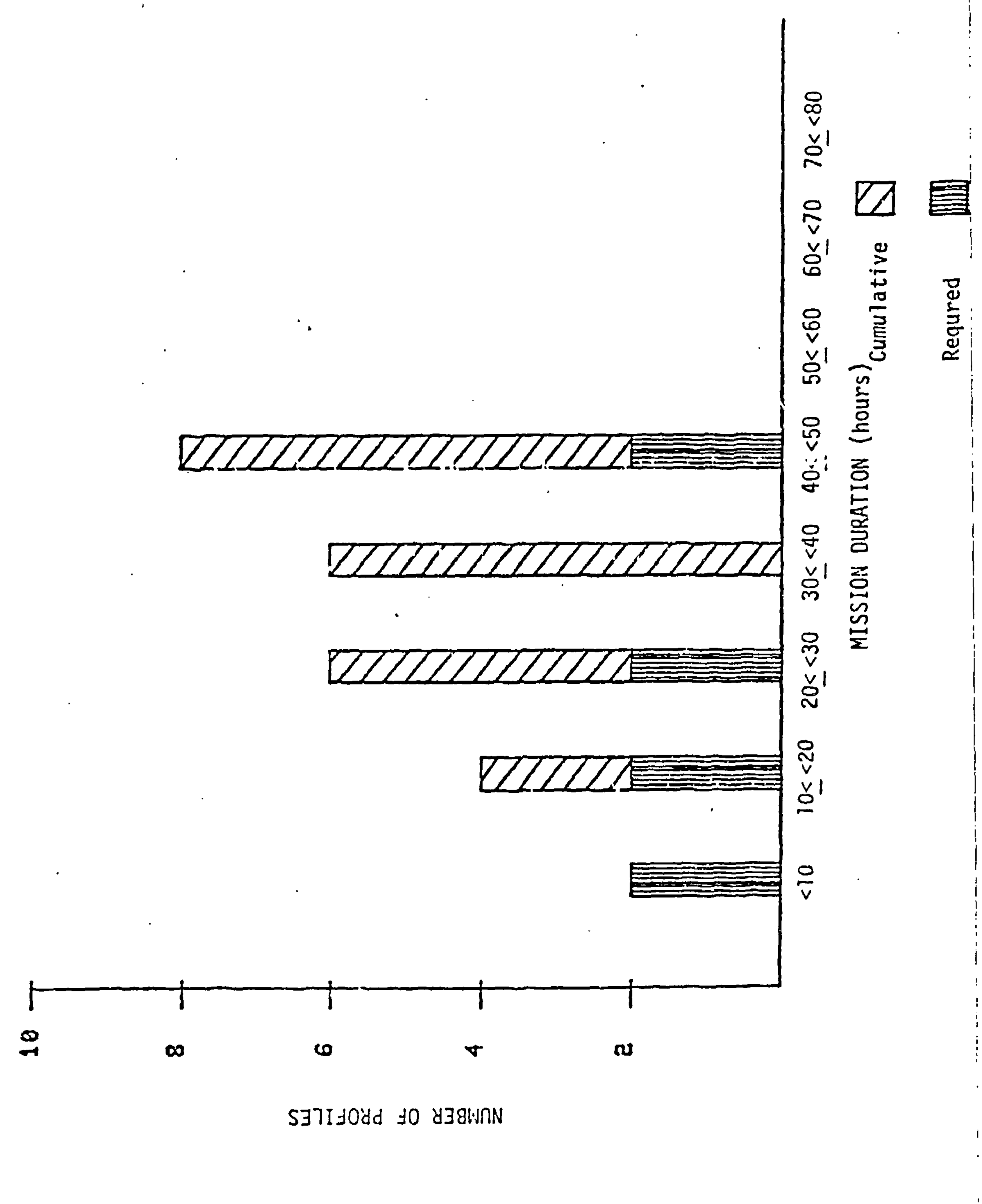

Figure F-22. Number of Profiles for Ice Operations.

APPENDIX G

EFFECTIVENESS MODEL

A description of the computer effectiveness model is presented in Chapter IV. This appendix provides the program listing.

```
      PRECISION INTEGER IDES1,IDES2
      DIMENSION TASK(7),SPEED(4),SWEEP(4),TTT(11),ITT(11),IOT(11),
     +         CREW(3),IS(7),C(4),CW(3),TTIME(8,11),ITIME(8,11),IOTME(8,11)
      DATA IS/2,2,1,2,1,3,4/,FP/4420./,
     +         CREW/235.38,360.88,567.88/,SPEED/10.,50.,1.,10./,
     +         SWEEP/.02,.06,.03,.05/, CW/1100.,1760.,2860./,
     +         C/223.18,211.81,55.77,.08/
      WT(JJ)=T6 + FP +WMP+ CREW(JJ)
      ISCRB=0
      DO 5 I=1,11
      ITT(I)=0
      TTT(I)=0.0
      IOT(I)=0
      DO 5 J=1,8
      TTIME(J,I)=0.0
      ITIME(J,I)=0
    5 IOTME(J,I)=0
      WRITE(2,904)
   10 READ(1,801) WMP,FJ,IDES1,IDES2
      READ(1,901)(TASK(I),I=1,7),SW,ID
      IF(WMP.LT.0.0) GOTO 2000
      ISW=SW+.1
      T6=TASK(6)
      DO 50 I=1,6
   50 DUR=0
      FC=0
      TIME=0.0
      DO 100 I=1,2
      J=I
      IF(TASK(I).EQ.0) GOTO 100
      IZ=IS(I)
      DUR=TASK(I)/SPEED(IZ)
      TIME=TIME + DUR
      JC=TIME / 10 + 1
      IF(JC.GT.3) JC=3
      CALL FCOMP(WT(JC),DUR,IZ,FC,FLIM)
      IF(FC.GT.FLIM) GOTO 1000
  100 CONTINUE
```

```
      DO 200 I=3,5,2
      J=I
      IF(TASK(I).EQ.0) GOTO 200
      DUR=TASK(I)
      TIME=TIME + DUR
      JC=TIME / 10 + 1
      IF(JC.GT.3) JC=3
      CALL FCOMP(WT(JC),DUR,IZ,FC,FLIM)
      IF(FC.GT.FLIM) GOTO 1000
  200 CONTINUE
      IF(TASK(4).EQ.0) GOTO 300
      J=4
      IZ=IS(4)
      DUR=TASK(4)/(SWEEP(ISW) * SPEED(IZ))
      TIME=TIME + DUR
      JC=TIME / 10 + 1
      IF(JC.GT.3) JC=3
      CALL FCOMP(WT(JC),DUR,IZ,FC,FLIM)
      IF(FC.GT.FLIM) GOTO 1000
  300 CONTINUE
      I=6
      J=I
      IF(TASK(6).EQ.0) GOTO 350
      IZ=IS(I)
      DUR=.5
      TIME=TIME+DUR
      JC=TIME/10+1
      IF(JC.GT.3) JC=3
      CALL FCOMP(WT(JC),DUR,IZ,FC,FLIM)
      IF(FC.GT.FLIM) GOTO 1000
350   CONTINUE
      I=7
      J=I
      IF(TASK(I).EQ.0) GOTO 400
      IZ=IS(I)
      DUR=TASK(I) / SPEED(IZ)
      TIME=TIME + DUR
      JC=TIME / 10 + 1
```

```
      IF(JC.GT.3) JC=3
      CALL FCOMF(WT(JC),DUR,IZ,FC,FLIM)
      IF(FC.GT.FLIM) GOTO 1000
  400 CONTINUE
      COST=0
      DO 550 I=1,3
  550 COST=COST+C(I)
      COST=CREW(JC)+COST
      COST=COST * TIME + C(4) * FC
      C1=COST/TIME
      TOT=TIME * IO
      WRITE(2,902) FJ,IDES1,IDES2,WMF,(TASK(I),I=1,7),ISW,IO,C1,COST,FC,TIME ,TOT
      I=TIME/10+1
      J=FJ+.1
      TTIME(J,I)=TTIME(J,I)+TOT
      ITIME(J,I)=ITIME(J,I)+1
      IOTME(J,I)=IOTME(J,I)+IO
      GOTO 10
 1000 WRITE(2,903)FJ,IDES1,IDES2,WMF,(TASK(I),I=1,7),ISW,IO,FC,FLIM,J
      ISCRB=ISCRB+1
      GOTO 10
 2000 CONTINUE
      DO 2500 J=1,8
      WRITE(2,908)J
      WRITE(2,905)
      DO 2400 I=1,11
      TTT(I)=TTT(I)+TTIME(J,I)
      ITT(I)=ITT(I)+ITIME(J,I)
      IOT(I)=IOT(I)+IOTME(J,I)
      IT=10*I
 2400 IF(I.LT.11) WRITE(2,906) IT,TTIME(J,I),ITIME(J,I),IOTME(J,I)
 2500 WRITE(2,910) TTIME(J,11),ITIME(J,11),IOTME(J,11)
      WRITE(2,905)
      DO 3000 I=1,10
      IT=10 * I
 3000 WRITE(2,906) IT,TTT(I),ITT(I),IOT(I)
      WRITE(2,910) TTT(11),ITT(11),IOT(11)
      WRITE(2,907) ISCRB
```

```
      STOP
905   FORMAT(///'DURATION MISSION TIME NUMBER OF PROFILES NUMBER OF MISSIONS')
906   FORMAT(' <',I5,5X,F8.2,5X,I8,5X,I8)
907   FORMAT(///'NUMBER OF PROFILES EXCEEDING CAPABILITIES =',I5)
  801 FORMAT(F6.1,F2.0,4A2)
  901 FORMAT(8F10.2,I5)
  902 FORMAT(F2.0,4A2,F5.0,7F7.1,3X,I1,4X,I4,' $',F8.2,' $',F9.2,1X,F7.1,2X,F5.2,2X,F8.2)
  903 FORMAT(F2.0,4A2,F5.0,7F7.1,3X,I1,4X,I4,/' FUEL CONSUMED= ',F7.1,1X,'GREATER THAN LIMIT =',
     +          F8.2,/'MISSION TERMINATED IN TASK',I4)
  904 FORMAT('     ID   MISSION  TASK    TASK    TASK    TASK    TASK    TASK    TASK SEARCH OCCUR- ',
     + ' HOURLY      TOTAL      FUEL  DURATION    TOTAL'/
     +       ,'  NUMBER PAYLOAD    1       2       3       4       5       6       7   TYPE   ENCE  ',
     + ' COST         COST    (LBS)    (HRS)    (HRS)')
  908 FORMAT(///,20X,'PROGRAM',I2)
  910 FORMAT(' >  100',5X,F8.2,5X,I8,5X,I8)
      END
```

```
      SUBROUTINE FCOMP(WT,DUR,IZ,FC,FLIM)
      DIMENSION CNSMP(4,2)
      DATA WGHT/26880./,FTOL/200./,DP/19242./,
     + CNSMP/300.,310.,337.,120.,.0786,.0301,.0490,.0001/
      FLIM=.9*(WGHT-WT)-FTOL
      WD=(DP-WT-FC)/CNSMP(IZ,1)
      IF(DUR.GT.WD) GOTO 10
      FC=FC + CNSMP(IZ,1)*DUR
      RETURN
   10 IF(WD.LT.0) GOTO 100
      DUR=DUR -WD
      FC=DP-WT
  100 FC=FC+(CNSMP(IZ,1)/CNSMP(IZ,2)+WT+FC-DP)*(EXP(CNSMP(IZ,2)*DUR)-1.)
      RETURN
      END
```

APPENDIX H

EFFECTIVENESS RESULTS

This appendix presents the data output of the computer effectiveness model (described in Chapter VIII and Appendix F).

The output includes hourly and mission cost (1979$), fuel consumed, mission duration, and total annual mission hours for each profile.

The first 11 columns summarize the mission profile and are input to the program. The next column is the average hourly cost, followed by the total cost of performing the mission. Both of these costs are based upon life cycle cost estimates. The next column gives the total fuel consumed in performance of the profile. The next column lists the duration of a single mission, and the last column gives the annual flight hour requirement associated with all occurrences of a profile. If a profile exceeds the capabilities of the vehicle, it is noted in the output.

ID NUMBER	MISSION PAYLOAD	TASK 1	TASK 2	TASK 3	TASK 4	TASK 5	TASK 6	TASK 7	SEARCH TYPE	OCCUR-ENCE	HOURLY COST	TOTAL COST	FUEL (LBS)	DURATION (HRS)	TOT (HR
1.1.1	1289.	50.0	150.0	1.0	0.0	0.0	2000.0	0.0	1	10	$ 751.14	$ 4131.25	1718.5	5.50	55.
1.1.2	1289.	50.0	300.0	2.0	0.0	0.0	2000.0	0.0	1	10	$ 751.05	$ 7135.01	2958.5	9.50	95.
1.1.3	1289.	100.0	200.0	2.0	0.0	0.0	5000.0	0.0	1	10	$ 751.07	$ 6384.07	2648.5	8.50	85.
1.1.4	1289.	100.0	300.0	2.0	0.0	0.0	5000.0	0.0	1	10	$ 876.54	$ 9203.70	3268.5	10.50	105.
1.1.5	1289.	100.0	200.0	4.0	0.0	0.0	5000.0	0.0	1	10	$ 876.54	$ 9203.70	3268.5	10.50	105.
2.1.1	734.	0.0	0.0	0.0	20.0	0.0	0.0	0.0	1	10	$ 1083.44	$ 21668.80	6200.0	20.00	200.
2.1.2	734.	0.0	0.0	0.0	35.0	0.0	0.0	0.0	1	75	$ 1083.44	$ 37920.40	10850.0	35.00	2625.
2.1.3	734.	0.0	100.0	4.0	20.0	0.0	0.0	0.0	1	25	$ 1083.44	$ 28169.44	8060.0	26.00	650.
2.1.4	734.	0.0	100.0	6.0	35.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 46587.91	13330.0	43.00	4300.
2.1.5	734.	50.0	0.0	0.0	3.0	0.0	0.0	0.0	1	10	$ 750.94	$ 3003.76	1240.0	4.00	40.
2.1.6	734.	50.0	50.0	4.0	10.0	0.0	0.0	0.0	1	50	$ 876.44	$ 14023.04	4960.0	16.00	800.
2.1.7	734.	50.0	0.0	0.0	15.0	0.0	0.0	0.0	1	50	$ 876.44	$ 14023.04	4960.0	16.00	800.
2.1.8	734.	50.0	50.0	2.0	15.0	0.0	0.0	0.0	1	100	$ 876.44	$ 16652.36	5890.0	19.00	1900.
2.1.9	734.	50.0	0.0	0.0	20.0	0.0	0.0	0.0	1	25	$ 1083.44	$ 22752.24	6510.0	21.00	525.
2.1.10	734.	50.0	100.0	4.0	20.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 29252.88	8370.0	27.00	2700.
2.1.11	734.	50.0	200.0	10.0	70.0	0.0	0.0	0.0	2	200	$ 1083.44	$ 41531.86	11883.3	38.33	7666.
2.1.12	734.	150.0	50.0	2.0	5.0	0.0	0.0	0.0	1	50	$ 876.44	$ 9640.84	3410.0	11.00	550.
2.1.13	734.	150.0	100.0	4.0	20.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 31419.76	8990.0	29.00	2900.
2.1.14	734.	500.0	50.0	2.0	25.0	0.0	0.0	0.0	1	50	$ 1083.44	$ 41170.71	11780.0	38.00	1900.
2.1.15	734.	500.0	100.0	4.0	50.0	0.0	0.0	0.0	2	200	$ 1083.44	$ 35392.38	10126.7	32.67	6533.
2.1.16	734.	500.0	200.0	8.0	100.0	0.0	0.0	0.0	2	100	$ 1084.49	$ 60008.21	17876.7	55.33	5533.
2.1.17	734.	2000.0	100.0	4.0	25.0	0.0	0.0	0.0	1	50					
FUEL CONSUMED= 26706.7 GREATER THAN LIMIT =18042.31															
MISSION TERMINATED IN TASK 4															
2.1.18	734.	2000.0	150.0	6.0	50.0	0.0	0.0	0.0	1	25					
FUEL CONSUMED= 57774.9 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.1.19	734.	2000.0	200.0	8.0	100.0	0.0	0.0	0.0	2	50					
FUEL CONSUMED= 39376.3 GREATER THAN LIMIT =18042.31															
MISSION TERMINATED IN TASK 4															
2.1.20	734.	1000.0	0.0	8.0	15.0	0.0	0.0	0.0	1	300	$ 1083.44	$ 46587.91	13330.0	43.00	12900.
2.2.1	734.	0.0	100.0	4.0	20.0	2.0	0.0	0.0	1	25	$ 1083.44	$ 30336.32	8680.0	26.00	700.
2.2.2	734.	0.0	100.0	6.0	35.0	2.0	0.0	0.0	1	100	$ 1083.46	$ 48755.52	13959.1	45.00	4500.
2.2.3	734.	50.0	50.0	2.0	10.0	2.0	0.0	0.0	1	10	$ 876.44	$ 14023.04	4960.0	16.00	160.
2.2.4	734.	50.0	50.0	2.0	15.0	2.0	0.0	0.0	1	50	$ 1083.44	$ 22752.24	6510.0	21.00	1050.
2.2.5	734.	50.0	100.0	4.0	20.0	2.0	0.0	0.0	1	10	$ 1083.44	$ 31419.76	8990.0	29.00	290.
2.2.6	734.	50.0	200.0	10.0	70.0	4.0	0.0	0.0	2	100	$ 1083.44	$ 45865.63	13123.3	42.33	4233.
2.2.7	734.	150.0	50.0	2.0	5.0	2.0	0.0	0.0	1	10	$ 876.44	$ 11393.72	4030.0	13.00	130.
2.2.8	734.	150.0	100.0	4.0	20.0	2.0	0.0	0.0	1	100	$ 1083.44	$ 33586.63	9610.0	31.00	3100.
2.2.9	734.	500.0	50.0	2.0	25.0	4.0	0.0	0.0	1	25	$ 1083.44	$ 45504.48	13020.0	42.00	1050.
2.2.10	734.	500.0	100.0	4.0	50.0	4.0	0.0	0.0	2	100	$ 1083.44	$ 39726.14	11366.7	36.67	3666.
2.2.11	734.	500.0	200.0	8.0	100.0	2.0	0.0	0.0	2	200	$ 1084.85	$ 62198.24	18786.1	57.33	11466.
2.2.12	734	2000.0	100.0	4.0	25.0	4.0	0.0	0.0	1	50					
FUEL CONSUMED= 29711.7 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.2.13	734.	2000.0	150.0	6.0	50.0	2.0	0.0	0.0	1	25					
FUEL CONSUMED= 61159.9 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.2.14	734.	2000.0	200.0	8.0	100.0	2.0	0.0	0.0	2	50					
FUEL CONSUMED= 41619.7 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.2.15	734.	1000.0	0.0	8.0	15.0	2.0	0.0	0.0	1	50	$ 1083.46	$ 48755.52	13959.1	45.00	2250.
2.3.1	734.	25.0	50.0	15.0	15.0	2.0	0.0	0.0	1	2	$ 1083.44	$ 36295.23	10385.0	33.50	67.
2.3.2	734.	25.0	50.0	2.0	15.0	2.0	0.0	100.0	1	1	$ 1078.46	$ 32892.71	7555.0	30.50	30.
2.3.3	734.	50.0	100.0	20.0	20.0	2.0	0.0	0.0	1	2	$ 1083.46	$ 48755.52	13959.1	45.00	90.
2.3.4	734.	100.0	100.0	20.0	50.0	2.0	0.0	0.0	1	1					
FUEL CONSUMED= 30521.1 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 4															
2.3.5	734.	1000.0	200.0	50.0	50.0	2.0	0.0	0.0	1	2					
FUEL CONSUMED= 29926.2 GREATER THAN LIMIT =18842.31															

2.3.6	734.	500.0	0.0	50.0	15.0	2.0	0.0	0.0	1	2					
FUEL CONSUMED= 20086.9 GREATER THAN LIMIT =18842.31															
MISSION TERMINATED IN TASK 3															
3.1.1	1234.	50.0	10.0	0.5	10.0	0.0	0.0	0.0	1	100	$ 876.44	$ 10254.37	3627.0	11.70	1170.
3.1.2	1234.	50.0	10.0	0.5	20.0	0.0	0.0	0.0	1	50	$ 1083.44	$ 23510.65	6727.0	21.70	1085.
3.1.3	1234.	100.0	10.0	0.5	10.0	0.0	0.0	0.0	1	100	$ 876.44	$ 11130.79	3937.0	12.70	1270.
3.1.4	1234.	100.0	10.0	0.5	20.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 24594.09	7037.0	22.70	2270.
3.1.5	1234.	100.0	10.0	0.5	50.0	0.0	0.0	0.0	3	100	$ 1083.44	$ 39039.95	11170.3	36.03	3603.
3.1.6	1234.	500.0	10.0	0.5	50.0	0.0	0.0	0.0	3	50	$ 1083.48	$ 47759.05	13670.0	44.03	2201.
3.1.7	1234.	1000.0	10.0	0.5	50.0	0.0	0.0	0.0	3	25	$ 1084.57	$ 58603.08	17515.4	54.03	1350.
3.1.8	1234.	200.0	0.0	4.0	0.0	0.0	0.0	0.0	1	100	$ 750.94	$ 6007.52	2480.0	8.00	800.
3.1.9	1234.	500.0	0.0	4.0	0.0	0.0	0.0	0.0	1	100	$ 876.44	$ 12270.16	4340.0	14.00	1400.
3.1.10	1234.	200.0	0.0	4.0	0.0	1.0	0.0	0.0	1	10	$ 750.94	$ 6758.46	2790.0	9.00	90.
3.1.11	1234.	500.0	0.0	4.0	0.0	1.0	0.0	0.0	1	10	$ 876.44	$ 13146.60	4650.0	15.00	150.
3.3.1	1234.	200.0	10.0	8.0	0.0	0.01	7000.0	0.0	1	1					
FUEL CONSUMED= 6222.4 GREATER THAN LIMIT = 3278.61															
MISSION TERMINATED IN TASK 3															
3.3.2	1234.	50.0	10.0	2.0	0.0	0.01	7000.0	0.0	1	1	$ 763.03	$ 2823.21	1706.2	3.70	3.
3.3.3	1234.	50.0	10.0	4.0	0.0	0.0	500.0	0.0	1	10	$ 751.13	$ 4281.44	1780.5	5.70	57.
3.3.4	1234.	50.0	10.0	4.0	0.0	0.0	1000.0	0.0	1	10	$ 751.13	$ 4281.44	1780.5	5.70	57.
3.3.5	1234.	100.0	10.0	4.0	0.0	0.0	500.0	0.0	1	10	$ 751.10	$ 5032.38	2090.5	6.70	67.
3.3.6	1234.	100.0	10.0	4.0	0.0	0.0	1000.0	0.0	1	10	$ 751.10	$ 5032.38	2090.5	6.70	67.
3.3.7	1234.	100.0	10.0	8.0	0.0	0.0	3000.0	0.0	1	5	$ 876.54	$ 9378.99	3330.[illegible]	10.70	53.
3.4.1	1234.	50.0	0.0	4.0	0.0	0.0	0.0	0.0	1	25	$ 750.94	$ 3754.70	1550.0	5.00	125.
3.4.2	1234.	50.0	0.0	12.0	0.0	0.0	0.0	0.0	1	10	$ 876.44	$ 11393.72	4030.0	13.00	130.
3.4.3	1234.	50.0	0.0	24.0	0.0	0.0	0.0	0.0	1	10	$ 1083.44	$ 27086.00	7750.0	25.00	250.
3.4.4	1234.	100.0	0.0	8.0	0.0	0.0	0.0	0.0	1	5	$ 876.44	$ 8764.40	3100.0	10.00	50.
3.4.5	1234.	100.0	0.0	36.0	0.0	0.0	0.0	0.0	1	5	$ 1083.44	$ 41170.71	11780.0	38.00	190.
4.1.1	4005.	25.0	25.0	0.0	10.0	0.0	0.0	0.0	1	0	$ 876.44	$ 9640.84	3410.0	11.00	0.
4.1.2	4005.	25.0	25.0	0.0	200.0	0.0	0.0	0.0	2	0					
FUEL CONSUMED= 29135.2 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED N TASK 4															
4.1.3	4005.	100.0	25.0	0.0	10.0	0.0	0.0	0.0	1	0	$ 876.44	$ 10955.50	3875.0	12.50	0.
4.1.4	4005.	100.0	25.0	0.0	100.0	0.0	0.0	0.0	2	0	$ 1083.52	$ 38826.22	11145.2	35.83	0.
4.1.5	4005.	500.0	25.0	0.0	50.0	0.0	0.0	0.0	2	0	$ 1083.44	$ 29433.45	8421.7	27.17	0.
4.1.6	4005.	500.0	25.0	0.0	200.0	0.0	0.0	0.0	2	0					
FUEL CONSUMED= 38796.2 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 4															
4.1.7	4005.	1000.0	25.0	0.0	50.0	0.0	0.0	0.0	2	0	$ 1083.62	$ 40274.41	11603.6	37.17	0.
4.1.8	4005.	1000.0	25.0	0.0	200.0	0.0	0.0	0.0	2	0					
FUEL CONSUMED= 52439.3 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 4															
4.1.9	4005.	3000.0	25.0	0.0	50.0	0.0	0.0	0.0	2	0					
FUEL CONSUMED= 23120.9 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 1															
4.1.10	4005.	3000.0	25.0	0.0	200.0	0.0	0.0	0.0	2	0					
FUEL CONSUMED= 23120.9 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 1															
4.2.1	4005.	50.0	0.0	0.0	10.0	0.0	0.0	0.0	4	0	$ 750.94	$ 3754.70	1550.0	5.00	0.
4.2.2	4005.	50.0	0.0	0.0	50.0	0.0	0.0	0.0	4	0	$ 1083.44	$ 22752.24	6510.0	21.00	0.
4.2.3	4005.	100.0	0.0	0.0	50.0	0.0	0.0	0.0	4	0	$ 1083.44	$ 23835.68	6820.0	22.00	0.
4.2.4	4005.	100.0	0.0	0.0	100.0	0.0	0.0	0.0	4	0	$ 1084.22	$ 45537.16	13428.5	42.00	0.
4.2.5	4005.	500.0	0.0	0.0	10.0	0.0	0.0	0.0	4	0	$ 876.44	$ 12270.16	4340.0	14.00	0.
4.2.6	4005.	500.0	0.0	0.0	50.0	0.0	0.0	0.0	4	0	$ 1083.44	$ 32503.20	9300.0	30.00	0.
4.2.7	4005.	500.0	0.0	0.0	100.0	0.0	0.0	0.0	4	0					
FUEL CONSUMED= 17098.3 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 4															
4.2.8	4005.	1000.0	0.0	0.0	10.0	0.0	0.0	0.0	4	0	$ 1083.44	$ 26002.56	7440.0	24.00	0.
4.2.9	4005.	1000.0	0.0	0.0	100.0	0.0	0.0	0.0	4	0					
FUEL CONSUMED= 23120.9 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 4															
4.2.10	4005.	1000.0	0.0	0.0	500.0	0.0	0.0	0.0	4	0					
FUEL CONSUMED= *286084 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 4															
4.2.11	4005.	2000.0	0.0	0.0	10.0	0.0	0.0	0.0	4	0	$ 1084.58	$ 47221.34	14264.7	4[illegible].00	0.

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 FUEL CONSUMED= 42254.5 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    4
4.2.13     4005. 2000.0    0.0    0.0  500.0    0.0     0.0     0.0    4       0
 FUEL CONSUMED= $522328 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    4
4.3.1      4005.   50.0    0.0    0.0    0.0    0.0     0.0  200.0    4       0 $ 1068.96 $ 22448.24  2710.0  21.00      0.
4.3.2      4005.   50.0    0.0    0.0    0.0    0.0     0.0 1000.0    4       0 $ 1068.39 $107907.58 12311.7  $101.      0.
4.3.3      4005.  100.0    0.0    0.0    0.0    0.0     0.0 1000.0    4       0 $ 1068.54 $108991.05 12622.3  $102.      0.
4.3.4      4005.  100.0    0.0    0.0    0.0    0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 24706.4 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    7
4.3.5      4005.  500.0    0.0    0.0    0.0    0.0     0.0  200.0    4       0 $ 1073.31 $ 32199.20  5500.0  30.00      0.
4.3.6      4005.  500.0    0.0    0.0    0.0    0.0     0.0 1000.0    4       0 $ 1069.63 $117659.19 15110.0  $110.      0.
4.3.7      4005.  500.0    0.0    0.0    0.0    0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 27219.0 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    7
4.3.8      4005. 1000.0    0.0    0.0    0.0    0.0     0.0  200.0    4       0 $ 1075.84 $ 43033.59  8600.0  40.00      0.
4.3.9      4005. 1000.0    0.0    0.0    0.0    0.0     0.0 1000.0    4       0
 FUEL CONSUMED= 18226.2 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    7
4.3.10     4005. 1000.0    0.0    0.0    0.0    0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 30366.7 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    7
4.3.11     4005. 2000.0    0.0    0.0    0.0    0.0     0.0  200.0    4       0 $ 1078.70 $ 64722.25 15048.3  60.00      0.
4.3.12     4005. 2000.0    0.0    0.0    0.0    0.0     0.0 1000.0    4       0
 FUEL CONSUMED= 24725.2 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    7
4.3.13     4005. 2000.0    0.0    0.0    0.0    0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 36931.1 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    7
4.4.1      4005.   50.0   50.0    1.0   10.0    0.0     0.0    0.0    4       0 $  750.94 $  5256.58  2170.0   7.00      0.
4.4.2      4005.   50.0   10.0    1.0   50.0    0.0     0.0    0.0    4       0 $ 1083.44 $ 24052.36  6882.0  22.20      0.
4.4.3      4005.   50.0   50.0    1.0   50.0    0.0     0.0    0.0    4       0 $ 1083.44 $ 24719.12  7130.0  23.00      0.
4.4.4      4005.  100.0   10.0    1.0   10.0    0.0     0.0    0.0    4       0 $  750.94 $  5406.77  2232.0   7.20      0.
4.4.5      4005.  100.0   50.0    1.0   10.0    0.0     0.0    0.0    4       0 $  750.94 $  6007.52  2480.0   8.00      0.
4.4.6      4005.  100.0   50.0    1.0   50.0    0.0     0.0    0.0    )       0 $ 1083.44 $ 26002.56  7440.0  24.00      0.
4.4.7      4005.  500.0   10.0    1.0   10.0    0.0     0.0    0.0    4       0 $  876.44 $ 13321.89  4712.0  15.20      0.
4.4.8      4005.  500.0   50.0    1.0   50.0    0.0     0.0    0.0    4       0 $ 1083.44 $ 34670.08  9920.0  32.00      0.
4.4.9      4005.  500.0   10.0    1.0  100.0    0.0     0.0    0.0    4       0
 FUEL CONSUMED= 17729.0 GREATER THAN LIMIT =15899.41
MISSION TERMINATED IN TASK    4
4.4.10     4005.  500.0   50.0    1.0  100.0    0.0     0.0    0.0    4       0
 FUEL CONSUMED= 18162.3 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    4
4.4.11     4005. 1000.0   10.0    1.0   10.0    0.0     0.0    0.0    4       0 $ 1083.44 $ 27302.67  7812.0  25.20      0.
4.4.12     4005. 1000.0   50.0    1.0  100.0    0.0     0.0    0.0    4       0
 FUEL CONSUMED= 24558.6 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    4
4.4.13     4005. 1000.0   50.0    1.0  500.0    0.0     0.0    0.0    4       0
 FUEL CONSUMED= $303836 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    4
4.4.14     4005. 1000.0   10.0    1.0  100.0    0.0     0.0    0.0    4       0
 FUEL CONSUMED= 23973.1 GREATER THAN LIMIT =15698.41
MISSION TERMINATED IN TASK    4
4.4.15     4005. 2000.0   50.0    1.0   10.0    0.0     0.0    0.0    4       0 $ 1084.99 $ 47909.69 15153.1  46.00      0.
4.4.16     4005. 2000.0   50.0    1.0  100.0    0.0     0.0    0.0    4       0
 FUEL CONSUMED= 44879.5 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    4
4.4.17     4005. 2000.0   50.0    1.0  500.0    0.0     0.0    0.0    4       0
 FUEL CONSUMED= $554738 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK    4
4.5.1      4005.   50.0   50.0    1.0    0.0    0.0     0.0  200.0    4       0 $ 1070.22 $ 24615.12  3330.0  23.00      0.
4.5.2      4005.   50.0   10.0    1.0    0.0    0.0     0.0 1000.0    4       0 $ 1069.57 $109207.75 12684.4  $102.      0.
4.5.3      4005.   50.0   50.0    1.0    0.0    0.0     0.. 1000.0    4       0 $ 1068.68 $110074.55 12933.0  $103.      0.
4.5.4      4005.  100.0   .0.0    1.0    0.0    0.0     0.0  200.0    4       0 $ 1070.34 $ 24831.80  3372.0  23.20      0.
[illegible]
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4.5.6      4005.  100.0    50.0    1.0     0.0     0.0     0.0 1000.0    4       0 $ 1068.83 $111158.05 13243.8  $104.      0.
4.5.7      4005.  500.0    10.0    1.0     0.0     0.0     0.0  200.0    4       0 $ 1073.70 $ 33499.32  5872.0  31.20      0.
4.5.8      4005.  500.0    50.0    1.0   . 0.0     0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 27847.8 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   7
4.5.9      4005.  500.0    10.0    1.0     0.0     0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 27596.4 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   7
4.5.10     4005.  500.0    50.0    1.0     0.0     0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 27847.8 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   7
4.5.11     4005. 1000.0    10.0    1.0     0.0     0.0     0.0  200.0    4       0 $ 1076.06 $ 44333.73  8972.0  41.20      0.
4.5.12     4005. 1000.0    50.0    1.0     0.0     0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 30997.3 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   7
4.5.13     4005. 1000.0    50.0    1.0     0.0     0.0     0.010000.0    4       0
 FUEL CONSUMED= $132670 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   7
4.5.14     4005. 1000.0    10.0    1.0     0.0     0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 30745.2 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   7
4.5.15     4005. 2000.0    50.0    1.0     0.0     0.0     0.0  200.0    4       0 $ 1079.08 $ 66902.66 15837.3  62.00      0.
4.5.16     4005. 2000.0    50.0    1.0     0.0     0.0     0.0 2000.0    4       0
 FUEL CONSUMED= 37734.5 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   7
4.5.17     4005. 2000.0    50.0    1.0     0.0     0.0     0.010000.0    4       0
 FUEL CONSUMED= $139963 GREATER THAN LIMIT =15998.41
MISSION TERMINATED IN TASK   7
4.6.1      4005.    50.0  100.0    2.0     1.0     0.0     0.0     0.0   1       0 $  750.94 $  4505.64  1860.0   6.00      0.
4.6.2      4005.    50.0  200.0    3.0     1.0     0.0     0.0     0.0   1       0 $  750.94 $  6758.46  2790.0   9.00      0.
4.6.3      4005.    50.0  200.0    7.0     5.0     0.0     0.0     0.0   1       0 $  876.44 $ 10517.28  3720.0  12.00      0.
4.6.4      4005.   200.0  100.0    2.0     1.0     0.0     0.0     0.0   1       0 $  750.94 $  6758.46  2790.0   9.00      0.
4.6.5      4005.   200.0  200.0    2.0     5.0     0.0     0.0     0.0   1       0 $  876.44 $ 13146.60  4650.0  15.00      0.
4.6.6      4005.   400.0  100.0    5.0     5.0     0.0     0.0     0.0   1       0 $ 1083.44 $ 21668.80  6200.0  20.00      0.
4.6.7      4005.   400.0  500.0   10.0     5.0     0.0     0.0     0.0   1       0 $ 1083.44 $ 35753.52 10230.0  33.00      0.
4.6.8      4005.   400.0 1000.0   10.0     5.0     0.0     0.0     0.0   1       0 $ 1084.39 $ 46728.75 13840.4  43.00      0.
4.6.9      4005.   400.0 1000.0   20.0    10.0     0.0     0.0     0.0   1       0
 FUEL CONSUMED= 16096.4 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   3
4.6.10     4005.   400.0 1000.0   10.0    10.0     0.0     0.0     0.0   1       0
 FUEL CONSUMED= 16096.4 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   4
4.7.1      4005.    50.0  100.0    2.0     1.0     5.0     0.0     0.0   1       0 $  876.44 $  9640.84  3410.0  11.00      0.
4.7.2      4005.    50.0  200.0    3.0     1.0    10.0     0.0     0.0   1       0 $  876.44 $ 16652.36  5890.0  19.00      0.
4.7.3      4005.    50.0  200.0    2.0     5.0    10.0     0.0     0.0   1       0 $ 1083.44 $ 23835.68  6820.0  22.00      0.
4.7.4      4005.   200.0  100.0    2.0     1.0     5.0     0.0     0.0   1       0 $  876.44 $ 12270.16  4340.0  14.00      0.
4.7.5      4005.   200.0  200.0    2.0     5.0    10.0     0.0     0.0   1       0 $ 1083.44 $ 27086.00  7750.0  25.00      0.
4.7.6      4005.   400.0  100.0    5.0     5.0     5.0     0.0     0.0   1       0 $ 1083.44 $ 27086.00  7750.0  25.00      0.
4.7.7      4005.   400.0  500.0   10.0     5.0    25.0     0.0     0.0   1       0
 FUEL CONSUMED= 19718.8 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   5
4.7.8      4005.   400.0 1000.0   10.0     5.0    50.0     0.0     0.0   1       0
 FUEL CONSUMED= 53772.6 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   5
4.7.9      4005.   400.0 1000.0   20.0    10.0    50.0     0.0     0.0   1       0
 FUEL CONSUMED= 16096.4 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   3
4.7.10     4005.   400.0 1000.0   10.0    10.0    20.0     0.0     0.0   1       0
 FUEL CONSUMED= 21767.1 GREATER THAN LIMIT =15898.41
MISSION TERMINATED IN TASK   5
4.8.1      4005.     0.0  500.0    5.0    10.0     0.0     0.0     0.0   1       0 $ 1083.44 $ 27086.00  7750.0  25.00      0.
4.8.2      4005.     0.0  100.0   10.0    10.0     0.0     0.0     0.0   1       0 $ 1083.44 $ 23835.68  6820.0  22.00      0.
4.8.3      4005.     0.0  200.0   10.0    50.0     0.0     0.0     0.0   4       0 $ 1083.45 $ 36837.29 10544.1  34.00      0.
4.8.4      4005.     0.0  500.0   20.0    50.0     0.0     0.0     0.0   4       0
 FUEL CONSUMED= 17098.3 GREATER THAN LIMIT =15898.41
[illegible]
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4.8.5	4005.	0.0	200.0	20.0	100.0	0.0	0.0	0.0	4	0					
FUEL CONSUMED= 24085.5 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 4															
4.8.6	4005.	0.0	500.0	40.0	100.0	0.0	0.0	0.0	4	0					
FUEL CONSUMED= 17098.3 GREATER THAN LIMIT =15898.41															
MISSION TERMINATED IN TASK 3															
4.9.1	4005.	50.0	0.0	0.0	0.0	0.0	500.0	0.0	1	0	$ 751.66	$ 1127.49	478.5	1.50	0.
4.9.2	4005.	50.0	0.0	0.0	0.0	0.0	2500.0	0.0	1	0	$ 751.66	$ 1127.49	478.5	1.50	0.
4.9.3	4005.	50.0	0.0	0.0	0.0	0.0	5000.0	0.0	1	0	$ 751.66	$ 1127.49	478.5	1.50	0.
4.9.4	4005.	500.0	0.0	0.0	0.0	0.0	500.0	0.0	1	0	$ 876.54	$ 9203.70	3268.5	10.50	0.
4.9.5	4005.	500.0	0.0	0.0	0.0	0.0	2500.0	0.0	1	0	$ 876.54	$ 9203.70	3268.5	10.50	0.
4.9.6	4005.	500.0	0.0	0.0	0.0	0.0	5000.0	0.0	1	0	$ 876.54	$ 9203.70	3268.5	10.50	0.
4.9.7	4005.	2000.0	0.0	0.0	0.0	0.0	500.0	0.0	1	0	$ 1084.35	$ 43916.35	13018.0	40.50	0.
4.9.8	4005.	2000.0	0.0	0.0	0.0	0.0	2500.0	0.0	1	0					
FUEL CONSUMED= 13944.2 GREATER THAN LIMIT =13648.41															
MISSION TERMINATED IN TASK 5															
4.9.9	4005.	2000.0	0.0	0.0	0.0	0.0	5000.0	0.0	1	0					
FUEL CONSUMED= 15572.5 GREATER THAN LIMIT =11398.41															
MISSION TERMINATED IN TASK 1															
4.9.10	4005.	5000.0	0.0	0.0	0.0	0.0	5000.0	0.0	1	0					
FUEL CONSUMED= *120458 GREATER THAN LIMIT =11398.41															
MISSION TERMINATED IN TASK 1															
4.10.1	4005.	10.0	100.0	2.0	1.0	1.0	500.0	0.0	1	0	$ 751.10	$ 5032.38	2090.5	6.70	0.
4.10.2	4005.	100.0	10.0	2.0	0.5	0.0	500.0	0.0	1	0	$ 751.15	$ 3905.97	1675.5	5.20	0.
4.10.3	4005.	200.0	200.0	2.0	0.5	1.0	500.0	0.0	1	0	$ 876.53	$ 10518.36	3733.5	12.00	0.
5.1.1	1734.	0.0	0.0	1.0	25.0	0.0	0.0	0.0	1	100	$ 1083.52	$ 28171.60	8087.0	26.00	2600.
5.1.2	1734.	0.0	0.0	1.0	50.0	0.0	0.0	0.0	2	100	$ 876.44	$ 15483.77	5476.7	17.67	1766.
5.1.3	1734.	200.0	0.0	1.0	75.0	0.0	0.0	0.0	1	50	$ 1083.44	$ 32503.20	9300.0	30.00	1500.
5.1.4	1734.	200.0	0.0	1.0	50.0	0.0	0.0	0.0	2	50	$ 1083.44	$ 23474.53	6716.7	21.67	1083.
5.2.1	1734.	50.0	0.0	0.0	50.0	0.0	0.0	0.0	2	25	$ 876.44	$ 15483.77	5476.7	17.67	441.
5.2.2	1734.	100.0	0.0	0.0	25.0	0.0	0.0	0.0	2	25	$ 876.44	$ 9056.55	3203.3	10.33	258.
5.2.3	1734.	500.0	0.0	0.0	25.0	0.0	0.0	0.0	2	50	$ 876.44	$ 16068.07	5683.3	18.33	716.
5.3.1	1734.	0.0	100.0	0.0	0.0	0.0	100.0	0.0	1	2	$ 751.37	$ 1678.43	788.5	2.50	5.
5.3.2	1734.	0.0	200.0	0.0	0.0	0.0	100.0	0.0	1	2	$ 751.18	$ 3380.31	1408.5	4.50	9.
5.3.3	1734.	0.0	500.0	0.0	0.0	0.0	100.0	0.0	1	2	$ 876.54	$ 9203.70	3268.5	10.50	21.
5.3.4	1734.	0.0	1000.0	0.0	0.0	0.0	100.0	0.0	1	2	$ 1083.49	$ 22211.60	6368.5	20.50	41.
6.1.1	565.	50.0	20.0	3.0	0.0	0.0	0.0	0.0	1	100	$ 750.94	$ 3304.14	1364.0	4.40	440.
6.1.2	565.	100.0	50.0	6.0	0.0	0.0	0.0	0.0	1	100	$ 750.94	$ 6758.45	2790.0	9.00	900.
6.1.3	565.	100.0	100.0	12.0	0.0	0.0	0.0	0.0	1	100	$ 876.44	$ 14023.04	4960.0	16.00	1600.
6.1.4	565.	200.0	50.0	6.0	0.0	0.0	0.0	0.0	1	100	$ 876.44	$ 9640.94	3410.0	11.00	1100.
6.1.5	565.	200.0	100.0	12.0	0.0	0.0	0.0	0.0	1	100	$ 876.44	$ 15775.92	5580.0	18.00	1800
6.2.1	565.	0.0	50.0	4.0	0.0	0.0	0.0	0.0	1	0	$ 750.94	$ 3754.70	1550.0	5.00	0.
6.2.2	565.	0.0	100.0	4.0	0.0	0.0	0.0	0.0	1	0	$ 750.94	$ 4505.64	1860.0	6.00	0.
6.2.3	565.	0.0	50.0	7.0	0.0	0.0	0.0	0.0	1	0	$ 750.94	$ 6007.52	2480.0	9.00	0.
6.2.4	565.	0.0	100.0	7.0	0.0	0.0	0.0	0.0	1	0	$ 750.94	$ 6758.46	2790.0	9.00	0.
6.2.5	565.	0.0	100.0	10.0	0.0	0.0	0.0	0.0	1	0	$ 876.44	$ 10517.28	3720.0	12.00	0.
6.3.1	565.	0.0	0.0	4.0	0.0	0.0	100.0	0.0	1	1	$ 751.18	$ 3380.31	1408.5	4.50	4.
6.3.2	565.	0.0	0.0	4.0	0.0	0.0	2700.0	0.0	1	1	$ 753.10	$ 3388.75	1516.5	4.50	4.
6.3.3	565.	0.0	0.0	20.0	0.0	0.0	100.0	0.0	1	1	$ 1095.60	$ 22254.80	6208.5	20.50	20.
6.3.4	565.	0.0	0.0	20.0	0.0	0.0	2700.0	0.0	1	1	$ 1085.60	$ 22254.80	6298.5	20.50	20.
6.3.5	565.	100.0	0.0	4.0	0.0	0.0	100.0	0.0	1	1	$ 751.11	$ 4882.19	2029.5	6.50	6.
6.3.6	565.	100.0	0.0	4.0	0.0	0.0	2700.0	0.0	1	1	$ 751.11	$ 4882.19	2029.5	6.50	6.
6.3.7	565.	100.0	0.0	20.0	0.0	0.0	100.0	0.0	1	1	$ 1033.49	$ 24378.48	6788.5	22.50	22.
6.3.8	565.	100.0	0.0	20.0	0.0	0.0	2700.0	0.0	1	1	$ 1083.49	$ 24378.48	6798.5	22.50	22.
7.1.1	776.	50.0	0.0	0.0	1.0	0.0	0.0	0.0	1	2000	$ 750.94	$ 1501.88	620.0	2.00	4000.
7.1.2	776.	50.0	0.0	0.0	5.0	0.0	0.0	0.0	1	500	$ 750.94	$ 4505.64	1860.0	6.00	3000.
7.1.3	776.	50.0	0.0	2.0	2.0	0.0	0.0	0.0	1	100	$ 750.94	$ 3754.70	1550.0	5.00	500.
7.1.4	776.	50.0	0.0	4.0	2.0	0.0	0.0	0.0	1	100	$ 750.94	$ 5256.58	2170.0	7.00	700.
7.1.5	776.	100.0	0.0	0.0	1.0	0.0	0.0	0.0	1	500	$ 750.94	$ 2252.52	930.0	3.00	1500.
7.1.6	776.	100.0	0.0	0.0	5.0	0.0	0.0	0.0	1	100	$ 750.94	$ 5256.58	2170.0	7.00	700.
7.1.7	776.	100.0	0.0	2.0	3.0	0.0	0.0	0.0	1	50	$ 750.94	$ 5256.58	2170.0	7.00	350.
7.1.8	776.	100.0	0.0	4.0	3.0	0.0	0.0	0.0	1	10	$ 750.94	$ 6758.46	2790.0	9.00	90.
7.1.9	776.	100.0	0.0	10.0	5.0	0.0	0.0	0.0	1	5	$ 876.44	$ 14029.48	5270.0	17.00	85.
7.1.10	776.	500.0	0.0	0.0	1.0	0.0	0.0	0.0	1	200	$ 876.44	$ 9640.84	3410.0	11.00	2200.
7.1.11	776.	[illegible]	0.0	0.0	5.0	0.0	0.0	0.0	1	200	$ 876.44	$ 13145.60	4650.0	15.00	3000.

7.1.13	776.	500.0	0.0	10.0	5.0	0.0	0.0	0.0	1	25	$ 1083.44	$ 27086.00	7750.0	25.00	625.
7.1.14	776.	1000.0	0.0	0.0	1.0	0.0	0.0	0.0	1	100	$ 1083.44	$ 22752.24	6510.0	21.00	2100.
7.1.15	776.	1000.0	0.0	0.0	10.0	0.0	0.0	0.0	1	50	$ 1083.44	$ 32503.20	9300.0	30.00	1500.
7.1.16	776.	1000.0	0.0	2.0	5.0	0.0	0.0	0.0	1	25	$ 1083.44	$ 29252.38	8370.0	27.00	675.
7.1.17	776.	1000.0	0.0	10.0	5.0	0.0	0.0	0.0	1	5	$ 1083.44	$ 27920.40	10850.0	35.00	175.
7.2.1	776.	50.0	0.0	2.0	1.0	0.0	500.0	0.0	1	100	$ 751.18	$ 3380.31	1408.5	4.50	450.
7.2.2	776.	50.0	0.0	2.0	5.0	0.0	500.0	0.0	1	50	$ 751.07	$ 6384.07	2648.5	8.50	425.
7.2.3	776.	50.0	0.0	2.0	5.0	0.0	1000.0	0.0	1	100	$ 751.07	$ 6384.07	2648.5	8.50	850.
7.2.4	776.	100.0	0.0	2.0	3.0	0.0	500.0	0.0	1	20	$ 751.08	$ 5633.13	2338.5	7.50	150.
7.2.5	776.	100.0	0.0	2.0	3.0	0.0	1000.0	0.0	1	20	$ 751.08	$ 5633.13	2338.5	7.50	150.
7.2.6	776.	500.0	0.0	2.0	3.0	0.0	500.0	0.0	1	10	$ 876.51	$ 13585.90	4818.5	15.50	155.
7.2.7	776.	500.0	0.0	2.0	3.0	0.0	1000.0	0.0	1	20	$ 876.51	$ 13585.90	4818.5	15.50	310.
7.2.8	776.	1000.0	0.0	2.0	5.0	0.0	500.0	0.0	1	10	$ 1083.48	$ 29795.68	8538.5	27.50	275.
7.3.1	776.	50.0	0.0	2.0	1.0	1.0	500.0	0.0	1	5	$ 751.14	$ 4131.25	1718.5	5.50	27.
7.3.2	776.	100.0	0.0	2.0	1.0	1.0	500.0	0.0	1	5	$ 751.11	$ 4882.19	2028.5	6.50	32.
7.3.3	776.	500.0	0.0	2.0	1.0	1.0	500.0	0.0	1	5	$ 876.51	$ 12709.46	4508.5	14.50	72.
7.3.4	776.	1000.0	0.0	2.0	1.0	1.0	500.0	0.0	1	5	$ 1083.48	$ 26545.36	7608.5	24.50	122.
7.4.1	776.	50.0	0.0	2.0	1.0	1.0	0.0	25.0	1	100	$ 745.87	$ 5594.05	1850.0	7.50	750.
7.4.2	776.	50.0	0.0	4.0	1.0	1.0	500.0	25.0	1	50	$ 872.75	$ 9727.48	2638.5	10.00	500.
7.4.3	776.	100.0	0.0	2.0	3.0	1.0	0.0	50.0	1	25	$ 870.59	$ 11317.72	3080.0	13.00	325.
7.4.4	776.	100.0	0.0	4.0	3.0	1.0	500.0	50.0	1	5	$ 871.61	$ 13509.90	3868.5	15.50	77.
7.4.5	776.	500.0	0.0	2.0	3.0	1.0	0.0	250.0	1	5	$ 1074.17	$ 44041.03	7960.0	41.00	205.
7.4.6	776.	500.0	0.0	4.0	3.0	1.0	500.0	250.0	1	5	$ 1074.73	$ 46750.72	8748.5	43.50	217.
7.5.1	776.	50.0	0.0	2.0	1.0	1.0	0.0	0.0	1	1500	$ 750.94	$ 3754.70	1550.0	5.00	7500.
7.5.2	776.	50.0	0.0	4.0	1.0	1.0	0.0	0.0	1	500	$ 750.94	$ 5256.58	2170.0	7.00	3500.
7.5.3	776.	100.0	0.0	2.0	3.0	1.0	0.0	0.0	1	200	$ 750.94	$ 6007.52	2480.0	8.00	1600.
7.5.4	776.	100.0	0.0	4.0	5.0	1.0	0.0	0.0	1	100	$ 876.44	$ 10517.28	3720.0	12.00	1200.
7.5.5	776.	500.0	0.0	2.0	5.0	1.0	0.0	0.0	1	100	$ 876.44	$ 15775.72	5580.0	18.00	1800.
7.5.6	776.	500.0	0.0	4.0	3.0	1.0	0.0	0.0	1	50	$ 876.44	$ 15775.92	5580.0	18.00	900.
7.5.7	776.	1000.0	0.0	2.0	3.0	1.0	0.0	0.0	1	100	$ 1083.44	$ 28169.44	8060.0	26.00	2600.
7.5.8	776.	1000.0	0.0	4.0	3.0	1.0	0.0	0.0	1	50	$ 1083.44	$ 30336.32	8680.0	28.00	1400.
7.6.1	776.	50.0	0.0	1.0	1.0	0.0	0.0	25.0	.	1000	$ 744.03	$ 4092.17	1230.0	5.50	5500.
7.6.2	776.	50.0	0.0	4.0	1.0	0.0	0.0	25.0	1	20	$ 746.47	$ 6344.99	2160.0	8.50	170.
7.6.3	776.	100.0	0.0	1.0	3.0	0.0	0.0	50.0	1	100	$ 869.53	$ 9564.84	2460.0	11.00	1100.
7.6.4	776.	100.0	0.0	4.0	3.0	0.0	0.0	50.0	'	5	$ 871.01	$ 12194.16	3390.0	14.00	70.
7.6.5	776.	500.0	0.0	1.0	3.0	0.0	0.0	250.0	1	25	$ 1073.70	$ 41874.16	7340.0	39.00	975.
7.6.6	776.	1000.0	0.0	1.0	3.0	0.0	0.0	500.0	1	2	$ 1073.17	$ 79414.56	13440.0	74.00	148.
8.1.1	1734.	0.0	0.0	0.0	10.0	0.0	0.0	0.0	2	25	$ 750.94	$ 2503.13	1033.3	3.33	83.
8.1.2	1734.	0.0	0.0	0.0	15.0	0.0	0.0	0.0	2	30	$ 750.94	$ 3754.70	1550.0	5.00	150.
8.1.3	1734.	0.0	0.0	0.0	60.0	0.0	0.0	0.0	2	100	$ 1083.44	$ 21668.80	6200.0	20.00	2000.
8.1.4	1734.	100.0	0.0	0.0	30.0	0.0	0.0	0.0	2	25	$ 876.44	$ 10517.28	3720.0	12.00	300.
8.1.5	1734.	400.0	0.0	0.0	30.0	0.0	0.0	0.0	2	25	$ 876.44	$ 15775.92	5580.0	18.00	450.
8.1.6	1734.	500.0	0.0	0.0	12.0	0.0	0.0	0.0	1	50	$ 1083.44	$ 23835.68	6820.0	22.00	1100.
8.1.7	1734.	800.0	0.0	0.0	100.0	0.0	0.0	0.0	2	75	$ 1084.10	$ 53482.45	15702.6	49.33	3700.
8.1.8	1734.	1200.0	0.0	0.0	60.0	0.0	0.0	0.0	2	75	$ 1083.55	$ 47676.41	13703.2	44.00	3300.

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