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N75-32032

FEASIBILITY STUDY OF MODERN AIRSHIPS PHASE I, VOL. I
SUMMARY AND MISSION ANALYSIS (TASKS II AND IV)

GOODYEAR AEROSPACE CORP.
AKRON, OH

AUGUST 1975

NASA CR-137692(1)

FEASIBILITY STUDY OF MODERN AIRSHIPS (PHASE I)

Volume I - Summary and Mission Analysis (Tasks II and IV)

Contract NAS2-8643

August 1975

Prepared for

Ames Research Center, Moffett Field, California

by

Goodyear Aerospace Corporation, Akron, Ohio

FOREWORD

This final technical report was prepared for the Ames Research Center, Moffett Field, Calif., by Goodyear Aerospace Corporation, Akron, Ohio, under NASA Contract NAS2-8643, "Feasibility Study of Modern Airships." The technical monitor for the Ames Research Center was Dr. Mark D. Ardema.

This report describes work covered during Phase I (9 December 1974 to 9 April 1975) and consists of four volumes:

Volume I	-	Summary and Mission Analysis (Tasks II and IV)
Volume II	-	Parametric Analysis (Task III)
Volume III	-	Historical Overview (Task I)
Volume IV	-	Appendices

The report was a group effort headed by Mr. Ralph R. Huston and was submitted in May 1975. The contractor's report number is GER-16146.

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NOMENCLATURE *

MODAL DEFINITIONS

Rail - Conventional rail, unit trains, trailer and container on flat car, services purchased by freight forwarders.

Regulated Motor Carrier - Intercity, local, and freight forwarder purchased services or regulated motor vehicles.

Private Motor Carrier - Intercity, local, and freight forwarder purchased services utilizing private and contract nonregulated motor vehicles.

Water - Local, internal, lakewise, coastwise shipping for the contiguous, domestic United States utilizing water-borne vessels.

Pipeline - All shipments utilizing pipelines.

Air - All shipments utilizing commercial air-borne vehicles.

COMMODITY TYPE DEFINITIONS

The Standard Transportation Commodity Code (32) freight designations were grouped into three commodity classes (bulk, break bulk, and liquid). The criteria for grouping commodities by type are as follows:

Bulk (B) - Small commodities not handled discretely (i.e., grain) or large items handled as one item per carload or truckload (tanks, cranes).

Break Bulk (BB) - Commodities discretely handled usually in packaged, crated, or other containerized form.

Liquid (L) - Chemicals, petroleums, and other liquid products existing naturally in the liquid physical state.

COMMODITY VALUE DEFINITIONS

The Standard Transportation Commodity Code (32) freight designations were grouped into three value classes (low, medium, high). The criteria for value classes are as follows:

*Source: DOT/OST, "Technological Forecasts: 1975-2000", AD-754-178, May 1970, Appendix 2.

Low Value - Between 0 and $200 per ton.

Medium Value - $200 to $1000 per ton.

High Value - Greater than $1000 per ton.

COMMODITY GROUPING BY TYPE AND VALUE

Bulk - Low Value - Farm products (01); fresh fish and other marine products (09); metallic ores (10); coal (11); nonmetallic minerals, except fuels (14); waste and scrap materials (40).

Bulk - Medium Value - None

Bulk - High Value - Machinery, except electrical (35)

Break Bulk - Low Value - Forest products (08); lumber and wood products, except furniture (24); stone, clay, glass, and concrete products (32).

Break Bulk - Medium Value - Food and kindred products, except milk (20); furniture and fixtures (25); pulp, paper, and allied products (26); printed matter (27); chemicals and allied products (28); rubber and miscellaneous plastic products (30); primary metal products (33); fabricated metal products, except ordnance machinery and transportation equipment (34).

Break Bulk - High Value - Ordnance and accessories (19); tobacco products (21); basic textiles (22); apparel and other finished textile products (23); leather and leather products (31); electrical machinery equipment and supplies (36); transportation equipment (37); instruments photo, optical, watches, and clocks (38); miscellaneous products of manufacturing (39).

Liquid - Low Value - Crude petroleum, natural gas, and natural gasoline (13); petroleum and coal products (29).

Liquid - Medium Value - None

Liquid - High Value - None

MILITARY MISSION TERMINOLOGY

LOTS	-	Logistics over the shore
IR	-	Infra-red
ESM	-	Electronic surveillance and monitoring
HF/DF	-	High-frequency direction finding
OTH	-	Over the horizon
VP	-	Shore-based
VCOD	-	Shore-based carrier on-board delivery
VERTREP	-	Vertical replenishment
ELF	-	Extra low frequency
SURTASS	-	Surveillance towed array sonar system
TOA/DME	-	Time of arrival/distance measuring equipment
MMRBM	-	Mobile medium-range ballistic missile
RPV	-	Remotely piloted vehicle
ELINT	-	Electronic intelligence
DEW	-	Distant early warning
BMEWS	-	Ballistic missile early warning system
White Alice	-	Canadian-based communications system
ICBM	-	Intercontinental ballistic missile

FEASIBILITY STUDY OF MODERN AIRSHIPS

VOLUME I - SUMMARY AND MISSION ANALYSIS (TASKS II AND IV)

Fred Bloetscher*

Goodyear Aerospace Corporation

SUMMARY

The history, potential mission application, and designs of lighter-than-air (LTA) vehicles were researched and evaluated to determine if there were combinations of transportation missions and airship concepts that became sufficiently attractive on the basis of the specified figure of merit (ton-miles per hour) to warrant more detailed study in Phase II.

The historical overview, presented in Reference 1, complies the background of lighter-than-air activity from the pre-World War I period to 1961. The information includes missions, markets, classes of airship configuration, operating procedures, and costs utilized in the mission analysis task.

The mission analysis in this volume includes the entire panorama of potential uses for modern airships in various lift categories. The missions range from the conventional to quite unique cargo movement. A concurrent analysis was made of potential Department of Defense (DOD) missions in three lift categories.

The objective of the mission analysis was to identify missions to which modern airship vehicles (MAV's) are potentially suited. Results of the mission analysis were combined with the findings of the parametric analysis task (Reference 2) to formulate the mission/vehicle combinations that Goodyear Aerospace recommends for further study in Phase II.

A survey of current transportation systems was made and potential areas of competition were identified as well as potential missions resulting from limitations of present systems. In addition, many potential unique mission possibilities were isolated. Finally, potential areas of military usage were investigated.

*Section head, Recovery Systems Engineering, Goodyear Aerospace Corporation, Akron, Ohio.

RECOMMENDED PHASE II MAV/MISSION COMBINATIONS

MAV/Mission Combination 1

This MAV/mission combination provides both a passenger and cargo service in the short-to-medium-range market. Of particular interest is the major airport feeder capability now being handled by helicopters and small STOL fixed-wing aircraft. In Phase II, Goodyear Aerospace Corporation (GAC) will analyze the potential of this capability in the context of the Lake Erie Regional Transportation Authority (LERTA) plans currently under development for placing a large international airport in the lake off Cleveland. This plan has provoked severe criticism in terms of noise and a requirement to provide much greater roadway access, some of it through downtown Cleveland.

Studying the combination as a major feeder of both passengers and cargo in this elaborate LERTA scenario will be extremely useful for planners in both groups. The MAV has the potential for minimizing the noise problem, airspace, and runway use by the feeders and should substantially reduce the ground traffic.

MAV characteristics for this combination are:

1.	VTOL	
2.	Conventional ellipsoidal shape	
3.	Length/maximum diameter	- 4.7
4.	Length	- 57.9 m (190 ft)
5.	Gross weight	- 18,144 kg (40,000 lb)
6.	Static lift/gross weight, β	- 0.2
7.	Volume	- 4511.4 cu m (159,300 cu ft)
8.	Cruise speed	- 82.2 m/s (160 knots)
9.	Design altitude	- 1524 m (5000 ft)
10.	Design range	- 643.6 naut mi (400 stat mi)
11.	Useful load	- 10,206 kg (22,500 lb)
12.	Propulsion	- Four tilting turboprops, 8000 SHP at sea level
13.	Estimated passenger capacity	- 50

Figure 1 shows the baseline vehicle concept for MAV/mission combination 1.

MAV/Mission Combination 3

This MAV/mission combination is directed toward the unique and immediately required market for a medium heavy-lift VTOL MAV capable of transporting large, heavy indivisible payloads comparatively short distances (371 km) (200 naut mi). It also has a near-term DOD requirement for all three services plus the Coast Guard. Primary civil missions are short-haul transport of outsize, heavy power-generating equipment up to 453,600 kg (500 tons) as well as short-haul transport of other outsize, heavy industrial equipment. Primary DOD missions include main battle tank/combat engineer vehicle lifter (U.S. Army); logistics over the shore, LOTS (U.S. Navy); intratheater equipment transport; and mobile ICBM equipment transporter (U.S. Air Force).

MAV characteristics for MAV/mission combination 3 are:

1.	VTOL	
2.	Conventional ellipsoidal shape	
3.	Gross weight	- 684,936 kg (1,510,000 lb)
4.	Static lift	- 376,488 kg (830,000 lb)
5.	Payload	- 226,800 kg (500,000 lb)
6.	Hull volume	- 446,040 cu m (15.75×10^6 cu ft)
7.	Gas volume	- 379,488 cu m (13.4×10^6 cu ft)
8.	Endurance	- Five hours
9.	Propulsion	- 10 CH-53E helicopters
10.	Hull diameter	- 56.4 m (185 ft)
11.	Hull length	- 216.4 m (710 ft)
12.	Width (with rotors)	- 102.7 m (337 ft)
13.	Design altitude	- 1524 m (5000 ft)

Figure 2 shows the baseline vehicle concept for MAV/mission combination 3.

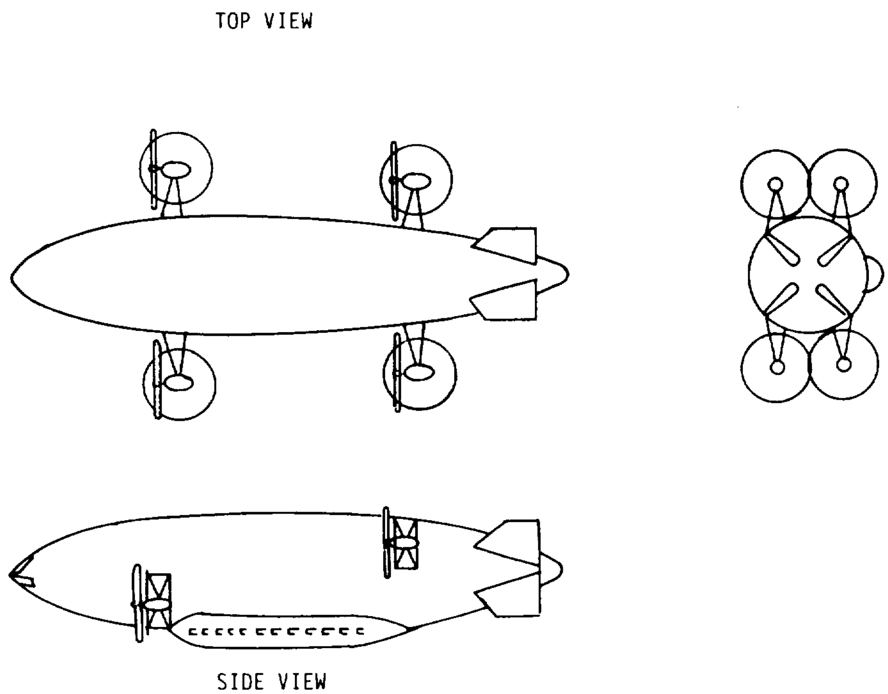

Figure 1 - Phase II Vehicle Concept No. 1

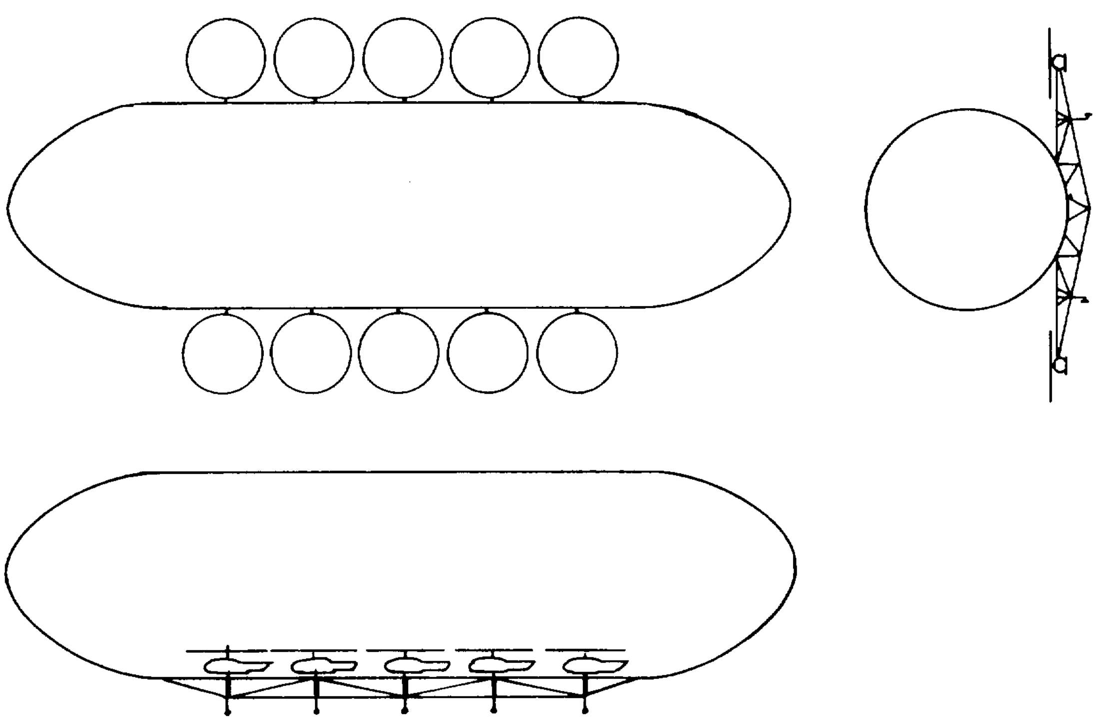

Figure 2 - Phase II Vehicle Concept No. 3

MAV/Mission Combination 4

This combination has no high rated civil transportation mission. However, it may well be the most important DOD mission area. If a MAV of this capability were developed and operated in satisfaction of the military missions described, a commercial market would evolve. The sea control mission requires a 77.1 m/s (150 knot), 907,200 kg (two million pounds) gross lift MAV capable of 720 hours of sustained flight. Such a vehicle is capable of most sea control functions. In a RPV carrier mission, this vehicle would serve as an air mobile RPV carrier capable of carrying, launching, and controlling large numbers of multiple-purpose RPV's for strike, reconnaissance, and deception. Secondary DOD missions include VP patrol, ocean escort, Bare Base (shelter) transporter, and mobile ICBM launcher.

MAV characteristics for MAV/mission combination 4 are:

1.	VTOL (neutrally buoyant)	
2.	Conventional ellipsoidal shape	
3.	Gross weight	- 907,200 kg (2×10^6 lb)
4.	Volume	- 1,127,136 cu m (39.86×10^6 cu ft)
5.	Length/maximum diameter	- 7.6
6.	Length	- 504.75 m (1656 ft)
	Useful load	- 353,868 kg (780,000 lb)
	Propulsion	
	a. Cruise	- 14 fixed turboprops (80,000 SHP at sea level)
	b. Loiter	- 2 fixed turboprops (860 SHP at sea level)
7.	Endurance	- 720 hours at 20 knots
8.	Cruise (design) speed	- 79.5 m/s (155 knots)
9.	Range at cruise speed	- 1350 km (720 naut mi)

Figure 3 shows the baseline vehicle concept for MAV/mission combination 4.

MAV/mission combination 2 (not described here) is not recommended for Phase II study, but it does have several interesting attributes, particularly in flight training and demonstration test bed operation, which recommend this combination for further study under other auspices.

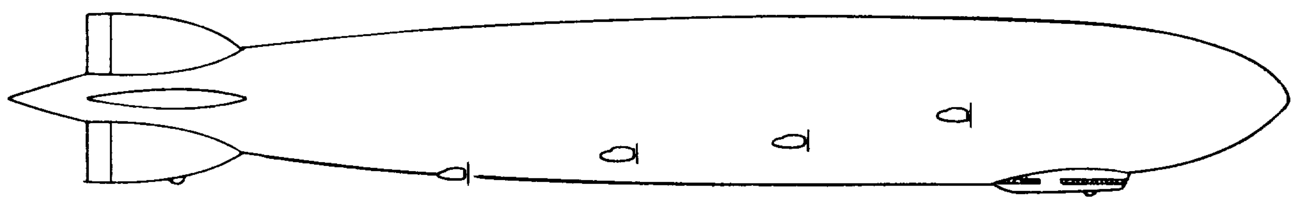

Figure 3 - Phase II Vehicle Concept No. 4

INTRODUCTION

The use of airships in the transportation and military field has steadily dwindled from immediately preceding and through World War II until the only specimens of the art today are found in the Goodyear advertising fleet. Certain attributes of LTA ships are stimulating renewed interest in the technology, particularly in the areas of energy conservation, environmental protection, and the need for unique large lift capability for certain missions. The military potential of the airship has been revitalized with the emerging capability of certain sensor and exotic weaponry for which the airship is recognized as an ideal platform because of its endurance, stability, and VTOL or hover capability.

The objectives of this study were to (1) provide a historical overview of the missions, vehicle configurations, performance, technology, and costs of airships of the past; (2) identify missions for which airships are uniquely suited or potentially competitive; (3) identify concepts for airships that are fully or partially buoyant and conduct a parametric study of these concepts to investigate the tradeoffs among aerodynamic performance, propulsion, and structural requirements; and (4) select the most promising vehicle/mission combinations for detailed study in Phase II. Goodyear Aerospace (GAC) was assisted in this study by the Battelle Columbus Laboratory (BCL) of Columbus, Ohio, and the Neilsen Engineering and Research (NEAR) Corporation of Palo Alto, Calif. This study has collected all available pertinent information on the history of airships, their design, costs, and operations so an objective judgment could be made on the state of the LTA art at the point of its slide into dormancy. Reference 1 describes the data together with an appraisal of the advances in various technologies appropriate to the design of a modern airship vehicle.

Together with the Transportation Research Group of BCL, GAC conducted an in-depth analysis of conventional, unique, and DOD mission areas. A rating system was developed to screen the multitude of missions into an optional set with required performance factors necessary in the potential MAV designs. The results of the mission analysis are described in this volume.

The parametric analysis in Volume II required extensive use of the Goodyear airship synthesis program (GASP) that has evolved over many years of GAC-sponsored R&D in the LTA field. The principal parameters included configuration characteristics; gross weight; static lift-to-gross weight ratios; VTOL, STOL, CTOL capability; and cruise velocity. The basic figure of merit was established by the statement of work as payload ton-miles per hour and range.

Three basic classes of MAV's were analyzed: conventional ellipsoidal airships, lifting body hybrid airships, and short-haul, heavy-lift hybrid vehicles. By examining the basic performance attributes of the three classes, the productivity figure of merit was judged to be applicable only to the first two. The applicable figure of merit for the third class was defined as the useful load-to-empty weight ratio.

The bulk of the results are presented parametrically as a function of gross weight and range to enable synthesis of specific vehicle characteristics to satisfy mission requirements defined in Task II.

This volume describes the evaluation and selection of the recommended vehicle/mission combinations for detailed study in Phase II. The optimal sets of conventional and unique transportation missions, other unique missions, and

DOD missions were specified in performance terms that were than compared to the results of the parametric analysis to establish the recommended vehicle/mission combinations. The missions were ultimately grouped into gross lift categories. Transportation missions were given highest priority although a number of nontransportation mission areas, particularly in the DOD requirements, deserve further study and several are recommended.

The results of the evaluation and selection process are described together with the recommended vehicle/mission combinations for further study in Phase II.

MISSION ANALYSIS OVERVIEW

As a part of Goodyear Aerospace's study of the feasibility of modern airships, a mission analysis was performed to identify potential missions for MAV's. Many uses or missions for such vehicles have recently been suggested. The emphasis in Phase I originally was oriented toward the use of MAV's in a transportation capacity. During the study, the scope of the mission analysis was expanded to include potential military missions.

The operational and performance characteristics required of MAV's (Reference 1) for meeting the potential missions isolated were necessarily reviewed in terms of past lighter-than-air capabilities and in view of the impact that today's technology may have on these past capabilities. The impact of today's technology was assessed through a Phase I parametric analysis of MAV's (Reference 2).

The vast number of potential missions defined necessitated that a ranking procedure be implemented to permit the most promising missions to be identified. The most promising missions and the required operational and performance requirements evolving from the mission analysis were then combined with the parametric analysis results to formulate the mission/vehicle combinations recommended for further study in Phase II.

APPROACH FOR SELECTING POTENTIAL MISSIONS

In generating the potential missions for which MAV's may be suited and in obtaining the general performance and operational characteristics that such MAV's should exhibit, the following approach was adopted:

1. Past commercial and military LTA missions along with past proposed missions were reviewed. Results of this effort served as a baseline from which to plausibly expand both the historical mission spectrum and the performance and operational capabilities of prior vehicles.
2. Present conventional and unconventional transportation systems were reviewed. Results from this review included possible areas of head-on competition, limitations of current systems that MAV's are uniquely suited to handle, and generalized performance and operational characteristics that MAV's must exhibit to possibly enter these mission areas.
3. Many inquiries, both civil and military, have been and continue to be made of the Goodyear organization relative to the possible use of airships. These inquiries were reviewed in terms of establishing both potential missions and the performance and operational characteristics that the MAV's should exhibit. Often these inquiries indicate a limitation in current systems and highlight particular requirements to which MAV's are uniquely suited.
4. In recent months, Goodyear has interfaced with various government agencies. The results of these discussions, as they relate to possible missions and required performance and operational characteristics, were included in the mission analysis results. Often, these discussions also involve a situation uniquely suited to MAV's or a complete void in the capability of existing systems.
5. The open literature that is continually monitored served as an additional source of potential missions and attendant performance and operational requirements during the mission analysis.
6. Finally, projected transportation needs and capabilities were reviewed as a potential mission source.

Implementation of this approach resulted in a vast number of possibilities. A ranking process was developed to isolate the most promising mission possibilities.

The general mission categories considered included:

1. Conventional missions (coded 000)
   a. Scheduled passenger (air, ground, water)
   b. Regulated cargo (air, ground, water)
   c. Unscheduled passenger (commercial, institutional)
   d. Unscheduled cargo (break bulk commercial)
2. Unique missions (coded 100 to 400)
   a. Heavy and/or large indivisible loads (commercial, institutional)
   b. Agricultural applications (commercial)
   c. Platform missions (commercial, institutional)
   d. Resources from remote regions (commercial)
3. Military (coded 500 to 700)
   a. U.S. Navy/U.S. Marine
   b. U.S. Air Force
   c. U.S. Army

PRESENT CONVENTIONAL MISSIONS

Passenger and Cargo

The mode of transportation normally will be selected based on its cost effectiveness to the user. A passenger will trade off increased transportation costs with the value of his time for conducting business, visiting, or enjoying a vacation and any reduction in other costs. The cargo shipper will trade off increased transportation costs with the increased value of the product to the purchaser and/or his cost decrease by reduced shipping times. Increased value of the product can be associated with faster response to buyer need, which can reduce the seller's inventory, improve quality of a product (perishables), or mean faster introduction of a product. Cost avoidance can be related to reduced inventories for the manufacturer, elimination of local warehouses, reduced packing requirements associated with air shipments, and reduced damage in transit with air shipments.

Transportation systems users also have the choice of regulated carriers or chartered carriers, or of creating their own system. The regulated carriers normally have controlled routes, schedules, and prices. The charter carriers normally have controlled routes or operating regions with limits on the frequency of operations between given points and in some instances minimum price constraints. If a potential user creates his own system, he has more flexibility in routes and schedules; ownership, however, requires capital investment.

The potential operator of a transportation system must consider the market and revenues for his services and the resulting costs to create and operate the transportation system. The size of the operator's market can be determined by comparing his potential services and prices with competing services for transporting people or products since the users will compare transportation prices, frequency of service, reliability of service, security, environment during transit, door-to-door times, and whether terminal support is required or door-to-door service is provided. A manufacturer also will consider the characteristics of his product including value per pound, density, size, weight, shelf life, environmental constraints, product cost per market price, and its annual volume. Transportation times affect his distribution costs by affecting inventory control and the accessibility to his distributors.

The operator must address each potential market and estimate the degree of market penetration for different transportation prices and services and estimate the type and number of vehicles required. An iterative process is required to determine when the total operating costs associated with the capacity of given number of similar vehicles match the potential markets and corresponding transportation prices and services. The operator will consider VTOL vehicles for potential markets when right of way, land costs, and/or construction costs are abnormally large for the size of the transportation market between points. The operator will trade off these yearly ground costs with the yearly costs of the vehicle system to arrive at minimum costs for given market sizes. For example, the present operating costs of helicopter vehicle systems are approximately an order of magnitude greater than CTOL vehicle systems and are used for small markets consisting of short-range missions requiring a minimum of fixed ground costs.

Present Conventional Passenger Missions and Competitive Modes

Various components of the United States passenger system have evolved based on their relative effectiveness to the user including the service provided - that is, regions of service, schedules, frequency, reliability, safety, comfort and door-to-door capability, door-to-door speed, and the price of transit (see Figures 4 through 7). The numbers of vehicles and terminals are presented in Figure 4. The quantities indicate, to some degree, the relative availability, frequency, and door-to-door capability of the different modes. Automobiles are included for reference since they dominate the total number of vehicles and possible transit points. The scheduled airlines have the least number of vehicles and the least number of terminals, which limits their service capability.

General aviation has a much larger number of vehicles and possible terminals and is used by people who desire better door-to-door speeds than are available using major terminals and available airline schedules. The number of intercity buses and trains is an order of magnitude greater than scheduled airline vehicles; however, they offer little time advantage over the automobile. The door-to-door speed or time advantages of scheduled airlines over the automobile, assuming equal schedule availability, normally occurs for trip lengths

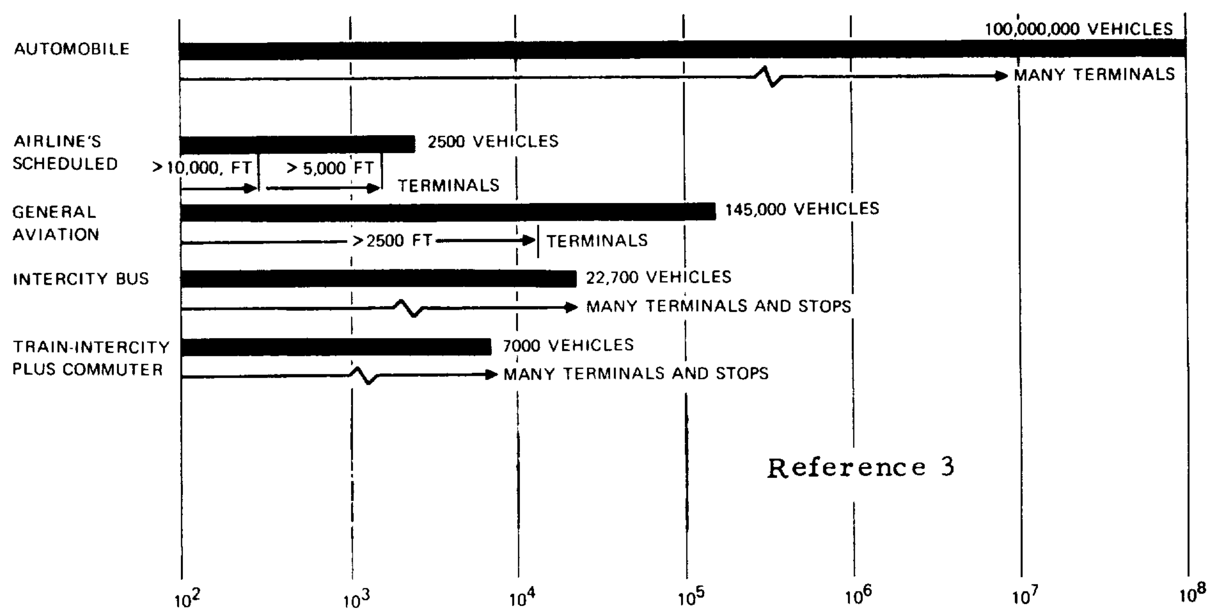

Figure 4 - Passenger Transportation System Service (Vehicles and Terminals)

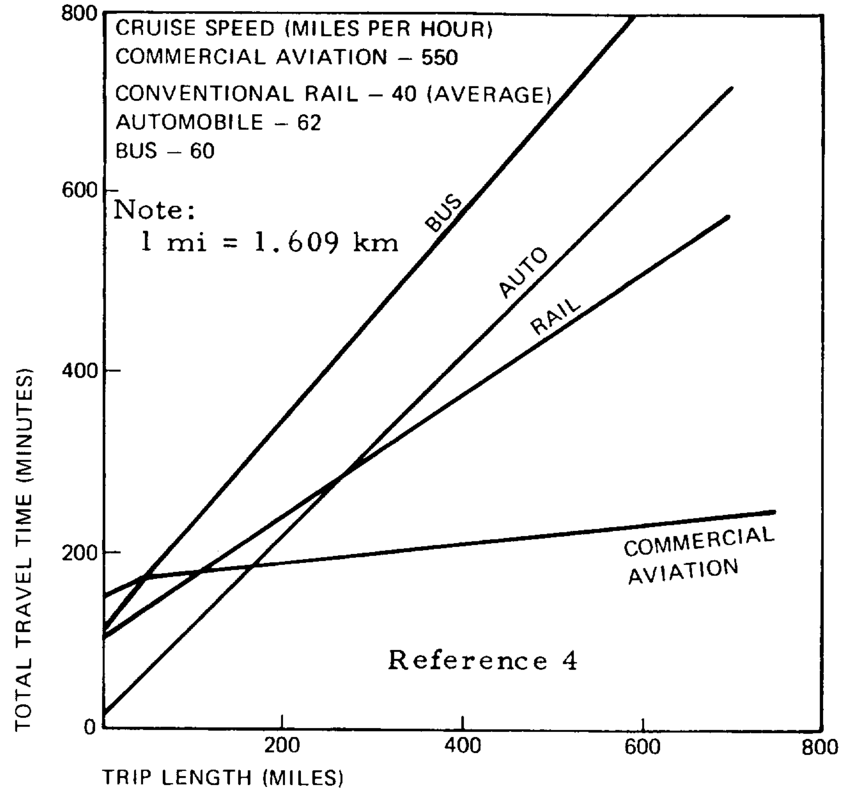

Figure 5 - Door-to-Door Travel Times for Several Transportation Modes

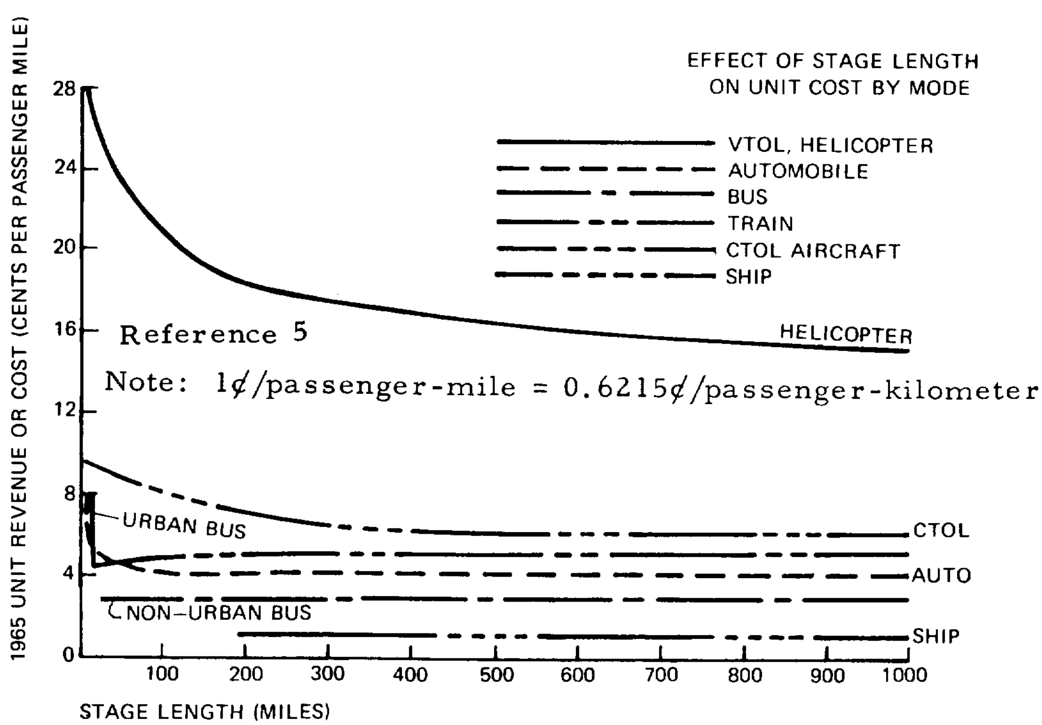

Figure 6 - 1965 Unit Revenue or Costs per Passenger-Mile of Several Transportation Modes

greater than 241.35 km (150 mi) (see Figure 5); this occurs because of the location of the terminals relative to the traveler's desired origin and destination and the required travel times with other forms of transportation that offset the greater block speed of scheduled airline vehicles.

A tradeoff with general aviation (non-jet) will extend the trip lengths to greater than 241.35 km (150 mi) for equal or less transit time considering the greater number of terminals and flexibility of scheduling general aviation compared to the scheduled airlines.

The factor of cost of transit is presented in Figure 6. The cost per mile generally increases with increasing speed and decreasing trip lengths. The increasing costs with shorter trip lengths result mostly from the reduced annual productivity of any given vehicle used for short hauls. The high costs of the helicopter transportation relative to the scheduled airliner reflects in part its lower relative productivity.

The present passenger market is shown in Figure 7 and is detailed in Table 1. The automobile dominates the market with the scheduled airlines second. General aviation has a much smaller segment because of the lower productivity and more specialized use of vehicles.

Fuel usage and the transportation provided are shown in Figure 8. The automobile provides the vast majority of the transportation and uses a corresponding percentage of fuel. The scheduled airlines provide approximately five percent

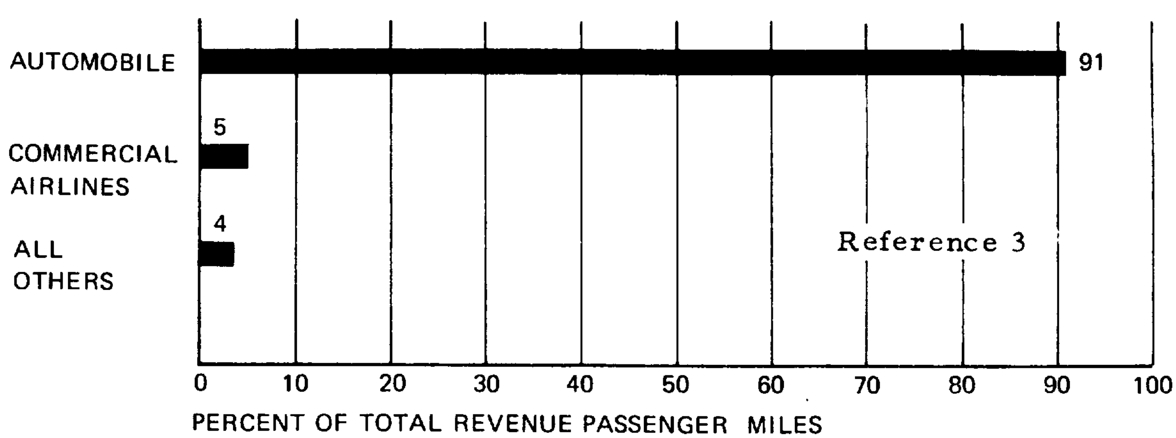

Figure 7 - Distribution of Passenger Traffic, 3379 Billion Passenger-Kilometers (2100 Billion Passenger-Miles): 1972

TABLE 1 - DOMESTIC PASSENGER MARKET SHARES - 1972 (REFERENCE 1)[a]

	Highway (4)			Local Transit(19)				Rail(24)		Air(29)			
		Bus(14)											
	Auto	Inter-city(15)	School(18)	Motor Bus(20)	Trolley Coach(21)	Surface Rail (22)	Sub & Elev(23)	Commut. (26)	Inter-city(27)	GA(30)	Air carrier(31)	Water(44)	Total
Expenditures & Revenues (millions of $'s)	$ 113,216	808	1,547	1,271	33	48	377	177	212	3,735	7,929	14	$ 129,367
(percent)	87.5	0.62	1.20	0.98	0.03	0.04	0.29	0.14	0.16	2.89	6.13	0.01	100
Vehicle Miles (millions)	1,003,498	1,181	2,359	1,308	30	32	386	? 58	?	3,571	2,042	-	1,014,465
(percent)	98.92	0.12	0.23	0.13	0.003	0.003	0.038	0.006		0.35	0.20	-	100
Passenger Miles (millions)	2,188,895	25,600	40,850	-	-	-	-	4,228	4,164	10,000	123,101	4,000	2,400,838
(percent)	91.17	1.07	1.70	-	-	-	-	0.176	0.173	0.417	5.13	0.167	100
Number of Vehicles	100,657,584	22,700	316,421	49,075	1,030	1,176	9,423	? 6,985	?	145,010	2,518	8	101,211,932
(percent)	99.45	0.022	0.313	0.048	0.001	0.001	0.009	0.007		0.143	0.003	0.0	100

[a] 1 mi = 1.609 km

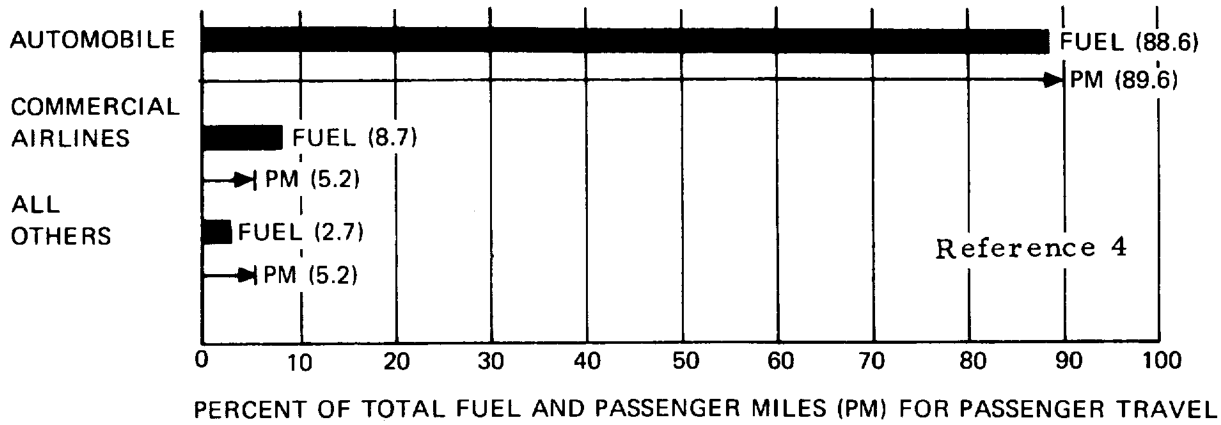

Figure 8 - Distribution of Fuel Use for Passenger Transportation, 1971

of the transportation and use approximately nine percent of the fuel. All other forms of transportation use approximately three percent of the fuel.

Present Scheduled Airline Missions

The scheduled airlines generate the second greatest number of passenger miles annually. A breakdown of scheduled airline traffic and other scheduled passenger forms considering passengers carried, revenue passenger miles, ticket trip lengths, hop lengths, and average revenue or costs per passenger mile is given in Table 2.

The trunk airlines have become long-haul passenger services, flying average ticket lengths of 1294 km (804 mi) and average hop length of 946 km (588 mi). The local airlines have average ticket lengths of 500 km (311 mi) and hop lengths of 298 km (185 mi), which is beyond the normal competitive trip time range of automobiles. Scheduled VTOL traffic is very short range 27 km (17 mi) and has not expanded in the last few years.

Scheduled ground systems carry more passengers annually for much shorter distances than air systems. Fares are approximately one-half CTOL air fares; however, the average ticket distances are so short that no door-to-door time savings are normally possible using any of the present scheduled CTOL air systems. The helicopter system can provide time savings over ground systems at short ranges; however, they are only available between a small number of locations and are relatively high cost.

TABLE 2 - SCHEDULED PASSENGER TRANSPORTATION (1974)[a]

Mode	Passengers Carried Millions	Passenger Miles Billions	Length, Miles Ticket	Length, Miles Hop	Average ¢/PM
US Airlines					
Trunks					
Domestic & International	170	160	945	-	6.13
Domestic Only	150	120	804	588	7
Local Airlines	35	11	311	185	10[b]
VTOL	0.6	0.01	17	16	90[b]
Ground					
Intercity Bus	393	26	65	-	3.16
Railroad (Commuter & Intercity)	261	8.4	22	-	4.65
Local Transit	5271	58	11	-	16.3

[a] 1 mi = 1.609 km, 1¢/passenger-mile = 0.6215¢/passenger-kilometer

[b] Subsidies not included.

The data from a detailed analysis conducted by DOT/OST using 1965 data are presented in Table 3 to illustrate the distribution of scheduled and automotive passenger traffic by stage lengths and modes. CTOL air traffic increases with increasing stage lengths starting with the stage length of 80.45 km to 321.8 km (50 to 200 mi). The only scheduled air service less than 80.45 km (50 mi) is by helicopter, and it generates only one-half of one percent of the service provided by taxi cab.

Since 1965, scheduled CTOL air traffic has more than doubled while scheduled VTOL air traffic has shown a slight decrease. The fares for CTOL are approximately unchanged from 1965 while the other systems have increased. The average VTOL fares have become more than twice the average 1965 rates. A further breakdown of scheduled helicopter operations for 1963, 1973, and projected for 1981 is presented in Table 4.

From the latter tables, it would appear that present air systems are deficient for ranges less than 80.45 km (50 mi) and are marginal timewise even in the 80.45 to 321.8 km (50 to 200 mi) stage. The deficiencies appear to include cost (twice that for a taxi) and lack of service (small numbers).

Present and Projected Passenger System Capabilities and Limitations

Projected capabilities of possible passenger aircraft available to fill the possible equipment needs for a potential short haul market are listed in Tables 5 through 8. The projected direct operating costs on the basis of available seat miles for the projected short haul aircraft are presented in Tables 9 and 10. In addition, some results from a specific market study by the Rand Corporation are presented as a reference also to include the projected costs of some other modes of transportation (Reference 3).

Passenger capacities of some of the projected short-haul CTOL aircraft are presented in Table 5. These aircraft require major airport facilities and have greater range capability than needed for a short haul market. The passenger capacity of some aircraft from design studies for the short haul market is presented in Table 6. These aircraft have potential for using shorter runways, 914 to 1219 m (3000 to 4000 ft), as RTOL/QSTOL aircraft for shorter ranges than the CTOL vehicles.

TABLE 3 - PASSENGER CARRYING ACTIVITY IN 1965

	Automobile		Bus		Train		Taxi		CTOL		VTOL		Ship	
Stage length	Pass[a] mi	¢/ P-M	Pass mi	¢/ P-M	Pass mi	¢/ P-M	Pass mi	¢/ P-M	Pass mi	¢/ P-M	Pass mi	¢/ P-M	Pass mi	¢/ P-M
0 to 2.5 mi														
Dense urban urban	26.4B	6.0	1.0B	5.0	1.0B	7.0	0.6B	20.0						
Other urban	44.1B	6.0	1.7B	8.0			0.9B	20.0						
Non urban	15.6B	6.0	0.2B	3.0										
2.5 to 20 mi.														
Dense urban urban	466.8B	5.0	17.6B	4.5	6.6B	4.0	2.5B	20.0			0.0125B	36.3		
Other urban														
Non urban	79.7B	5.0	0.4B	3.0	0.3B	4.8								
20 to 50 mi														
Dense urban urban	97.9B	5.0	3.7B	4.5	1.4B	4.0								
Non urban	28 3B	5.0	0.6B	3.0	2.3B	4.8					N/A	23.0		
50 to 200 mi												28.9		
Non urban	228.3B	4.0	4.9B	3.0	6.2B	5.0			2.6B	7.0	N/A	18.1	N/A	1.0
200 to 500 mi												15.0		
Non urban	149.4B	4.0	7.6B	3.0	7.0B	5.0			9.6B	6.0	N/A	16.2	N/A	1.0
500 to 1000 mi												15.0		
Non urban	114.8B	4.0	3.9B	3.0	0.6B	5.0			14.5B	6.0				
1000 to 3500 mi												15.0		
Non urban	202.5B	4.0	6.2B	3.0	1.2B	5.0			31.4B	6.0				

[a] 1 mi = 1.609 km, 1¢/passenger-mile = 0.6215¢/passenger-kilometer

TABLE 4. HELICOPTER DATA FOR INDUSTRY

Item	Units	1963*	1973*	1981*
Activity				
Revenue passengers enplaned	Pax	477,000[8]	613,000[8]	
Revenue passenger-miles**	P-M	12,510,000[8]	10,979,000[7]	
Revenue passenger load-factor	%	45.2[8]	43.6[7]	
Freight ton-miles hauled	Ton-mi	6,000[8]	2,744[7]	
Express ton-miles hauled	Ton-mi	44,000[8]	8,027[7]	
Mail ton-miles hauled	Ton-mi	74,000[8]	3,439[7]	
Total revenue ton-miles hauled	Ton-mi	124,000[8]	14,210[7]	
Ton-mile load factor	%	43.4[8]	44.1[8]	
Average length of haul	miles	26[8]	18[8]	
Scheduled aircraft revenue miles	Miles	1,462,000[8]	1,085,000[8]	3,000,000[5]
Scheduled aircraft revenue hours	Hours	15,222,000[8]	10,239,000[8]	30,000[5]
Commercial aircraft in service	-	20[6]	13[6]	18[5]
Active general aviation aircraft	-	Not available	2,800[5]	4,000[5]
Finances				
Passenger operating revenue	$	3,284,000[8]	8,895,000[8]	
Freight operating revenue	$	41,000[8]	70,000[8]	
Express operating revenue	$	217,000[8]	52,000[8]	
Mail operating revenue	$	193,000[8]	20,000[8]	

*Superscripts refer to references at the end of the volume.

**System international conversion factors are listed at end of table.

TABLE 4. (CONTINUED)

Item	Units	1963*	1973*	1981*
Total operating revenue	$	8,637,000[8]	10,092,036[8]	
Total operating expenses	$	8,839,000[8]	10,236,789[8]	
Expenses from flying operations	$	1,744,000[8]	2,949,000[8]	
Expenses from maintenance	$	2,789,000[8]	2,842,000[8]	
Expenses from GS, and admin	$	3,305,000[8]	4,147,000[8]	
Depreciation and amortization	$	1,000,000[8]	298,000[8]	
Investment in flight equipment	$	9,670,000[8]	3,443,000[8]	
Investment in ground property	$	1,555,000[8]	781,000[8]	
Subsidy	$	Not available	317,000[6]	
Performance				
Unit passenger revenue	¢/P-M	26.3	81.0	
Unit freight revenue	¢/T-M	683.3	2,551.0	
Unit express revenue	¢/T-M	493.2	647.8	
Unit mail revenue	c/T-M	260.8	581.6	
Rate of return on investment	%	1.1[8]	Negative[8]	
Debt-to-equity ratio	:1	0.78[7]	3.89[7]	

NOTE: 1¢/ton-mile = 6.85×10^{-4}¢/kg-km, 1¢/passenger-mile = 0.6215¢/passenger-kilometer.

TABLE 5 - PASSENGER CAPACITY, SHORT-HAUL CTOL JET AIRCRAFT OPTIONS (1978-1983)

Aircraft Class	Type	Manufacturer	Designation	Passengers: All Coach	Passengers: Mixed	Passengers: Max Payload/Max Range*
Standard CTOL						
2 Engine	Standard	Boeing	737-100	101	--	-- --
		MDC	DC9-10	--	--	-- --
	Stretch	Boeing	737-200	115	--	23,000#/900 nm
		MDC	DC9-30	105	97 (12/85)	22,000/1,343
3 Engine	Standard	Boeing	727-100	119	--	-- --
	Stretch	Boeing	727-200	166	--	27,500/1,600
Wide Body CTOL						
2 Engine	Short-Range	MDC	Twin 10	--	239 (29/210)	49,000/2,000
		Lockheed	Twin 1011	222	211 (21/190)	47,000/1,550
		Airbus	A-300 (B2)	281	239	56,000/1,300
3 Engine	Short-Range	Boeing	7X7	227	201 (23/178	40,000/1,800
		MDC	DC-10-10	--	260	59,200/2,840
		Lockheed	L-1011	334	260	53,450/2,800

*1 lb = 0.4536 kg, 1 naut mi = 1.853 km

TABLE 6 - PASSENGER CAPACITY, SHORT-HAUL RTOL/QSTOL JET AIRCRAFT OPTIONS (1978-1983)

Aircraft Class	Type	Manufacturer	Designation	Passengers: All Coach	Passengers: Mixed	Passengers: Max Payload/Max Range*
RTOL						
2 Engine	Mechanical Flap	Boeing	737-200MF	115	--	24,000#/1,800 nm
		MDC	DC9-20MF	75	--	22,000/900
		MDC (NASA)	4000' MF	150	--	30,000/500
		LAC (NASA)	4000' MF	148	--	29,000/500
3 Engine	Mechanical Flap	Boeing	4000' QSH	138	119 (20/99)	28,000/750
QSTOL						
2 Engine	Over-the-Wing	Boeing	CMST-OTW	164	--	33,000/950
	Hybrid	LAC (NASA)	3000' OTW/IBF	148	--	29,000/500
4 Engine	Externally-Blown Flap	MDC	CMST-EBF	151	--	30,200/500
		MDC (NASA)	3000' EBF	150	--	30,000/500

*1 lb = 0.4536 kg, 1 naut mi = 1.853 km

The weights of these aircraft are presented in Tables 7 and 8. The economic characteristics of these same aircraft are presented in Tables 9 and 10. The direct operating costs based on available passenger statute miles is from 1.36 to 2.2 cents for conventional jets and from 1.01 to 2.58 cents for projected RTOL/QSTOL vehicles for trip lengths of 804.5 km (500 mi) under the ground rules of the study.

Another study conducted by the Rand Corporation calculated the possible door-to-door costs and times of CTOL, RTOL, STOL, and VTOL aircraft, 134 m/s (300-mph) tracked air-cushioned vehicles (TACV), and 67 m/s (150-mph) improved passenger train (IPT) for the Los Angeles/San Francisco Market. Some of the results from the market analysis are presented in Table 11. The total operating costs per passenger mile for the air system were 4.34 to 6.34 cents while the two ground systems costs were 8.20 and 15.41 cents. The least cost was for CTOL vehicles, which required the least capital investment; the most cost was for the TACV because of the huge fixed right-of-way costs. The least door-to-door time was by VTOL (145 minutes for VTOL versus 170 minutes for CTOL).

The largest U.S. civil rotary wing aircraft have passenger capacities of 44 to 45 at gross weights of 19,051 km to 20,866 km (42,000 to 46,000 lb). The maximum still air range is 756 km (470 mi). Some larger experimental vehicles are being investigated with gross weights exceeding 45,360 kg (100,000 lb).

Conventional Passenger MAV Mission Potential

General aviation is filling a mission/market need to reduce door-to-door times for distances beyond what the readily available automobile can cover rapidly and at distances shorter than those distances where the large commercial jet's better block times can compensate for its limited schedule times and the long times related to the terminal transportation and servicing. These competitive distances for general aviation range from less than 322 km (200 mi) to more than 804.5 km (500 mi) if only propeller aircraft are considered and shorter ranges if helicopters are considered.

TABLE 7 - OPERATING WEIGHTS, SHORT-HAUL CTOL JET AIRCRAFT OPTIONS (1978-1983)

Aircraft Class	Type	Manufacturer	Designation	Weights* Max T/O	Max. Lndg.	OWE	Wing Load
Standard CTOL							
2 Engine	Standard	Boeing	737-100	93,000#	89,000#	56,700#	--
		MDC	DC9-10	90,700	81,700	--	--
	Stretch	Boeing	737-200	108,000	97,000	58,200	--
		MDC	DC9-30	108,000	99,000	57,880	108#/ft^2
3 Engine	Standard	Boeing	727-100	153,000	135,000	87,000	--
	Stretch	Boeing	727-200	169,000	148,000	95,000	--
Wide Body CTOL							
2 Engine	Short-Range	MDC	Twin 10	339,000	323,000	208,460	94
		Lockheed	Twin 1011	276,000	260,000	171,000	105
		Airbus	A-300 (B2)	302,000	281,100	186,980	--
3 Engine	Short-Range	Boeing	7X7	270,000	--	164,730	92
		MDC	DC-10-10	410,000	347,800	--	--
		Lockheed	L-1011	409,000	348,000	225,491	--

*1 lb = 0.4536 kg, 1 lb/sq ft = 4.882 kg/sq m

TABLE 8 - OPERATING WEIGHTS, SHORT-HAUL RTOL/QSTOL JET AIRCRAFT OPTIONS (1978-1983)

Aircraft Class	Type	Manufacturer	Designation	Weights* Max T/O	Max Lndg	OWE	Wing Load
RTOL							
2 Engine	Mechanical Flap	Boeing	737-200MF	115,500#	103,000#	60,000#	--
		MDC	DC9-20MF	97,700	--	50,480	91#/ft^2
		MDC (NASA)	4000' MF	155,800	--	--	91
		LAC (NASA)	4000' MF	136,950	--	--	93
3 Engine	Mechanical Flap	Boeing	4000' QSH	167,000	--	112,800	--
QSTOL							
2 Engine	Over-the-Wing	Boeing	CMST-OTW	173,000	--	147,000	--
	Hybrid	LAC (NASA)	3000' OTW/IBF	147,400	--	--	93
4 Engine	Externally-Blown Flap	MDC	CMST-EBF	159,400	--	108,900	92
		MDC (NASA)	3000' EBF	149,000	--	--	102

*1 lb = 0.4536 kg, 1 lb/sq ft = 4.882 kg/sq m

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TABLE 9 - ECONOMIC CHARACTERISTICS, SHORT-HAUL CTOL JET AIRCRAFT OPTIONS (1978-1983)

Aircraft Class	Type	Manufacturer	Designation	DOC Economics Study Price	DOC Economics ASSM (500)	DOC Economics ASSM (1000)
Standard CTOL						
2 Engine	Standard	Boeing	737-100	$4.47M		--
		MDC	DC9-10	--		--
	Stretch	Boeing	737-200	5.30M	1.48-1.70	--
		MDC	DC9-30	5.00M		--
3 Engine	Standard	Boeing	727-100	6.53M		--
	Stretch	Boeing	727-200	7.75M	2.200	¢1.700
Wide Body CTOL						
2 Engine	Short-Range	MDC	Twin 10	18.0M	1.540	1.280
		Lockheed	Twin 1011	--	--	--
		Airbus	A-300 (B2)	17.5M	1.800	1.500
					1.361	1.080 2 man
3 Engine	Short-Range	Boeing	7X7	13.7M	1.437	1.145 3 man
		MDC	DC-10-10	--	--	1.200
		Lockheed	L-1011	19.3M	1.700	1.400

TABLE 10 - ECONOMIC CHARACTERISTICS, SHORT-HAUL RTOL/QSTOL JET AIRCRAFT OPTIONS (1978-1983)

Aircraft Class	Type	Manufacturer	Designation	DOC Economics Study Price	DOC Economics ASSM (500)	DOC Economics ASSM (1000)
RTOL						
2 Engine	Mechanical Flap	Boeing	737-200MF	--	--	--
		MDC	DC9-20MF	$6.8M	¢2.58	¢2.20
		MDC (NASA)	4000' MF	9.9M	1.72	--
		LAC (NASA)	4000' MF	8.7M	1.68	--
3 Engine	Mechanical Flap	Boeing	4000' QSH	10.0M	1.04	1.02
QSTOL						
2 Engine	Over-the-Wing	Boeing	CMST-OTW	--	1.01	0.95
	Hybrid	LAC (NASA)	3000' OTW/IBF	9.4M	1.79	--
4 Engine	Externally-Blown Flap	MDC	CMST-EBF	10.45M	2.18	--
		MDC (NASA)	3000' EBF	10.5M	1.88	--

TABLE 11 - SAMPLE OF RESULTS FROM RAND CORPORATION STUDY RESULTS OF SERVICE AND COSTS[a]

	Base (CTOL)	RTOL	STOL	VTOL	TACV	IPT
Annual pax volume (millions)	6.5	5.4	5.3	4.9	9.1	5.8
Annual pax miles (millions)	1,956	1.660	1,709	1,463	2,440	1,625
Cost/pax mile (cents)	4.34	6.34	5.79	6.00	15.41	8.20
Capital investment required (millions)	135	145	305	190	1,856	434
Subsidy/year (millions)	0	0	0	0	277	74
Door-to-door time: L. A. -S. F. (min)	171	157	145	145	199	314
Fare: L. A. -S. F. ($)	13.84	20.22	19.19	19.51	15.00	15.00
Door-to-door costs: L. A. -S. F. ($)(business)	17.17	23.71	21.66	21.69	18.46	18.49
Door-to-door cost: L. A. -S. F. ($)(non-business)	15.42	21.92	20.24	20.56	16.70	16.73

Best	Green
Next Best	Blue
Inferior	Orange
Worse	Red

Reference 4

[a] 1 mi = 1.609 km, 1¢/passenger-mile = 0.6215¢/passenger-kilometer

This transportation mission is a potential market for MAV as a STOL if the availability and operating costs are similar to general aviation. The mission can be even of shorter ranges when the MAV operates as a VTOL because of the increasing availability of landing sites and the system's availability to potential passengers. Scheduled passenger mission potential is between city centers (coded 001), between minor airports (coded 002), and airport feeder service (coded 003). This market consists of scheduled MAV services for regions and at ranges not provided by the trunk airlines or to regions not being serviced by local airlines. The size of these vehicles is tentative because the market size will also be determined by their transit prices.

Between City Centers (001) - This mission consists of regularly scheduled service between city centers that are 32.18 km to 80.45 km (20 to 50 mi) apart. VTOL capability will provide stations that are readily accessible to the potential passenger and minimize the time to and from the terminals. The system's vehicles should be able to cruise so that block times of 30 to 60 minutes are possible. Because of the high possible volume of this system, the vehicle size can be 100 to 150 passengers. Low noise will be a constraint when this system is in the urban regions.

Between Minor Airports (002) - This mission consists of regularly scheduled service between minor airports at ranges of 80.45 km to 322 km (50 to 200 mi). A VTOL/STOL capability is required to increase the possible number of stations and improve the accessibility to population centers. This market is smaller than the previous market, and a passenger capacity of 30 to 50 appears desirable to be able to provide sufficient scheduled flights.

Airport Feeder (003) - This mission consists of a regularly scheduled feeder service to major terminals from smaller population centers. A VTOL capability is required for it to be at readily available locations. Low noise will be a requirement during takeoff and landing. The range of these missions will be 32.18 to 80.45 km (20 to 50 mi). The vehicle size should be sufficient for 30 to 50 passengers. Larger vehicles are possible if the ticket prices are nearer to special ground transportation prices.

Present Conventional Cargo Missions and Competing Forms

The United States cargo transportation system also has developed on its relative effectiveness to the user considering services provided, *i.e.*, regions of service, schedules, frequency, reliability of service, security of shipment, environment for the cargo, and door-to-door capability, door-to-door times, and the total price of transit. The number of vehicles, terminals, and stops in the United States market gives an indication of the possibility of service; these are presented in Figure 9. The local truck is included for reference as it dominates the number of vehicles and possible transit points. The number of intercity trucks and rail vehicles are an order of magnitude less than local trucks while water and air vehicles and terminals are many orders of magnitude less in number.

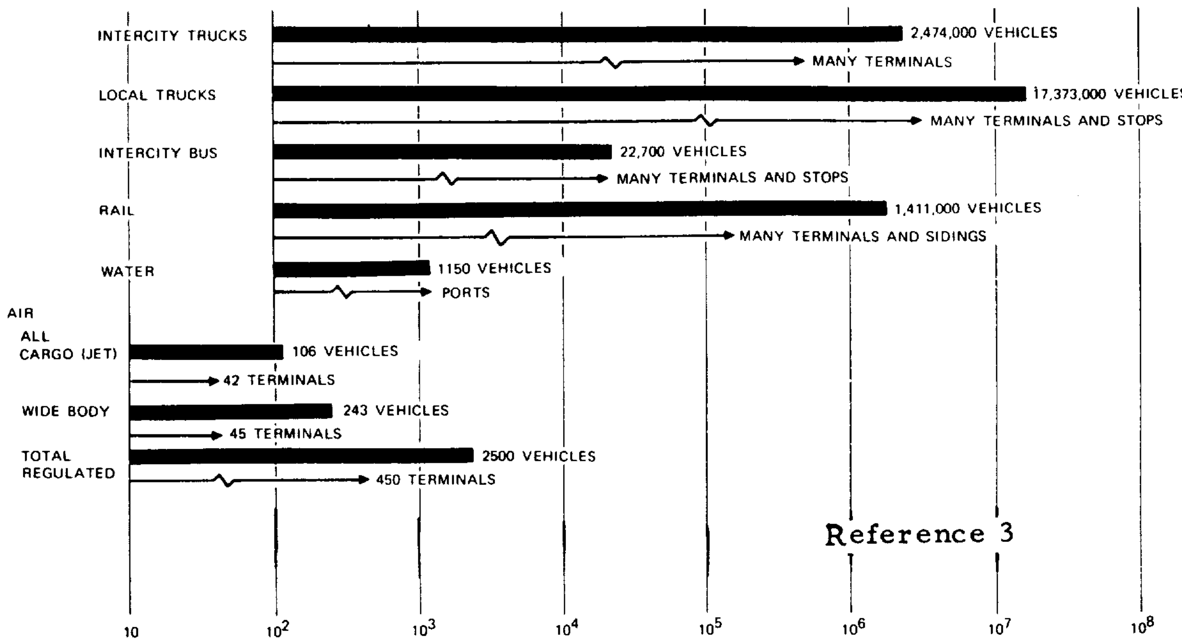

Figure 9 - Cargo Transportation System Service (Vehicles and Terminals)

Speed is not as significant to shippers as to passengers, except as it affects costs of product distribution. Shippers, like passengers, are primarily interested in the time lapse between pickup and delivery. Cargo can have a large portion of its transit time taken up by terminal handling. For distances up to 804.5 km (500 mi), the availability of trucks and their terminal times relative to air normally results in trucks being the fastest means of conventional transportation. Rail shipping times are normally greater than truck shipping times. Costs for transporting are important; the average rates for the different modes of transportation are:

1.	Intercity truck (regulated and nonregulated)	8.9 ¢/RTM
2.	Rail	1.6 ¢/RTM
3.	Air	23.9 ¢/RTM
4.	Water	0.33¢/RTM
5.	Pipeline	0.33¢/RTM

The average rates for truck and air are significantly greater than the other three modes.

The resulting cargo market shares are presented in Figure 10. The market is somewhat equally shared by four modes, each having 20 percent or more of the traffic. Air generates 5256 billion kg-km (3.6 billion ton-miles) per year, which is less than one percent of the total market. Fuel use in the cargo market can be evaluated from the data in Figure 11.

The fuel use relationships are considerably different than for the passenger market, where the automobile dominated the fuel use (88.6 percent) and service provided (89.6 percent). The pipeline uses approximately the same percentage of fuel (26 percent) as transportation provided (27.8 percent), while the truck uses most of the total fuel (56.2 percent) for 28.9 percent of the service. Rail and water are by far the most efficient forms using 8.5 percent and 5.5 percent of the fuel and providing 27.8 percent and 19.1 percent of the service, respectively. Commercial airlines use 3.8 percent of the fuel in providing 0.1 percent of the cargo service.

Evaluation of Present Cargo Mission to Determine Potentially Competitive Conventional Missions for MAV's

General - For this analysis, interest was limited to the U.S. domestic transportation marketplace. Readily available U.S. Department of Transportation statistics were extracted from documents covering 1965 to 1972. A 1975 update is now in progress but is not yet available. Every attempt has been made to select the latest available data. Therefore, the following discussion provides a nominal picture of the U.S. domestic cargo transportation system in the early 1970's.

The main purpose of this analysis was to develop a description of key relationships between the various conventional transportation modes and their respective operation and economic attributes. It is recognized that future economic trends will alter the attributes identified below. However, speculations and forecasts of the situation some 10 to 20 years in the future were intentionally excluded to maximize credibility in the conclusions to be drawn regarding potentially competitive MAV missions.

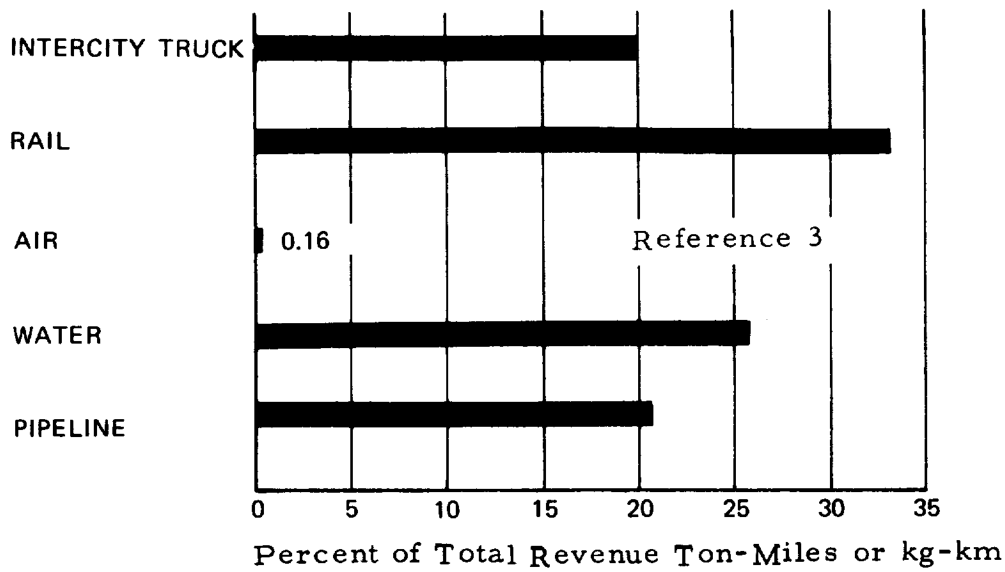

Figure 10 - Distribution of Cargo Transportation, 3.41932 X 10^{15} kg-km (2342 Billion Ton-Miles, (1972)

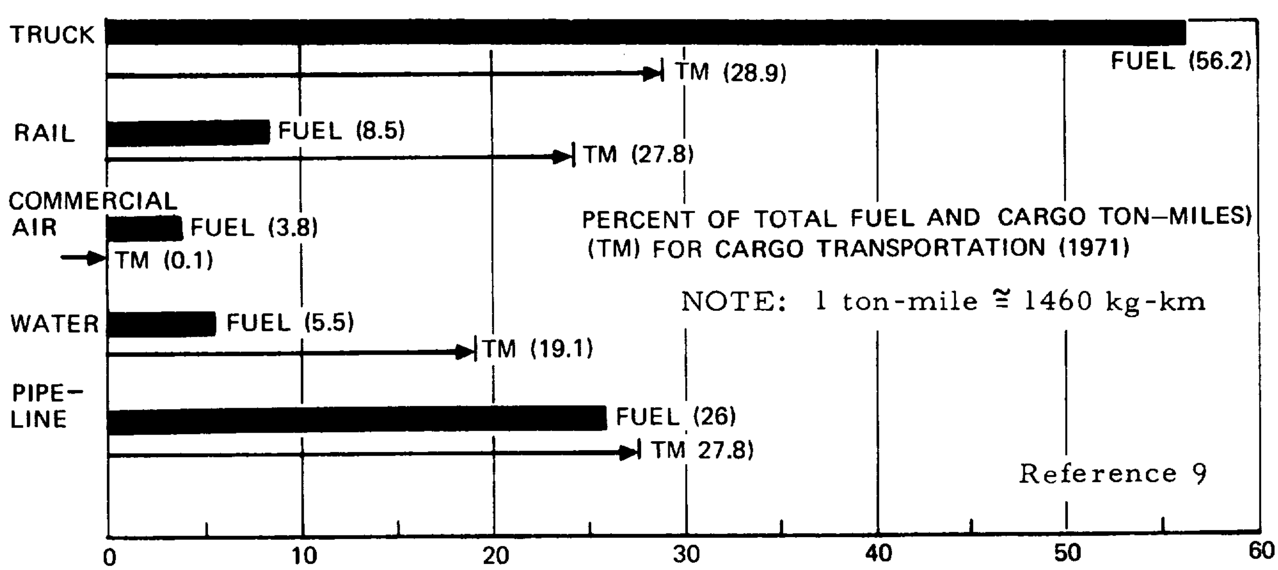

Figure 11 - Distribution of Fuel Use for Cargo Transportation (1971)

Alternatively, emphasis in the following analysis has been put on developing a reasonably accurate picture of "current" relationships between the respective modes and attributes. This approach is consistent with a later step in the analysis, which will hypothetically assume the availability of MAV alternatives in an early 1970's marketplace.

Before proceeding with a detailed intramodal assessment of individual cargo modes and markets, several intermodal comparisons are made to provide a perspective on the role of each mode within the total cargo transportation system.

Intermodal Comparisons

Market Shares - Table 12 gives selected market share statistics for 1972. In terms of annual total expenditures and revenues, the trucking industry is by far the most dominant mode at a level of approximately 84 percent of the total. This figure can be further separated into the following intramodel market shares.

Item	Expenditures and revenues (millions of $)	Percent of all cargo modes
Intercity truck		
ICC regulated	18,700	17
Nonregulated (private)	22,968	21
Local truck	50,498	46
Totals	92,166	84

This breakdown indicates that expenditures and revenues are distributed almost equally between regulated and private intercity trucks.

The second highest mode in Table 12 in terms of expenditures and revenues is rail at 12 percent of the national total. Intercity bus, air, water and pipeline constitute the balance at only four percent.

TABLE 12 - SELECTED MARKET SHARE STATISTICS (REFERENCE 3)[a]

Attribute	Highway: Truck Intercity	Highway: Truck Local	Highway: Intercity Bus	Rail	Air	Water	Pipeline	Total
Expenditures & Revenues (Millions of $'s)	41,668(b)	50,498	140	12,572	877[c]	1,982[d]	1,593	$ 109,330
(Percent)	38	46	0.1	12	0.8	2	1	100%
Vehicle Miles (Millions)	70,272	174,252	N/A[e]	452	33	1,755	- -	246,764
(Percent)	28	71	N/A	0.2	0.01	0.7	- -	100%
Cargo Ton Miles (Millions)	470,000[f]	N/A	60	784,300	3,662[g]	603,542	480,000	2,341,564
(Percent)	20	N/A	0.003	33	0.2	26	21	100%
Number of Vehicles	2,474,000	17,373,000	22,700	1 ,410,568	156	1,150[h]	- -	21,281,574
(Percent)	12	82	0.1	7	0.0007	0.005	- -	100%

(a) 1 mi = 1.609 km, 1 ton-mile = 1460 kg-km

(b) ICC Regulated = $18,700 M; Non-Regulated = $22,968 M.

(c) Certified = $792 M:Supplemental = $85 M.

(d) Does not include commercial fishing, $704 M.

(e) N/A denotes statistics not available.

(f) ICC Regulated = 190,000 M: Non-Regulated = 280,000 M.

(g) Certificated = 3,403 M: Supplemental = 259 M.

(h) Does not include commercial fishing, 1,155.

In terms of vehicle mile statistics, the trucking industry again dominates with a market share of approximately 99 percent. Local trucking represents the majority of this amount at 71 percent. The second highest mode is water at only 0.7 percent. The intercity bus data was not available but can be assumed to be relatively insignificant.

Cargo ton-mile data is of special interest because it will be used to define one of the major MAV mission attributes. The Table 12 data indicates that the national cargo market on a ton-mile basis is approximately equally divided between intercity truck (20 percent), rail (33 percent), water (26 percent), and pipeline (21 percent). This distribution is somewhat misleading because data was not available for the local truck mode. This is undoubtedly a sizable market and can be inferred from the vehicle mile and number of vehicles given in Table 12.

The number of vehicles in Table 13 indicates that the local trucking industry dominates the cargo transportation vehicle population at 82 percent. Intercity trucks are the second highest and represent only 12 percent.

All of the preceding statistics emphasize the dominant role of trucks in the U.S. cargo transportation system, both in terms of the local (intracity) marketplace and the intercity marketplace. Further intramodal market details of this dominant mode will be presented in a later subsection.

Block Speed - Figure 12 shows average 1956 block speeds as a function of trip length. The trend for trucks prior to the 1973 fuel crisis was probably upward from the numbers shown in Figure 12 due to continuing federal highway construction programs. However, the 1965 figures are probably representative of the postfuel crisis of 1974.

Note in Figure 12 the rapidly increasing block speed as a function of range for CTOL air, compared with regulated or private trucks. From a speed point of view, doubling average truck speed still would not close the gap with CTOL air above an 80.45 km (50-mi) trip length. However, doubling truck block speeds below 80.45 km (50-mi) trip lengths could offer significant time benefits.

Ton-Mile Prices - A convenient U.S. Department of Transportation data format already exists for categorizing cargo pricing data in a meaningful way. This data format also will be used in later subsections to describe other selected performance attributes of the U.S. cargo transportation system. Definitions and the general characteristics of the method are given in the nomenclature section at the beginning of this volume.

Representative pricing data for the various cargo transportation modes are presented in Tables 13 through 18 for each of the three major commodity types and each of the three major commodity value categories.

Dramatic price differentials typically exist within a given mode between the lower trip lengths and the longer trip lengths for any given commodity type/commodity value combination. This is not particularly unexpected, but absolute unit price as a function of trip length constitutes an especially important screening criteria for identification of potentially competitive MAV missions. Pricing data in Tables 13 through 18 will be addressed more thoroughly in the next section.

Potentially Price-Competitive Cargo Markets - For screening out potentially competitive conventional modes, the pricing data presented in the preceding subsection is particularly valuable. Initial cost analyses of MAV vehicle alternatives indicate that cargo can be transported with an MAV for a price as little as 0.010275¢/kg-km (15¢ per ton-mile) (1974 $). Using this figure as

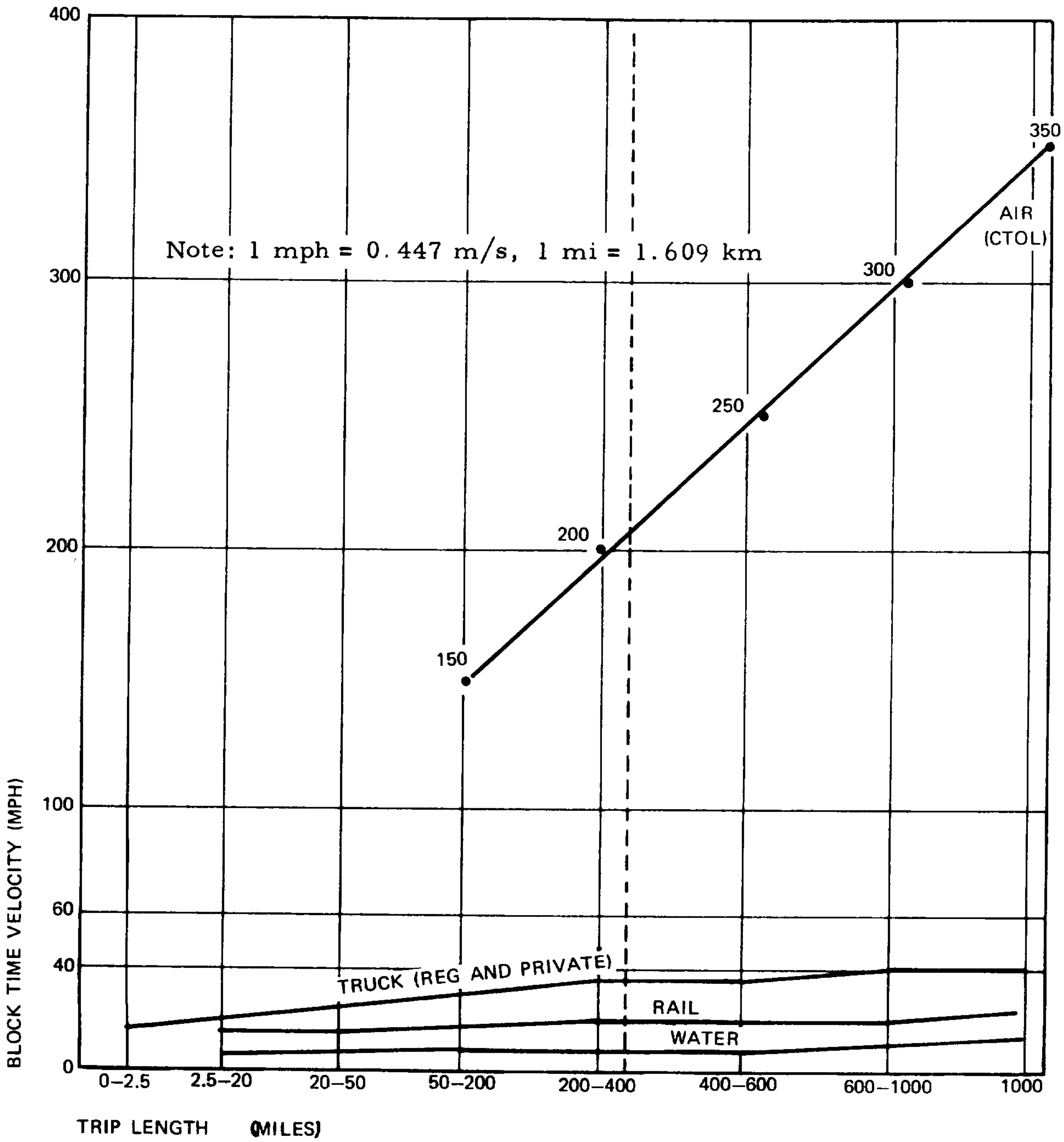

Figure 12 - Cargo Mode Block Speed (1965)

TABLE 13 - 1965 PRICING DATA FOR LOW VALUE, BULK COMMODITIES[a] (¢/TON-MILE)

Trip Length, Sm[b]	Regulated Truck	Private Truck	Rail	Air	Water	Pipeline
0 - 2.5	- -	- -	- -	- -	- -	- -
2.5 - 20	- -	- -	6.2	- -	1.09	- -
20 - 50	8.4	7.9	6.2	- -	1.1	- -
50 - 200	3.68	3.39	2.89	- -	0.49	- -
200 - 400	2.26	2.11	1.72	- -	0.4	- -
400 - 600	1.70	1.62	1.31	- -	0.33	- -
600 - 1000	1.42	1.33	1.11	- -	0.29	- -
> 1000	- -	- -	0.85	- -	0.27	- -

(a) Reference 5, Appendix 2.
(b) 1 statute mile = 1.609 km, 1¢/ton-mile ≅ 6.85×10^{-4}¢/kg-km

TABLE 14 - 1965 PRICING DATA FOR HIGH VALUE, BULK COMMODITIES[a] (¢/TON-MILE)

Trip Length, Sm[b]	Regulated Truck	Private Truck	Rail	Air	Water	Pipeline
0 - 2.5	- -	- -	- -	- -	- -	- -
2.5 - 20	18.0	17.2	15.3	- -	0.92	- -
20 - 50	18.0	17.2	15.3	- -	0.92	- -
50 - 200	8.11	7.82	7.13	- -	0.42	- -
200 - 400	4.99	4.74	4.20	- -	0.36	- -
400 - 600	3.82	3.68	3.33	- -	0.28	- -
600 - 1000	3.18	3.07	2.78	- -	0.23	- -
> 1000	2.49	2.40	2.10	- -	0.23	- -

(a) Reference 5, Appendix 2.
(b) 1 statute mile = 1.609 km, 1¢/ton-mile ≅ 6.85×10^{-4}¢/kg-km

minimally price competitive criteria and applying it to the conventional mode price data in Tables 13 through 18, it was found that the conventional cargo markets in Table 19 are potential candidates for an MAV application.

TABLE 15 - 1965 PRICING DATA FOR LOW VALUE, BREAK BULK COMMODITIES[a] (¢/TON-MILE)[b]

Trip Length Sm	Regulated Truck	Private Truck	Rail	Air	Water	Pipeline
0 - 2.5	- -	25.0	- -	- -	- -	- -
2.5 - 20	11.2	23.7	- -	- -	1.13	- -
20 - 50	11.2	23.0	4.5	- -	1.13	- -
50 - 200	4.9	4.38	2.17	- -	0.50	- -
200 - 400	2.96	2.68	1.13	- -	0.41	- -
400 - 600	2.31	2.06	0.95	- -	0.33	- -
600 - 1000	1.85	1.70	0.80	- -	0.30	- -
>1000	- -	- -	0.54	- -	0.27	- -

(a) Reference 5, Appendix 2.
(b) 1 statute mile = 1.609 km, 1¢/ton-mile $\cong$ 6.85 $\times 10^{-4}$¢/kg-km.

TABLE 16 - 1965 PRICING DATA FOR MEDIUM VALUE, BREAK BULK COMMODITIES (¢/TON-MILE) (REFERENCE 5, APPENDIX 2)

Trip Length, Sm[a]	Regulated Truck	Private Truck	Rail	Air	Water	Pipeline
0 - 2.5	- -	48.0	- -	- -	- -	- -
2.5 - 20	20.6	38.3	- -	- -	- -	- -
20 - 50	20.6	38.3	5.5	- -	0.81	- -
50 - 200	9.28	8.72	2.55	- -	0.30	- -
200 - 400	5.65	5.27	1.52	- -	0.30	- -
400 - 600	4.39	4.09	1.19	- -	0.24	- -
600 - 1000	3.62	3.45	0.97	- -	0.32	- -
> 1000	2.95	2.72	0.69	- -	0.20	- -

(a) 1 statute mile = 1.609 km, 1¢/ton-mile $\cong$ 6.85 $\times 10^{-4}$¢/kg-km.

Based on the 1965 values listed in Table 19, MAV cargo transportation could be competitive with truck and rail modes at trip lengths of only 0 to 80.45 km (0 to 50 statute miles). Within this range, competition is limited to the commodity type/commodity value combinations indicated.

TABLE 17 - 1965 PRICING DATA FOR HIGH VALUE, BREAK BULK COMMODITIES[a] (¢/TON-MILE)[b]

Trip Length, Sm	Regulated Truck	Private Truck	Rail	Air	Water	Pipeline
0 - 2.5	- -	86.0	- -	- -	- -	- -
2.5 - 20	32.2	65.8	- -	- -	1.11	- -
20 - 50	32.2	65.8	12.8	- -	1.10	- -
50 - 200	11.5	12.27	5.97	71.6	0.5	- -
200 - 400	8.79	9.4	3.55	29.8	0.41	- -
400 - 600	6.98	7.46	2.75	21.0	0.34	- -
600 - 1000	5.77	6.14	2.29	19.0	0.30	- -
> 1000	4.91	5.28	1.72	17.0	0.34	- -

(a) Reference 5, Appendix 2.
(b) 1¢/ton-mile ≅ 6.85 × 10^{-4}¢/kg-km.

TABLE 18 - 1965 PRICING DATA FOR LOW VALUE, LIQUID COMMODITIES[a] (¢/TON-MILE)[b]

Trip Length, Sm	Regulated Truck	Private Truck	Rail	Air	Water	Pipeline
0 - 2.5	- -	4.80	- -	- -	- -	- -
2.5 - 20	3.30	4.00	- -	- -	- -	0.76
20 - 50	3.30	3.90	4.1	- -	0.76	0.64
50 - 200	1.47	0.82	1.92	- -	0.34	0.30
200 - 400	0.90	0.50	1.92	- -	0.28	0.23
400 - 600	0.69	0.38	0.90	- -	0.23	0.21
600 - 1000	0.57	0.30	0.74	- -	0.20	0.19
> 1000	0.46	- -	0.57	- -	0.20	0.17

(a) Reference 5, Appendix 2.
(b) 1¢/ton-mile ≅ 10^{-4}¢/kg-km.

Alternatively, all air mode trip lengths above 80.45 km (50 statute miles) are potentially price competitive. Because of the rapidly increasing block speed advantage of air shown in Figure 12, interest in the remaining mission analysis discussion will be limited to air mode trip lengths between 80.45 km and 643.6 km (50 and 400 statute miles). This cutoff is somewhat arbitrary, but it is known

TABLE 19 - POTENTIALLY PRICE-COMPETITIVE CARGO MARKETS FOR MAV'S (1965 ¢/TON-MILE)[a]

Mode	Commodity Type	Commodity Value	Trip Length (sm) 0-2.5	2.5-20	20-50	50-200	200-400	400-600	600-1000	>1,000
• Air	Break Bulk	High	-0-[b]	-0-	-0-	72	30	21[c]	19[c]	17[c]
• Regulated Truck	Bulk	High	-0-	18	18					
	Break Bulk	Medium	-0-	21	21					
		High	-0-	32	32					
• Private Truck	Bulk	High	-0-	17	17					
	Break Bulk	Low	25	24	23					
		Medium	48	38	38					
		High	86	66	66					
• Rail	Bulk	High	-0-	15	15					

(a) 1 statute mile = 1.609 km, 1¢/ton-mile ≅ 6.85×10^{-4}¢/kg-km.
(b) Conventional cargo trip lengths by mode with price greater than 15¢/ton-mile.
(c) Block speed becomes the dominant modal selection criteria.

that shippers begin to weigh block speed more heavily than price on most high-value commodity air transportation routes over 643.6 km (400 statute miles) and thus would favor HTA. The remaining intramodal discussion of conventional competitive modes will be limited to the particular markets identified in Table 19.

Intromodal Comparisons in Price-Competitive Markets

Because of the strong interrelationship between cargo price, trip length, commodity value, and commodity type, several general relationships for MAV price competitive markets will be presented before consideration of the individual cargo modes.

General Market Characteristics - The 1965 distribution of U.S. domestic ton-miles as a function of MAV competitive trip lengths, commodity types, and commodity values is shown in Table 20.

In summary, 47 percent of the MAV price competitive market involves break bulk, high-value commodities. On a purely trip-length basis, 46 percent of the MAV price-competitive market occurs in the 32.18 km to 80.45 km (20 to 50 statute mile) range. Subsequent intramodal analyses will focus on these most dominant potential market sectors.

TABLE 20 - 1965 CARGO VOLUME IN POTENTIAL MAV PRICE-COMPETITIVE MARKETS[(a)] (MILLIONS OF TON-MILES)[(b)]

Commodity		Trip Length (Sm)[(c)]						
Type	Value	0 - 2.5	2.5 - 20	20 - 50	50 - 200	200 - 400	Totals	Percent
	Low			- None -				
Bulk	High		800	1,280			2,080	1.7%
	Low	32	2,240	9,600			11,872	9.7%
Break Bulk	Medium	160	16,160	33,760			50,080	41%
	High	160	7,200	11,520	24,160	14,560	57,600	47%
Liquid	Low			- None -				
Totals		352	26,752	56,160	24,160	14,560	121,984	100
Percent		0.29%	22%	46%	20%	12%	100%	

(a) Reference 5, Appendix 2.
(b) Total 1965 U.S. Domestic Cargo Volume = 1,600,000 million ton-miles.
(c) 1 statute mile = 1.609 km, 1 ton-mile = 1460 kg-km.

Air (CTOL) - All air cargo falls in the break bulk, high value commodity category. The 15 largest commodity categories in order of 1973 air cargo revenue earned are given in Table 21 to give an indication of the particular break bulk, high value products most commonly shipped by air freight. The 1965 stage-length distribution of these commodities by ton-miles and revenue earned are given in Table 22. All stage lengths from 80.45 km (50 statute miles) to greater than 1609 km (1000 statute miles) are shown to provide a complete picture over all trip lengths.

As seen from Table 22, only 14 percent of the 1965 air cargo ton-miles was generated in 80.45 to 643.6 km (50 to 400 statute miles) MAV-price competitive trip lengths, but generated 38 percent of all 1965 air cargo revenue.

Regulated Truck - The MAV price-competitive segments of the regulated truck market are summarized in Table 23 according to 1965 ton-miles and in Table 24 according to 1965 revenue earned. In each case, the market is dominated by break bulk, medium value commodities over trip lengths of 32.18 km to 80.45 km (20 to 50 statute miles).

TABLE 21 - LEADING COMMODITIES SHIPPED BY AIR FREIGHT IN 1973 (REFERENCE 6)[a]

ELECTRIC/ELECTRONIC EQUIPMENT, PARTS, APPLIANCES
PRINTED MATTER
MACHINERY AND PARTS
CUT FLOWERS, NURSERY STOCK, HORTICULTURE
WEARING APPAREL (EXCEPT FUR OR FUR TRIMMED)
AUTO PARTS AND ACCESSORIES
PLASTIC MATERIALS AND ARTICLES
PHOTOGRAPHIC EQUIPMENT, PARTS, FILM
AIRCRAFT, ENGINES, PARTS
TOOLS AND HARDWARE
FRUITS AND VEGETABLES
METAL PRODUCTS
CHEMICALS, ELEMENTS, COMPOUNDS
BAGGAGE AND PERSONAL EFFECTS
TEXTILES, CARPETING, YARN, THREAD

[a] Leading break bulk, high value commodities in decreasing order of revenue earned.

Private Truck - The MAV price-competitive segments of the private truck market are summarized in Tables 25 and 26. The same percentage market share pattern still exists in the sense that break bulk, medium value commodities and 32.18 km to 80.45 km (20 to 50 statute miles) trip lengths dominate the market. However, total private truck-cargo volume (in ton-miles) is approximately four times the volume shown for regulated trucks and total private revenue shown for regulated trucks. In the absence of institutional considerations, the private truck, break bulk, medium value, 32.18 km to 80.45 km (20 to 50 statute miles) trip length industry represents the single largest MAV price-competitive market place.

TABLE 22 - 1965 CARGO VOLUMES AND REVENUES IN ALL AIR CARGO MARKETS

Attribute	Trip Length (Sm)[a]						Totals
	0 - 50	50 - 200[b]	200 - 400[b]	400 - 600	600 - 1000	>1,000	
Ton-Miles							
Millions	none	32	160	320	480	320	1,312
Percent	none	2%	12%	24%	37%	24%	100%
Revenue Earned							
Millions $'s	none	35	78	65	43	78	299
Percent	none	12%	26%	22%	14%	26%	100%
		(b)					

(a) 1 statute mile = 1.609 km
(b) MAV price-competitive trip lengths.

TABLE 23 - 1965 CARGO VOLUMES IN MAV PRICE-COMPETITIVE REGULATED TRUCK MARKETS (MILLIONS OF TON-MILES)

Commodity		Trip Length (Sm)[a]		Totals	Percent
Type	Value	2.5 - 20	20 - 50		
Bulk	High	160	320	480	4 %
Break Bulk	Medium	3,500	5,280	8,780	73 %
Break Bulk	High	960	1,760	2,720	23 %
Totals		4,620	7,360	11,980	100 %
Percent		39 %	61 %	100 %	

(a) 1 statute mile = 1.609 km

TABLE 24 - 1965 REVENUES EARNED IN MAV PRICE-COMPETITIVE REGULATED TRUCK MARKETS (MILLIONS OF $)

Commodity		Trip Length (Sm)[a]		Totals	Percent
Type	Value	2.5 - 20	20 - 50		
Bulk	High	43	56	99	3 %
Break Bulk	Medium	857	1,290	2,147	65 %
Break Bulk	High	394	658	1,052	32 %
Totals		1,294	2,004	3,298	100 %
Percent		39 %	61 %	100 %	

(a) 1 statute mile = 1.609 km

TABLE 25 - 1965 CARGO VOLUMES IN MAV PRICE-COMPETITIVE PRIVATE TRUCK MARKETS (MILLIONS OF TON-MILES)

Commodity		Trip Length (Sm)[a]			Totals	Percent
Type	Value	0 - 2.5	2.5 - 20	20 - 50		
Bulk	High	-none-	480	800	1,280	3 %
Break Bulk	Low	32	1,120	1,600	2,752	5 %
Break Bulk	Medium	160	12,640	18,080	30,880	62 %
Break Bulk	High	160	6,240	8,800	15,200	30 %
Totals		352	20,480	29,280	50,112	100 %
Percent		0.7 %	41 %	58 %	100 %	

(a) 1 statute mile = 1.609 km, 1 ton-mile = 1460 kg-km

Rail - Cargo volume and revenue data for the last remaining MAV price-competitive market are given in Table 27. Relatively minor portions of the market fall in the MAV price-competitive range. The respective figures in

TABLE 26 - 1965 REVENUES EARNED IN MAV PRICE-COMPETITIVE PRIVATE TRUCK MARKETS (MILLIONS OF $)

Commodity		Trip Length (Sm) [(a)]			Totals	Percent
Type	Value	0 - 2.5	2.5 - 20	20 - 50		
Bulk	High	-none-	100	160	260	0.9%
Break Bulk	Low	9	329	437	775	3%
Break Bulk	Medium	113	5,802	8,227	14,917	54%
Break Bulk	High	91	4,893	6,928	11,912	43%
Totals		213	11,124	15,752	27,864	100%
Percent		0.8%	40%	57%	100%	

(a) 1 statute mile = 1.609 km

TABLE 27 - 1965 CARGO VOLUMES AND REVENUES IN ALL BULK, HIGH VALUE RAIL CARGO MARKETS

Attribute	Trip Length [(a)]							Totals
	2.5 - 20[b]	20 - 50[b]	50 - 200	200 - 400	400 - 600	600 - 1000	71,000	
Ton-Miles [(a)]								
Millions	160	160	640	1,280	1,920	1,280	1,440	6,880
Percent	2%	2%	9%	19%	28%	19%	21%	100%
Revenue Earned								
Million $'s	17	26	48	65	74	43	39	312
Percent	5%	8%	15%	21%	24%	14%	13%	100%
	(b)							

(a) 1 statute mile = 1.609 km, 1 ton-mile = 1460 kg-km
(b) Denotes MAV price-competitive trip lengths.

4.02 km to 80.45 km (2.5 to 50 statute miles) range are four percent of the bulk, high value cargo volume and 13 percent of the revenue earned.

Present Scheduled Air Cargo System Capabilities and Limitations

In addition to carrying passengers, U.S. commercial CTOL transport vehicles have under-the-floor cargo capacity. The under-the-floor cargo compartment capacities range from less than 907 kg (one ton) for the Beech B-99 to more than 45,360 kg (50 tons) for the 747-200B while carrying passengers. These same aircraft types and some others have cargo capacities of more than 113,400 kg (125 tons); that is the 747F. The all-cargo aircraft require FAA takeoff field lengths of 1417.3 to 3505.2 m (4650 to 11,500 ft).

The quantities of aircraft serving the air-freight market and the number of suitable airports determine their relative availability (locations and schedule frequency); see Table 28. A further breakdown as to where and how often the service is provided can be determined from Table 29, which presents cargo activity at major airports.

Containers were used for 19 percent of the freight volume in 1973. The standard sizes of these containers are given in Table 30. These containers have volumes from 0.377 to 14.16 cu m (13.3 to 500 cu ft) and have minimum weights of from 45.36 to 1360.8 kg (100 to 3000 lb). Dimensions are restricted to cross-sections of approximately 2.1336 by 2.1336 m (7 by 7 ft) and lengths of approximately 3.048 m (10 ft).

The number of container movements and the sources of these movements indicate their availability and their frequency of use (Tables 31 and 32).

Conventional Cargo MAV Mission Potential

The analysis of the different modes of conventional cargo transportation show that MAV vehicles are potentially competitive, based on price with ground systems for missions of 32.18 to 80.45 km (20 to 50 mi) and based on price and block time with CTOL trunk airline systems from 80.45 to 643.6 km (50 to 400 mi). The availability and VTOL capability of a MAV system can extend the range for competing with air if the capability reduces or eliminates the normal ground transit time and terminal times associated with large CTOL systems.

TABLE 28 - DOMESTIC AIR FREIGHT STATISTICS (1973)

A. AIRCRAFT IN SERVICE (ALL CARGO AND WIDE-BODY)

Aircraft	Number in service		Total	Average payload (lbs)**
	All cargo	Wide body		
B-707-320C.	6		6	73,000
B-707-323CF	13		13	89,500
B-707-331C	8		8	75,240
B-727-QC	45		45	40,000
DC-9-30F	2		2	27,378
DC-8-63F	17		17	100,000
DC-8-50F	15		15	76,240
747		109	109	50,000*
DC-10		86	86	23,000*
L-1011.		48	48	27.000*
TOTALS	106	243	349	

B. AIRPORTS SERVED

Airports served in the United States 452

Cities served with all cargo aircraft 42

Cities served with wide-body aircraft. 45

Cities served by all cargo and/or wide-body aircraft. 55

C. FREQUENCY OF DEPARTURES

	Trunk	Regional
Frequency of all cargo (departures per week)	1469	74
Frequency of wide-body (departures per week)	4627	--
Average number departures between 8:00 p.m. and 3:30 a.m.	4583	939

*Average cargo capacity after full passenger and baggage complement on wide-body-combination passenger/cargo aircraft.

**1 lb = 0.4536 kg

TABLE 29 - FREIGHT TONS ENPLANED AT TOP 10 AIRPORTS (REFERENCE 9)

Airport	Freight tons enplaned/yr*	Aircraft departures/yr
Chicago (O'Hare)	375,747	278,728
John F. Kennedy	320,836	114,343
Los Angeles	296,554	146,330
San Francisco	203,491	117,558
Atlanta	115,119	207,677
Detroit	109,285	88,630
Miami	102,991	93,850
Newark	78,604	78,571
Seattle-Tacoma	75,158	52,468
Dallas (Love Field)	73,440	131,887

*1 ton = 907.2 kg

TABLE 30 - AIR FREIGHT CONTAINERS, 1973 (REFERENCE 9)

Container type	Maximum external dimensions (in.)*	External cube capacity (cu ft)	Minimum weight (lb)	Allowable tare weight (lb)
A-1 A-2 A-3	Length 108/125 Width 88 Height 81-87/45 (contoured)	Up to 425 426 to 475 476 to 500	3000 (net)	Actual Actual Actual
LD-7	Length 125 Width 88 Height 63/60 (contoured)	382, 401	2800 (net)	Actual
LD-3	Length 79 Width 60.4 Height 64 (contoured)	166	1100 (net)	Actual
B	Length 84 Width 58 Height 76/45 (contoured)	179.70	1800 (gross)	200

*1 in. = 0.0254 m, 1 cu ft = 0.02832 cu m, 1 lb = 0.4536 kg

TABLE 30 - (CONTINUED)

Container type	Maximum external dimensions (in.)*	External cube capacity (cu ft)	Minimum weight (lb)	Allowable tare weight (lb)
LD-N	Length 56 Width 55 Height 57	101.6	900 (net)	100
B-2	Length 58 Width 42 Height 76/45 (contoured)	98.25	900 (gross)	100
D	Length 58 Width 42 Height 45	63.44	500 (gross)	63
E	Length 42 Width 29 Height 25.5	17.97	130 (net)	18
QD	Length 39.5 Width 27.5 Height 21	13.30	100 (net)	13
LD-W	Length 98 Width 42.2 Height 41.6	73.4	500 (net)	Actual

*1 in. = 0.0254 m, 1 cu ft = 0.02832 cu m, 1 lb = 0.4536 kg

TABLE 31 - CONTAINERS MOVING UNDER CONTAINER TARIFFS (SHIPPER LOADED), 1973

TOTAL CONTAINER MOVEMENTS	413,854
TOTAL ACTUAL NET WEIGHT (TONS)*	389,129,882
AVERAGE WEIGHT PER CONTAINER (TONS)	0.94
TOTAL REVENUE	$105,804,004
AVERAGE REVENUE PER CONTAINER	$6255.17

*1 ton = 907.2 kg

TABLE 32 - NUMBER OF ORIGINATING CONTAINER MOVEMENTS (TOP 10 CITIES)

City	Code	Number of originating movements
Chicago	ORD	67,551
Los Angeles	LAX	55,901
New York	JFK	45,466
Detroit	DTW	34,403
San Francisco	SFO	24,716
Newark	EWR	22,548
Philadelphia	PHL	15,536
Dallas	DAL	11,114
Atlanta	ATL	11,051
Boston	BOS	10,887
Minneapolis	MSP	10,849

Some very long range missions have been postulated to carry high-value products. These missions appear to have potential, if costs per ton-mile for very large MAV can be less than present CTOL air systems. The scheduled cargo mission potential is between city centers (025), between shipper/customer (026), and very long range (027). This market consists of scheduled commercial MAV services for regions now limited to ground transportation. VTOL is suggested for these regions not presently served effectively by local or trunk airlines. The very long-range mission considers the savings in time over ships and in costs over CTOL aircraft.

Additional descriptions of the desired missions and vehicle characteristics follow.

Between City Centers (025) - This mission consists of regularly scheduled service between city centers 32.18 to 80.45 km (20 to 50 mi) apart. A VTOL capability is required to provide station locations that are readily accessible to the user. Flight speeds can be as moderate as the distances are short. The size of the vehicle should be related to cargo payloads of 4536 to 9072 kg (5 to 10 tons).

Between Shipper/Customer (026) - The purpose of this mission is to transport cargo from collection points near major shippers to collection points near or directly to their destination. The cargo is primarily high-value, break-bulk that is associated with manufactured products. The range for these missions is about 80.45 km to 643.6 km (50 to 400 mi) with a VTOL capability and is competitive with CTOL door-to-door times. The payload capacity is postulated at 9072 to 13,608 kg (10 to 15 tons).

Very Long Range (027) - This mission is designed to transport high-value cargo (such as packaged meat) from a surplus region (such as Australia) to Japan or the West Coast of the United States. This mission is designed to drastically reduce the transit time associated with ships at a price considerably less than that associated with conventional jet aircraft. The size of the market allows the selection of the most economical MAV size. Tentatively, the cargo capability is 453,600 to 907,200 kg (500 to 1000 tons) for a range of 4827 to 8045 km (3000 to 5000 mi).

PRESENT UNIQUE TRANSPORTATION AND SERVICE MISSIONS

Present Unscheduled/General Aviation Passenger Missions

This mission/market category contains the very large number of general aviation aircraft and private automobiles (automobiles were discussed earlier as a reference for comparison with scheduled passenger service).

The desire for door-to-door speed and schedule freedom by businessmen can be deduced from the large number of business/executive aircraft listed in Table 33 plus an additional 3407 helicopters in general aviation that use the many close-in airports and heliports or helistops. The quantities of helicopters by operators are 2605 for commercial, 802 for companies, and 467 for non-military government agencies. A listing of landing sites is presented in Table 34.

The higher costs of general aviation transportation over scheduled airlines normally are justified by the users in the savings of executives' or businessmen's door-to-door times because of the more flexible schedules and reduced local transportation times associated with general aviation.

TABLE 33 - FIXED-WING GENERAL AVIATION FLEET COMPOSITION, SELECTED USER CATEGORIES, 1971 (REFERENCE 11)

	Business/ Executive	Personal	Instruction	Rental
Single Prop				
1-3 Seats	2,619	26,460	6,532	2,108
≥ 4 Seats	20,013	42,387	4,731	3,482
	22,632	68,847	11,263	5,590
Multi Prop				
Twin < 12.5#	9,957	2,334	468	264
Twin > 12.5#	712	73	30	41
Multi >12.5#	32	14	4	14
Twin T/P < 12.5#	772	16	1	2
Twin T/P > 12.5#	222	1	-0-	1
	11,695	2,438	503	322
Exec Jet				
Twin < 20.0#	418	9	-0-	1
Twin >20.0#	329	7	-0-	-0-
Multi < 20.0#	-0-	-0-	-0-	-0-
Multi > 20.0#	130	2	-0-	-0-
	877	18	-0-	1

TABLE 34 - NUMBER OF AVAILABLE AIRPORTS BY RUNWAY LENGTHS AND AVAILABLE HELIPORTS OR HELISTOPS

Airport runway lengths (ft) *			Heliports or helistops	
Less than 5000	5000 to 9999	Over 10, 000	Civil	U. S. Forest Service plus off-shore platforms
10, 537	1254	279	2300	2300

*1 ft = 0.3048 m

General Aircraft Fleet Composition and Use (1971)

The U.S. total fixed-wing, general aviation fleet composition presented in Table 33 is discussed further considering only the business/executive fleet composition, flight hours, flight hours per aircraft operation, annual operation per aircraft, and their percentage of the total U.S. domestic general aviation fixed wing aircraft operations.

Fleet Composition

The four aircraft user categories most likely to operate from the case study airports were singled out from the available data. All aircraft types are included regardless of engine type or aircraft weight. This matrix of aircraft population was adopted as the common baseline for all subsequent derivations.

Flight Hours - Total U.S. domestic flight hours for the business/executive aircraft of the aircraft types listed in Table 33 are given in Table 35. The 1971 national average for annual flight hours per aircraft type is given in Table 36. These numbers are a simple division of the Table 35 values by the Table 33 values.

No data are accumulated by the FAA on a national basis for total operations represented by the Table 36 flight hours. Equivalent aircraft operations are needed to adjust available FAA forecasts of "local" general aviation operations. The assumptions necessary to relate aircraft operations to flight hours are discussed below.

Flight Hours Per Aircraft Operation - Assumptions made to relate actual flight hours to estimated aircraft operations are given in Table 37. In the case of business/executive, it was necessary to assume a typical one-way cross-country trip length and groundspeed. These assumptions are shown in parentheses where applicable.

The resulting national average values in Table 37 are considered reasonable for this study. These values were compared with other available local airport data, and the relationship between users and aircraft types are reasonably

TABLE 35 —FIXED WING BUSINESS/EXECUTIVE AIRCRAFT, AVIATION HOURS OF SERVICE, SELECTED USER CATEGORIES (1971)

Aircraft Type	Hours of Service
Single prop	
1-3 seats	283,049
≥ 4 seats	3,529,437
	3,812,486
Multi-prop (lb)*	
Twin < 12,500	2,877,413
Twin > 12,500	144,347
Multi > 12,500	4,728
Twin T/P < 12,500	404,494
Twin T/P > 12,500	166,657
	3,597,639
Exec jet (lb)	
Twin < 20,000	237,057
Twin > 20,000	206,925
Multi < 20,000	-0-
Multi > 20,000	80,162
	524,144

*1 lb = 0.4536 kg

accurate. Absolute values vary greatly from airport to airport depending on their proximity to other major metropolitan areas. However, the numbers in Table 37 are judged to be reasonably valid for typical general aviation operations to and from the Los Angeles and Chicago metropolitan regions.

Annual Operations Per Aircraft - After deriving the detailed relationship between flight hours and operations by aircraft type, these numbers can be used to compute the annual average operations per aircraft type and user. What is needed is an annual average weighted according to the flight hours per operation unique to each aircraft type. The computation and resulting values are given in Table 38.

TABLE 36 - ANNUAL FLIGHT HOURS PER BUSINESS/ EXECUTIVE AIRCRAFT, FIXED WING GENERAL AVIATION, SELECTED USERS, 1971

Aircraft type	Annual flight hours
Single prop	$\frac{3,812,486}{22,632} = 169$
Multi prop	$\frac{3,597,639}{11,695} = 307$
Exec jet	$\frac{524,144}{877} = 598$

TABLE 37 - ASSUMED FLIGHT HOURS PER BUSINESS/ EXECUTIVE AIRCRAFT OPERATION, FIXED WING GENERAL AVIATION, SELECTED USERS, 1971

Aircraft type	Hours per flight
Single prop	1.5 (180 Sm at 120 mph)*
Multi prop	1.0 (250 Sm at 250 mph)
Exec jet	0.8 (400 Sm at 500 mph)

( ) denotes assumed distance and ground speed for average flight.

*1 statute mile = 1.609 km, 1 mph = 0.447 m/s

<u>U.S. Domestic Total Aircraft Operations</u> - The Table 38 values were then translated back into national totals by multiplying them by the Table 33 fleet composition data. The resulting national distribution of business/executive operations by aircraft type is given in Table 39.

TABLE 38 - ESTIMATED ANNUAL OPERATIONS PER BUSINESS/EXECUTIVE AIRCRAFT, FIXED-WING GENERAL AVIATION, SELECTED USERS, 1971

Aircraft type	Annual operations (hours)
Single prop	$\frac{169}{1.5} = 113$
Multi prop	$\frac{307}{1.0} = 307$
Exec jet	$\frac{598}{0.8} = 748$

TABLE 39 - ESTIMATED BUSINESS/EXECUTIVE AIRCRAFT AND THEIR PERCENTAGE OF TOTAL FIXED-WING GENERAL AVIATION OPERATIONS, SELECTED USERS, 1971

Aircraft type	Total operation hours
Single prop	22,632 × 113 = 2,560,000
Multi prop	11,695 × 307 = 3,600,000
Exec jet	877 × 748 = 655,000
% of total	6,815,000 (17%)

Helicopters - The large number of helicopters in general aviation compared with the small number in scheduled passenger service indicates they are cost effective where the amount of traffic is small and their high operating costs can be offset by the saving of other costs associated with using the more efficient airplane; that is, land costs, right-of-way costs, construction costs, and/ or value of passengers time.

The Aerospace Industries Association has predicted the distribution of aircraft by mission in 1975. Approximately 43,000 fixed-wing and 1800 rotary wing vehicles are predicted for use in general aviation for unscheduled transportation missions in 1975.

The general passenger helicopter market is predominantly small vehicles (2 to 4 place) with lesser amounts of vehicles with a 13 to 15 passenger capacity or a 25 to 44 passenger capacity. The small helicopters are used as passenger transportation to and from airports, remote work areas, offshore platforms, and rescue areas. The larger vehicles are used to transport workers to offshore platforms and to remote sites. They also carry supplies in addition to the passengers.

The helicopters produced in calendar years 1968 through 1972 (see Table 40) indicate the typical vehicle mix and the trends.

Present Passenger Equipment Capabilities and Limitations

The equipment in unscheduled passenger service includes many of the same vehicles for scheduled service, plus a large range of the smaller general aviation passenger vehicles for use from small airports. Propeller-driven vehicles conduct the largest number of missions in this market. They have FAA takeoff field length capabilities of from 365.8 to 823 m (1200 to 2700 ft) and have seating capabilities of 2 to 11 people. Their maximum cruise speeds are from 55.9 to 134 m/s (125 to 300 mph), and their maximum still air ranges are 965.4 to 2896.2 km (600 to 1800 mi). Their factory prices result in prices per seat of from less than $10,000 to approximately $30,000.

TABLE 40 - PRODUCTION OF COMMERCIAL HELICOPTERS BY NUMBER OF HELICOPTERS SHIPPED (REFERENCE 12)*

Company and model	1968	1969	1970	1971	1972
Total	522	534	482	469	575
Bell total	364	339	288	274	329
47 series	151	134	124	110	97
204 series	...	...	...	1	...
205 series	29	49	23	13	17
206 series	184	156	138	129	193
212 series	...	...	2	21	22
Boeing-Vertol total	...	...	...	5	6
CH-47C	...	...	...	5	6
Enstrom total	13	25	...	17	38
F-28A	13	25	...	17	38
Fairchild total	64	42	37	21	28
FH-1100	60	40	37	21	28
12 series	4	2	...	...	...
Hughes total	72	108	149	137	155
300's	57	43	74	54	71
500's	15	65	75	83	84
Sikorsky total	9	20	8	15	19
S-61	6	13	6	9	13
S-62	3	7	...	...	...
S-65	...	...	2	6	6

*All figures exclude foreign licenses.

A lesser number of higher-speed aircraft are turbine powered (turbofan/turbojet aircraft and turboprop aircraft). All of these aircraft are multiengine, with most twin engine, a few three engine, and one four engine. The turbofan/turboprop aircraft have 914.4 to 1828.8 m (3000 to 6000 ft) FAA takeoff field requirements that limit the number of airports available for their use compared with the propeller airplanes. Their flight speeds and ranges approach domestic regulated carriers. Their factory prices result in prices per passenger seat of from $100,000 to $375,000.

The turboprop aircraft for these missions have twin engines and have FAA takeoff field requirements of 609.6 to 989.1 m (2000 to 3245 ft), which is comparable to the larger twin reciprocating engine aircraft. Their maximum cruise speeds are from 111.8 to 163.1 m/s (250 to 365 mph); they have maximum ranges, with 45 minutes of reserve, of 2413.5 to 4505.2 km (1500 to 2800 mi). Their factory prices range from $50,000 to approximately $100,000 per passenger seat.

Unscheduled Passenger Mission Potential

The market is presently being served by general aviation vehicles, both fixed and rotary wing. These missions normally are associated with specialized activities that have not developed sufficient volume for sufficient periods of time or with sufficient regularity to become a regulated carrier activity (activities such as sight-seeing and cruises are listed under platform missions (300's) since they were not considered basic transportation missions). These missions include service for off-shore platforms (050); service to remote areas (051); and emergency service (052) for commercial passenger. Institutional passenger missions include forest service transportation (060), fire fighting (061), and rescue (062). The unscheduled civil missions primarily are to regions having limited size landing sites and minimal conventional transportation systems.

Commercial

Service to Off-Shore Platforms (050) - These missions require the rapid transfer of personnel from shore areas to platforms 80.45 to 321.8 km (50 to 200 mi) off-shore. Limited landing facilities are available on the platform and the vehicle must have VTOL capability. Passenger capacities of 30 to 50 are contemplated for this mission.

Service to Remote Regions (051) - These missions require the transfer of personnel between the many construction sites in Alaska and the far North. Limited landing facilities are available and a VTOL or STOL (unimproved runway) capability is required. Ranges of 321.8 to 804.5 km (200 to 500 mi) and passenger capacities of 10 to 30 are contemplated.

Emergency Service (052) - This mission is basically an ambulance-type mission of short range. The vehicle will require a VTOL capability to interface with hospitals and probable landing sites.

Institutional Passenger

Forest Service Transportation (060) - The purpose of this mission is to move personnel between work areas and bases. A range of 32.18 to 80.45 km (20 to 50 mi) as a VTOL with a passenger capacity of 10 to 30 comtemplated.

Forest Fire Fighting (061) - This mission is designed to move personnel between bases and work areas to control fires. A VTOL capability and a range of 160.9 to 321.8 km (100 to 200 mi) is contemplated. Because of the equipment associated with the men, a passenger capacity equivalent to 30 people is contemplated.

Rescue (062) - This mission is designed for rescue of people over land (Coast Guard missions are listed later in this report). The need may be caused by natural disasters; flood, fire, snow, or accidents. The missions will be conducted by local government agencies. The tentative range is 160.9 to 321.8 km (100 to 200 mi), and the capacity is 10 to 30 people.

Present Unscheduled/General Aviation Cargo Missions

The unscheduled air cargo mission includes special shipments to airports not served by scheduled airlines, cargo not carried by scheduled airlines, and/or shipments at times or frequencies not offered by scheduled airlines.

The limitations of service frequency, the number and locations of major cargo terminals, and cargo size restrictions have caused many shippers to charter aircraft or to purchase their own cargo aircraft. The large size of some indivisible loads also exceeds the size limits of scheduled airline equipment. The Guppy, the Super Guppy, and the present modifications underway on 747 aircraft to transport the space shuttle orbiter externally are examples of efforts to overcome scheduled air cargo or even surface cargo size limitations for special transportation missions.

A large number of general aviation vehicles are conducting cargo transportation missions to small airports; that is, airports with runways less than 1524 m (5000 ft) long; however, their cargo size and weight capabilities are less than those of scheduled airline vehicles. The use of helicopters to move outsize cargo at low speeds also has been limited because of their limited lift capabilities.

Present Unscheduled Cargo System Capabilities and Limitations

The unscheduled/general aviation cargo services include most of the same aircraft for the scheduled airlines cargo service, including rotary wing aircraft. In addition, there are some specialized aircraft consisting of modified aircraft for unique purposes and a family of agricultural aircraft. Some modified aircraft include the Guppy, the Super Guppy, and the 747.

The agricultural aircraft have evolved to fulfill the mission requirements for chemical applications in agriculture. The normal operating speeds of these single-engine aircraft are from 38 to 62.6 m/s (85 to 140 mph). Their takeoff distances at gross weights range from 120 to 580 m (395 to 1900 ft). The maximum still air ranges are from 467 to 1195 km (290 to 743 mi), and their hopper capacities are from 0.765 to 1.0 cu m (27 to 35 cu ft). Their factory prices range from $28,000 to $72,500.

Unscheduled General Cargo MAV Mission Potential

This market is being served by private trucks or general aviation helicopters at short ranges; private trucks and general aviation vehicles at medium range; and chartered aircraft or ships at very long range. These missions are described below:

Cargo Between Plants (075) - This VTOL mission could be conducted by chartered or private MAV vehicles between plants of manufacturers to transfer high-value, break-bulk cargo. The mission length is 80.45 to 643.6 km (50 to 400 mi) with a cargo capacity of 4536 kg to 9072 kg (5 to 10 tons).

Cargo to Customers (076) - This mission could deliver direct from the manufacturer to the customer. A VTOL vehicle with cargo capacity and range equal to category 075 is estimated for this mission.

Very Long Range (077) - This mission is similar to the scheduled very long range mission (027); however, the vehicle will not always land at terminals with complete cargo handling equipment and thus the MAV will have to carry some of its own, which may reduce its productive payload. The size of the containerized break bulk market allows selection of the most economical MAV size for ranges of 4827 to 8045 km (3000 to 5000 mi).

Heavy Lift Large Indivisible Load MAV Mission Potential

The general characteristics of this market/mission category are items that are oversize or overweight for transporting over present roadways or railroads or are essentially one-time heavy-duty shipments to a region not otherwise requiring right-of-ways for roads or railroads. Examples of these missions are summarized below. Almost all missions require VTOL capabilities because of the probable conditions at the destination site and possibly at the origin.

Commercial (Heavy Lift)

Power Generating Equipment (101) - This equipment is oversize and overweight for land shipment and represents the heaviest and densest unit loads of 45,360 to 453,600 kg (50 to 500 tons). In the past, waterways and special rail cars have been used to transport assemblies and subassemblies to the site. The present desire to locate power stations away from waterways and population centers because of environmental or safety reasons eliminates direct water or rail transportation to the site and creates need for a special one-time transportation system for stage lengths of approximately 80.45 to 160.9 km (50 to 100 mi).

Large Industrial Equipment (102) - This mission/market covers a broad range of items associated with the construction of refineries, chemical plants, pipelines, and manufacturing plants. Normally, these plants are located away from waterways and population centers for environmental and safety reasons and do not require movement of outsize products once in operation.

Mining Equipment (103) - This mission is listed separately because of the need for greater vehicle range due to the remoteness of the mine sites.

Prefabricated Buildings (104) - This mission is to transport oversize "prefabricated" homes, conventional size homes, offices, and factory building units from the factory to the site. The shipments are oversize and essentially one time to a site even though many (such as homes) can be delivered to a relatively concentrated area. Payload size is estimated to range from 22,680 to 90,720 kg (25 to 100 tons). Either VTOL capability or elaborate ground preparation and ground handling for other forms are requirements at the site for final placement of the units. Since many missions can be considered at one time, a VTOL capability was selected in place of ground preparation and equipment associated with STOL.

Large Aerospace Vehicles (105) - This mission requires one-time shipment or a limited number of shipments of large vehicles. Their weights are in the 22,680 to 90,720 kg (25 to 100 ton) range. A VTOL or a STOL capability for more useful load can be considered since many of the fabrication and test areas are near airfields. The limited locations of manufacturing facilities and flight sites will require transportation ranges of 804.5 to 2413.5 km (500 to 1500 mi). Security during transportation will be a factor because of the nature of these vehicles.

Institutional (Heavy Lift)

Coast Guard - Aids to Navigation (ATN) (106) - One part of the aids-to-navigation missions is to transport large indivisible loads, such as buoys, up to 643.6 km (400 mi) from bases. The largest projected load is 272, 160 kg (300 tons) and is to be picked up and set into the water at speeds less than 2.6 m/s (5 knots). There are no high-speed flight requirements for this mission.

Coast Guard - Marine and Environmental Protection (MEP) (107) - One portion of this mission also requires transporting large indivisible loads also to be placed in the water at speeds less than 2.6 m/s (5 knots). The range and payload requirements are the same as category 106.

Agricultural Transportation MAV Mission Potential

The general characteristic of the agricultural transportation market/mission category is the lack of suitable forms of transportation for carrying one-time or seasonal items over difficult terrain or in remote regions without crop or soil damage. The sizes and weights of the individual items normally are within conventional transportation limits, and the items may require interfacing with conventional systems.

Almost all missions require VTOL capabilities because of their locations, the types of terrain, and the required operational functions. The market/missions are summarized below.

Timber Harvesting (201) - These missions are in areas not amenable to conventional transportation. The trees may be in difficult locations, in locations where the soil can be permanently damaged, or in locations uneconomical to harvest using conventional techniques. The economics of timber harvesting in these regions has been under investigation using tethered balloons and helicopters for many years. Typically, missions are very short range and require a VTOL capability for rapidly loading the timber at the site and unloading the timber in the yard to obtain sufficient productivity to offset the costs of these transportation systems.

A second mission is between the yard and conventional transportation to save the cost of roads and special trucks. Payload weights to 22,680 kg (25 tons) appear suitable for loads from the yard.

Special vehicle considerations are associated with the conditions experienced by the ground crew during hookup and unloading of the timber. The noise, dust due to downwash, and static discharges associated with heavy lift helicopter rotor systems create an undesirable environment for these operations.

Chemical/Seeding Applications (202) - These missions are associated with dusting or spraying crops to improve their yields and/or quality and planting crops. The crops range from foods to timber. Flight vehicles for this mission include special aircraft and helicopters in some special regions. The LTA vehicle for this mission should be VTOL with reasonable payloads and have the capability for larger payloads as a STOL vehicle since small airports are available in many farming regions. The speed, range, and payload capabilities should be flexible to meet the many combinations of operating sites, distances to the crop areas, and dispersion speeds. Special environmental impact requirements are associated with controlling the chemical applications accurately and limiting the ground noise level to acceptable values, considering the low flight altitudes associated with chemical applications.

Crop Harvesting (203) - This mission is similar to the tree harvesting mission in remote areas. The LTA vehicle mission is transporting crops to local pickup areas from regions not normally amenable to conventional equipment because of crop or soil damage. The mission consists of picking up many manually filled containers of medium - to high - value crops, such as grapes, that are located on the side of terraced hills or other difficult terrain and taking them to a local trucking site. A VTOL capability is required to hover for picking up and off-loading the containers. The ranges are short, and most of the LTA vehicle's useful load can be allocated to payload. Special consideration must be given to the vehicle-created environment that affects the workers. Transporting the crops will require an environment that does not damage them. The more important factors are the vibration and acceleration loads associated with pickup, carriage, and landing of the containers.

Livestock Transfer (204) - These missions are seasonal and include transferring livestock from one range to another or from a range to a feed lot. Since open unimproved regions are involved, a VTOL capability is required. The transportation distances normally are several hundred miles. Flight speeds are not important; however, the flight environment is very important to minimize the effect on the animals. The transportation system replaces the lack of drovers, herders, or trail hands for driving the animals at an acceptable slow pace from one feeding range to another. Trucking has not been completely acceptable for this function because of the poor condition of the animals after transportation. The desired LTA vehicle must provide a low g, low-noise, ventilated environment with minimum crowding and contact between animals.

Platform/Service Mission Potential

The general characteristics of the platform/service market/mission category are associated with providing suitable platforms with equipment and operators for patrolling pipe/electrical lines, monitoring natural resources, local security, and pleasure missions. Examples of this mission category are summarized below. The missions require speeds ranging from very low 2.6 m/s (five knots) to medium speeds 36 to 77 m/s (70 to 150 knots) and may require medium to long endurance periods; that is, greater than 100 hours. Takeoff and flight requirements depend on the mission and include all vehicle capabilities (VTOL, STOL, and/or CTOL).

The market/missions are presented first by commercial and then by institutional uses.

Commercial (Platform/Service)

Patrol of Pipe/Electrical Powerlines (301) - These missions require small vehicles that serve as platforms for the pilot to inspect at high rates the lines over a range of terrain not suitable for high-speed ground vehicles. The LTA vehicles also should have low-speed capability to inspect specific portions of the lines that may be damaged. The vehicle also can be used to bring in small repair crews. A vehicle with VTOL capability would be the most useful for this mission.

Aerial Survey (302) - These missions obtain detailed information for construction or similar projects. The vehicles required are small and contain a pilot and an operator for the photographic equipment. Low-speed flight capability is desired; however, STOL capability may be sufficient for these missions.

Advertising (303) - These missions require modern night signs and power generation equipment weighing 907.2 to 1814.4 kg (one to two tons). Low vehicle noise is an important consideration for this class of mission.

Sightseeing (304) - Vehicles for this mission can have STOL instead of VTOL capabilities since they will typically operate from small to medium size airports and fly at low speeds. The passenger capacity can be small (20 people), and a payload weight of five tons is tentatively indicated for the passengers and their accommodations. The onboard environment should be pleasant and attractive to the potential customers.

Seismographic Surveys in Water (305) - These missions are designed to locate possible oil, gas, and other natural resources. Medium to large vehicles are required to carry and tow arrays at low speeds 2.6 m/s (five knots), record the returns of sound from earth structures, chart their shape, and map their locations. The platform equipment and related operators require a vehicle payload capacity of 18,144 to 27,216 kg (20 to 30 tons) plus life-support provisions for flights of over 100 hours. VTOL capabilities are required for low speed control at tow and for placing the array in the water. Because of the nature of the mission, a room-type environment with low noise, vibration, and acceleration levels is desired for the operators; the vehicle must be designed to transmit a minimum amount of sound energy into the water.

MAV Cruises (306) - These missions consist of pleasure cruises within tourist regions around the world. Vehicles can have STOL characteristics since reasonable ground facilities are available to handle the passengers and provisions at the landing points. The onboard environment will have to be pleasant to compete with cruise ships; that is, low noise and spacious, with recreation areas, entertainment, and staterooms. The ranges, accommodations, service personnel, and large passenger size (100's) needed for a cruise mission result in vehicles with payload requirements of approximately 90,720 kg (100 tons).

Institutional (Platform/Service)

Police Surveillance (307) - These missions consist of airborne surveillance and control of regions by local police departments. Vehicles being investigated for this market include helicopters and STOL aircraft. Takeoff and landing sites normally are located within the controlled region to permit fast response in emergencies and to be able to easily interface with other police units. The payload includes one or two policemen/pilots, their equipment, and provisions for an eight-hour flight. The vehicles should be designed to be quiet and have a minimum effect on the environment because almost all missions will be at low altitudes over populated regions.

Border Patrol (308) - These missions consist of airborne surveillance and control of border regions by enforcement agencies. The mission requires VTOL/STOL capabilities to be able to provide close-in surveillance. Takeoff requirements can be either VTOL for short emergency missions or STOL for longer range scheduled patrols. A 1814.4 to 4536 kg (two - to five-ton) payload consisting of crew, equipment, and provisions for at least eight hours are tentative requirements. The environment within the vehicle should be room-like for efficient operation during eight hour patrols.

Coast Guard - Search and Rescue (SAR) (309) - This mission requires searching large regions of water in detail and an ability to board personnel during rescue. Low-speed flight capability, long endurance, payloads of 22,680 to 45,360 kg (25 to 50 tons) and dash speeds of up to 77.1 m/s (150 knots) are desired vehicle capabilities.

Coast Guard - Enforcement of Law and Treaties (ELT) (310) - This mission requires surveillance of large regions off the coast. Payload, endurance, and dash speed requirements are the same as category 309.

Coast Guard - Small SAR Drone (311) - The drone mission is designed to extend the coverage of the mother vessel for search and rescue. Low-speed or VTOL flight is desired for the drone to aid or even pick up survivors.

Coast Guard - Aids to Navigation (ATN) (312) - One portion of this mission is to service equipment to ranges of 3218 km (2000 mi) with dash speeds up to 102.8 m/s (200 knots). The payload for this mission is approximately 907.2 kg (10 tons). Low-speed flight capability, down to 2.6 m/s (five knots), is required for servicing surface equipment.

Coast Guard - Marine and Environmental Protection (MEP) (313) - One portion of this mission requires the same vehicle characteristics as for the 312 mission.

Air Pollution (314) - This mission is designed to measure air quality at many stations around municipalities. At present, multiple ground stations are being tested to perform this function. The LTA vehicle for this mission can be relatively small and provide the endurance and equipment for EPA missions. The air sampling task can be performed during static or low-speed flight using an inlet system that is lowered below the vehicle to draw ambient air through the instruments. The air can be analyzed onboard in real time or near real time. The LTA vehicle system should be resource efficient based on its purpose and should not contaminate the air it is measuring.

Water Resource Monitoring (315) - This mission consists of monitoring the character of the water in streams, lakes and oceans to determine the effect of effluents from municipalities and industry. Typical missions include photograph and sample collection during static flight for water quality analysis.

Vehicle range can be short, for local use, or several hundred miles for use over the larger lakes or along the nation's coasts. Endurance capability for all vehicles should be at least eight hours.

Crop Surveillance (316) - This mission consists of monitoring the amount of land and the type of crops in production and determining the probable crop yields. Satellites and aircraft are being used to photograph the fields. The photographs then become the basis for data reduction and crop yield evaluations. The payload for the LTA vehicle system will consist of photographic or other sensing equipment plus operators.

Fish Monitoring (317) - This mission is designed to monitor the locations, movements, and catches of fish. The LTA vehicle system will be similar in size, payload weight, and endurance to the other small surveillance vehicles. Noise is one important vehicle design constraint for limiting possible effect of the vehicle presence on fish movements. An all-weather capability is needed because of the possible weather changes during the longer endurance missions and fog associated with takeoff and landing operations near a coast line.

Hospital Emergency Disaster Care (318) - This mission is designed to provide a hospital/emergency disaster care vehicle. This mission requires a fairly large vehicle to provide space for medical care and to transport the supplies needed after a disaster. The mission requires a vehicle that can land in regions with a minimum of preparation; that is, have VTOL or STOL capabilities using unprepared surfaces. A minimum payload capability of 22,680 kg (25 tons) is postulated in addition to an onboard emergency hospital capability. Missions have been postulated where the vehicle serves both as a hospital for specialized care and as a carrier of medical personnel and portable hospital shelters to set up ground stations for general care.

Resources from Remote Regions - MAV Mission Potential

The general characteristics of this market/mission are designed to transport bulk cargo (dry, liquid, or gaseous) from remote regions that otherwise would require large fixed transportation system investments. Takeoff and landing characteristics can be VTOL or STOL from unprepared surface for limited resource situations or more conventional for extensive resource situations.

The market/missions are commercial and include:

Ore/Ore Pellets (401) - These missions transport limited supplies of high-grade ore or ore/pellets from the interior of remote regions to the coast. Flight ranges from 80.45 to 482.7 km (50 to 300 mi) are typical. The size of the LTA vehicle will be based on economics associated with the projected output from the mine, distances, and overall investment costs and value of the cargo. A payload weight between 9072 to 22,680 kg (10 to 25 tons) is postulated for this mission, with the larger payload associated with the longest flights and larger mine outputs. Large sizes for greater productivity rates were not considered for these missions because mines producing very large rates of ore tend to justify the investment for conventional transportation systems at the contemplated ranges.

Petroleum (402) - These missions are for transporting oil from remote regions (such as Alaska or the far North) or across water regions to the coast, the rail head, or the refinery. Large vehicles to obtain minimum transportation costs are postulated for bulk oil transport because of the low value of the oil. Restrictions against possible competing conventional ground transportation systems relative to the environment make this a possible mission. Ranges up to 1609 km (1000 mi) and payloads from 90,720 to 453,600 kg (100 to 500 tons) are postulated for these missions.

Gaseous (403) - These missions consist of transporting large quantities of bulk gases directly from the source to a terminal. They are postulated to avoid the large fixed-site costs for gas liquefication plants.

The range of these LTA vehicles should be more than 4827 km (3000 mi); the payload weight would be based on the vehicle size for minimum transportation costs because of the low value of the gas.

The gas will be stored in large gas cells within the vehicle envelope, and the amount of air displaced by the gas is postulated to be as much as 453,600 kg (500 tons). The return flight may place special requirements on the vehicle design such as separate helium gas cells sufficient to support the airship when empty of gaseous payload and/or the capability to generate appreciable amounts of aerodynamic lift.

Military MAV Mission Potential

A review of stated and potential U.S. Air Force, U.S. Navy, and U.S. Army operational requirements led to the selection of the following military missions where the particular virtues of a modern airship appear to overcome operational deficiencies:

U.S. Navy/U.S. Marines

Logistics Over The Shore (LOTS) (501) - The MAV, including those versions with water ballasting capability, are ideal vehicles for performing the LOTS* mission (including containers, barges, and unit deliveries of tanks and other tracked vehicles).

Sea Control (502) - The sea control concept requires the inclusion within a platform of a wide variety of sensors, weapons, and control equipment. The large volume, payload, endurance, and potential 51.4 m/s (100 knot) speed capability make the MAV an ideal sea control platform. Missions include surface surveillance (IR, ESM, HF/DF, OTH radar), air surveillance (E-2C capability) including SLBM detection and attack, underwater surveillance and operations, towed arrays, sonobuoys, acoustic decoys, and command and control.

Long Endurance Shore-based (VP) Patrol (503) - The MAV is an ideal vehicle to perform a long endurance VP patrol because of its capability to (1) conduct all surveillance tasks of a standard VP mission, (2) tow listening and other devices, and (3) carry a much larger payload for many times the flight hours of a VP aircraft.

Heavy Lift, Including VCOD, VERTREP Logistics Support (504) - Certain MAV configurations would make ideal onboard delivery systems for large and heavy cargos using their low-speed capability to transfer without landing. The MAV also would be useful in ship-to-ship cargo and personnel transfer operations.

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*Refer to Nomenclature section for definition of terms used in military missions description.

Airborne Command and Control, Including Data Relay, ELF, HF/DF (505) - The MAV ability to conduct long endurance missions at varying altitudes and velocities from hover upwards and to project energy directly into the sea make it an unusually attractive platform to conduct these missions.

Arctic Operations (506) - The MAV is an efficient platform for supplying remote stations and for conducting special operations in areas where there are no supporting facilities available.

NOAA Support (Meteorology, Aerology) (507) - The long endurance and stationkeeping capability of the MAV are the primary characteristics required of a weather station in ocean areas far removed from land.

Minesweeping (508) - Tests have been conducted using small airships to perform this function. Medium-sized MAV configurations are efficient in the techniques and performance required for both mechanical and influence sweeping. Precise navigation is readily achievable. The use of the EDO Corporation sea sled in this mode is effective.

Ocean Escort (509) - The MAV will be a much more effective escort platform than its World War II predecessor, which was considered an ideal vehicle. The large MAV's will be able to conduct long-range passive surveillance, dash-to-datum, localize, identify, and prosecute attacks.

MAV Flight Training (510) - The medium-lift capability MAV's will be suitable flight training platforms for all sizes. The potential for erecting a MAV in the near term from existing ZPG-3W components will provide the necessary lead time to train operational crews prior to the availability of large MAV's.

Demonstration Platform (511) - The ZPG-3W platform in mission code 510 additionally provides a vehicle to test and demonstrate both advanced MAV subsystems and new mission equipment. For example, subsystems include materials, vectored thrust propulsion, BLC, stern propulsion, and water landing gear. New mission equipment includes high-energy lasers, large towed arrays (SURTASS), the EDO Corporation sea sled, and weapons.

U.S. Air Force

Bare Base Transporter (601) - The objective of the Bare Base operation is to emplace quickly a functioning Air Force flight facility into an unprepared area. Use of an MAV with VTOL not requiring self replenishment at the site in delivering large cargo lots - such as the shelters - significantly adds to operational efficiency.

Intratheater Transporter (602) - The airship load-carrying capability makes an attractive comparison with the requirements for an intratheater transporter as defined by the CX-6 VSTOL characteristics.

Remote Station Support Transporter (603) - Resuppling and remanning current and future remote sites such as the DEW, WHITE ALICE, BMEWS type of remote stations are cost effective missions for a MAV not requiring prepared landing sites or self-replenishment.

TOA/DME Station (604) - The use of TOA/DME techniques for ELINT, target location, and possible strike RPV applications is gaining acceptance. The large-payload, long-endurance capabilities of a MAV make it a strong candidate for such a platform.

RPV Carriage/Launch/Control Platform (605) - The large volume and payload weight capability of the MAV provide the most important features required for an air mobile platform to carry and manage significant numbers of both strike and reconnaissance RPV's.

Mobile ICBM Transporter (606) - Goodyear's long experience in the mobile missile field including Mace, MMRBM, and the off-road mobile ICBM programs includes an appreciation of the role of the air platform in interlaunch site missile movement for deception purposes. The spectrum of larger MAV's is an effective candidate for this purpose.

Mobile Missile Launcher (607) - The large payload and long endurance capability of the MAV makes it an ideal platform for the carriage and launch of both tactical and strategic weapons.

U.S. Army

Small Observation/Command and Control (701) - The Army has a continuing need for small aerial vehicles capable of fairly long endurance missions for observation and command and control.

Artillery Movement System (702) - The ability to lift and rapidly reposition heavy artillery is a continuing battlefield requirement. Weapons include 105 and 155 mm guns.

Large Indivisible Payload Lifter (703) - A multiple-mission capability lifting vehicle is required for various combat support roles, including port operations and bridging equipment.

Main Battle Tank/Combat Engineer Vehicle Payload Lifter (704) - A need exists to provide aerial lifter support for such extremely large systems as the main battle tank, combat engineer vehicle, and armor recovery vehicles.

Surveillance Drone (705) - The Army has expressed the need over many years for a lightweight unmanned battlefield surveillance system.

Unmanned Logistics Support System (706) - The ability to rapidly inject supplies into forward battle areas using unmanned VTOL type vehicles will increase the efficiency of the logistic support function.

MAV SYSTEM PERFORMANCE AND OPERATIONAL REQUIREMENTS FOR POTENTIAL MISSIONS

General

The MAV system performance requirements are summarized in Tables 41 through 43. The data includes vehicle performance requirements, requirements relative to the passenger or cargo, and factors relative to its transportation effectiveness. The major performance requirements are associated with its capability for a range of flight speeds, either for takeoff and landing or for fulfilling unique mission requirements such as transferring payloads at low

TABLE 41 - SCHEDULED AND UNSCHEDULED CIVIL PASSENGER AND GENERAL CARGO TRANSPORTATION MISSIONS*

Missions	Vehicle Requirements									
	Performance				Pax/Cargo Requirements			Transport Effectiveness		
	Take-off or Flight	Speed (kts)	Range (NM)	Endurance (Hrs)	Size	Payload Weight (tons)	Environment	Schedule	Inter-faces With	Competes With
Scheduled Passenger										
001 Between city centers	VTOL	5–100	20–50	–	100–150 pax	–	confortable	regular	surface	ground transpo.
002 Between minor airports	VTOL STOL	5–100	50–200	–	30–50 pax	–	comfortable	regular	surface	ground transpo. general aviation
003 Airport Feeder	VTOL	5–100	20–50	–	30–50P	–	comfortable	regular	surface	ground transpo.
Scheduled Cargo										
025 Between city centers	VTOL	5–100	20–50	–	break bulk	5–10	norm A/C	regular	surface	ground transpo.
026 Between shipper/ customer	VTOL	5–100	50–400	–	break bulk	5–10	norm A/C	regular	surface/ none	ground transpo. general aviation
027 Very long range	VTOL/STOL	75–150	3000 – 5000	50–100	break bulk	500–1000	norm A/C	regular	surface	ships–A/C
Unscheduled Passenger										
050 Service to Off-Shore Platforms	VTOL	5–150	50–200	–	30–50 pax	–	comfortable	definite	surface/ none	general aviation (helicopter)
051 Remote Regions	VTOL/STOL	5–150	200–500	–	10–30P	–	comfortable	definite	surface	general aviation
052 Emergency Service	VTOL	5–100	20–50	–	5–10P	–	comfortable	on call	none	general aviation

*1 knot = 0.51389 m/s, 1 nautical mi = 1.853 km, 1 ton = 970.2 kg

TABLE 41 - (CONTINUED)

Missions	Vehicle Requirements									
	Performance				Pax/Cargo Requirements			Transport Effectiveness		
	Take-off or Flight	Speed (kts)	Range (NM)	Endurance (Hrs)	Size	Payload Weight (tons)	Environment	Schedule	Inter-faces With	Competes With
Institutional Passenger										
060 Forrest Service Transpo	VTOL	5-100	20-50	-	10-30P	-	comfortable	definite	none	general aviation
061 Fire Fighting	VTOL	5-100	100-200	-	30P	-	comfortable	on call	none	general aviation
062 Rescue	VTOL	5-150	100 - 200	-	10-30P	-	comfortable	on call	none	general aviation
Unscheduled Cargo										
075 Cargo between plants	VTOL	5-100	50-400	-	break bulk	5-10	norm A/C	definite	none	ground,GA
076 Cargo to Customer	VTOL	5-100	20-400	-	break bulk	5-10	norm A/C	definite	none	ground,GA
077 Very long range	VTOL/STOL	25-150	3000-5000	50 - 100	break bulk	500-1000	norm A/C	definite	surface	ships-A/C

TABLE 42 - UNIQUE MISSIONS AND VEHICLE REQUIREMENTS (HEAVY/OUTSIZE CARGO)

Missions	Vehicle Requirements									
	Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
Heavy Lift-Outsize Transportation	Take Off	Speed KTS	Range N.M.	Endurance HRS	Size	Weight TONS	Environment	Schedule	Inter-faces With	Competes With
COMMERCIAL										
101. Power Generating Equipment	VTOL STOL*	5-50	20-50 50-200	3 6	Out sized	50-500	Med. g	Flexible	Ship or Rail	Special Ground Vehicles (+) Right of Way Costs
102. Large Industrial Equipment	VTOL STOL*	5-50	20-50 50-200	3 6	Out sized	50-250	Med. g	Flexible	Ship or rail	Special Ground Vehicles (+) Right of Way Costs
103. Mining Equipment (Remote Sites)	VTOL STOL*	5-50	200-400 400-600 600-1000	16 24 40	Out sized	50-100	Med. g	Flexible	Ship or rail	Special Ground Vehicles (+) Right of Way Costs
104. Prefabricated Buildings	VTOL	5-50	20-50 50-200	3 6	Out sized	25-100	Low g	Flexible	No other Form	Building at site (+) private truck
105. Large Aerospace Vehicles	STOL	50-100	200-400 400-600 600-1000	8 12 20	Out sized	25-100	Low g	Flexible	No other form	Special Vehicles
INSTITUTIONAL										
106. Coast Guard Aids to Navigation (ATN)	VTOL STOL	50-30	200-400	24	Out sized	300	Low g	Some Flexibility	Ships	Ships, Aircraft
107. Coast Guard Marine and Environmental Protection (MEP)	VTOL	5-30	200-400	24	Out sized	300	Low g	Some Flexibility	Ships	Ships, Aircraft

* Unprepared Fields

Note: 1 knot = 0.51389 m/s, 1 nautical mi = 1.853 m/s, 1 ton = 970.2 kg

TABLE 42 - UNIQUE MISSIONS AND VEHICLE REQUIREMENTS (AGRICULTURAL)

Missions	Vehicle Requirements									
	Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
Agricultural Transportation	Take Off	Speed KTS	Range NM	Endurance HRS	Size	Weight TONS	Environment	Schedule	Inter-faces With	Competes With
COMMERCIAL										
Timber Harvesting (Difficult Terrain) 201.	VTOL VTOL	5-50 5-50	2.5-20 20-50	4 4	May be out sized	5-10 25	Medium & Medium &	Flexible Flexible	Yarder Rail/ Truck	Helicop-ter Private Truck
Chemical/Seeding Applications 202.	VTOL STOL *	5-75 50-75	20-50 50-200	2 4	Bulk	1-2 3-5	Medium &	Based on Cargo	Bulk Truck	Helicop-ter Special Aircraft
Crop Harvesting (Difficult Terrain) 203.	VTOL	5-50	20-50	2	Bulk	1-2	Medium &	Based on Cargo	Truck Rail	Manpower, Special small ATVs
Live Stock (Range/Range/ Feed Lot) 204.	STOL *	50-75	50-200	6	Ani-mals	25-100	Low & Low noise	Based on season	None	Truck plus right of way

* Unprepared Fields

TABLE 42 - UNIQUE MISSIONS AND VEHICLE REQUIREMENTS (PLATFORM)

Missions	Vehicle Requirements									
	Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
Platform	Take Off	Speed KTS	Range MILES	Endurance HOURS	Size	Weight TON	Environment	Schedule	Inter- faces With	Competes With
COMMERCIAL										
301. Pipeline/Electric Line Patrolling	VTOL STOL *	5-75	50-200	4 - 6	Crew Equip	0.5-1	Low g Low noise	Flexible	No other forms	Helicop- ter Ground
302. Aerial Surveying	STOL *	25-100	50-200	4 - 6	Crew Equip	0.5-1	Low g Low noise	Flexible	No other forms	Aircraft Sate- llites
303. Advertising	STOL *	5-50	50-200	4 - 6	Crew Equip	1-2	Low g Low noise	Flexible	No other form	TV, radio, printed matter
304. Sightseeing	STOL *	50-50	50-200	4 - 6	Pass- en- gers 10-30	2-5	Low g Low noise	Flexible	No other form	Other Recrea- tional forms
305. Seismographic Surveys in Water	VTOL S?	5-75	1000-3000	200	Crew Out- size Equip.	20-30	Low g Low noise Life Support	Definite All Weather	No other forms	Special Ships
306. MAV Cruises	STOL	25-75	100-3000	200	100-300 Pass- en- gers	25-75	Low g Low noise Spacious	Definite All Weather	Standard forms	Cruise ships, air tours resort hotels

* Unprepared Fields

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TABLE 42 - (CONTINUED)

Missions	Vehicle Requirements									
	Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
Platform	Take Off	Speed KTS	Range MILES	Endurance HOURS	Size	Weight TON	Environment	Schedule	Inter-faces With	Competes With
INSTITUTIONAL										
307. Police Surveillance	VTOL STOL *	5-75	50-200	6-8	Crew, Equip	1	Low g Low noise	Some Flexi-bility	No other forms	Helicop-ters, STOL air-craft, ground vehicles
308. Border Patrol	VTOL STOL *	5-75	400-600	8-16	Crew, equip	2	Low g Low noise	Some Flexi-bility	No other forms	Helicop-ters, STOL aircraft, ground vehicles
309. Coast Guard Search and Rescue (SAR)	VTOL STOL *	5-150	1000-2000	240-360	Crew Equip	25-50	Low g Low noise Life Support	Definite All Weather	Ships during mission	Ships, ships(+) helicop-ters
310. Coast Guard Enforcement of Laws and Treaties (ELT)	VTOL STOL *	5-150	1000-2000	240-360	Crew Equip	25-50	Low g Low noise Life support	Definite All Weather	Ships during mission	Ships, ships (+) helicop-ters

* Unprepared Fields

TABLE 42 - (CONTINUED)

Missions Platform	Vehicle Requirements: Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
	Take Off	Speed KTS	Range MILES	Endurance HOURS	Size	Weight TON	Environment	Schedule	Interfaces With	Competes With
INSTITUTIONAL (Cont)										
311. Coast Guard Small LTA drone to support SAR missions launched from ships	VTOL	5-35	50-200	2-6	Equip	0.1 0.3	Compatible with equip.	Some Flexibility	Ships, survivors during mission	Ships, ships(+) helicopters
312. Coast Guard Aids to Navigation (ATN)	VTOL STOL	5-200	2000	24	Normal	10	Quiet	Limited Flexibility	Ships	Ships
313. Coast Guard Marine and Environmental Protection (MEP)	VTOL STOL	5-200	2000	24	Normal	10	Quiet	Limited Flexibility	Ships	Ships
314. Air Pollution	STOL * CTOL	5-50	50-200	6-8	Crew, equip	1	Low g Low noise	Some Flexibility	no other forms	Helicopter, STOL aircraft, ground vehicles
315. Water Resource Monitoring	STOL * CTOL	5-50	50-200 200-400	6-8 8-16	Crew equip	1 2	Low g Low noise	Some Flexibility	No other forms	Helicopter. aircraft Satellite
316. Crop Surveillance	STOL* CTOL	25-100	50-200	4-6	Crew equip	0.5-1	Low g Low noise	Some Flexibility	No other forms	Aircraft, Satellite
317. Fish Monitoring	VTOL STOL*	5-50	50-200	6-8	Crew equip	0.5-1	Low g Low noise	Some Flexibility	no other forms	Ships helicopters
318. Hospital-Emergency Disaster Care	VTOL STOL&	5-75	50-200 200-400	6-8 8-16	Patients Crew equip	25	Low g Low noise	On call	ground	ground
*Unprepared Fields										

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TABLE 42 - UNIQUE MISSIONS AND VEHICLE REQUIREMENTS (REMOTE REGIONS)

Missions Transportation of Resources from Remote Regions	Vehicle Requirements									
	Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
	Take Off	Speed KTS	Range MILES	Endurance HOURS	Size	Weight TONS	Environment	Schedule	Interfaces With	Competes With
COMMERCIAL										
401. Ore/Ore Pellets	VTOL STOL *	5-75	200-400	3 - 6	Bulk	20	Not Critical	Some Flexibility	Ships, none	Creating ground systems
402. Petroleum	STOL *	25-75	1000-3000	20 - 60	Bulk	100-500	Not Critical except safety	Some Flexibility	No other forms	Creating ground systems (+) ships
403. Gaseous	STOL *	25-75	3000	20 - 60	Bulk	100 to 500	Not Critical except safety	Some Flexibility	No other forms	Creating ground facilities, (+) ships

* Unprepared Fields

TABLE 43 - MILITARY MISSIONS AND VEHICLE REQUIREMENTS*

Missions	Vehicle Requirements									
	Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
	Take Off or Mission	Speed (kts)	Range (mi)	Endurance (hrs)	Size	Weight (tons)	Environment	Schedule	Inter-faces With	Competes With
U. S. Navy										
501 - Logistics over the shore (LOTS)	VTOL	5-50	20-200	3-6	out-size	100 - 200	Normal	All weather	Ship/Shore	Barges, LASH Aerocranes, Mobile
502 - Sea Control	VTOL	5-150	1000-8000	240-720	crew, equip	500 - 750	low noise life support	All weather	None	Ships, Aircraft
503 - VP Patrol	VTOL	5-150	1000-8000	240-720	crew, equip	500 - 750	low noise life support	All weather	None	Ships, Aircraft
504 - Heavy Lift	VTOL	5-150	1000-8000	120-720	large cargo	500 - 1000	normal life support	All weather	None	Ships
505 - Airborne Command and Control	VTOL	5-75	1000-3000	200	crew equip	5 - 10	Low noise life support	All weather	None	Aircraft
506 - Arctic Support	VTOL	5-150	4000-20,000	100-200	norm + outsize	500 - 2000	normal life support	All weather	None	Aircraft
507 - NOAA Support Weather Station	VTOL	5-75	1000-3000	200	Crew, equip	10-20	Normal life support	All weather	Shore stations Satellites	Ships, Aircraft
508 - Mine Sweeping	VTOL	5-50	400	6 - 16	Out-size	20-30	Normal	Some flexibility	None	Helicopter Ships
509 - Ocean Escort	VTOL	5-150	1000-8000	240 - 720	Crew Out-size equip	500-750	Low noise Life Support	All weather	None	Ships
510 - Flight Training	VTOL	5-100	1000-3000	100	Crew	5-10	Low noise Life Support	All Weather	None	None/Simulators
511 - Demonstration Platform	VTOL	5-100	400	6 - 16	Crew Out-size equip	50-100	Low noise Life Support	All Weather	None	Ships/Aircraft

*1 knot ± 0.51389 m/s, 1 mile = 1.609 km, 1 ton=970.2 kg

TABLE 43 - (CONTINUED)

Missions	Vehicle Requirements									
	Performance				Cargo/Equipment Reqmts			Transport Effectiveness		
	Take Off or Mission	Speed (kts)	Range (mi)	Endurance (hrs)	Size	Weight (tons)	Environment	Schedule	Inter-faces With	Competes With
USAF										
601. Bare Base Trans-porter	VTOL	5-150	1000 8000	120-720	Con-tainer	500 - 1000	Normal Life Support	All Weather	None	Limited Aircraft
602. Intra-Theatre Transport	STOL	50-100	200 1000	8-20	Out-size	25 - 100	Normal	All Weather	Surface	Limited aircraft
603. Remote Station Transporter	VTOL	5-150	4000 20,000	100-200	Out-size Con-tainers	500 - 2000	Normal Life Support	All Weather	None	Limited, large aircraft
604. TOA/DME Station	VTOL	5-75	1000 3000	200	Crew Equip	10 - 20	Low noise Life Support	All Weather	None	Limited, large aircraft
605. RPV Carrier	VTOL	5-150	1000 8000	150-350	Crew RPV's	250 750	Normal Life Support	All Weather	None	none
606. Mobile ICBM Transporter	VTOL	5-75	200 400	4 - 10	Out-size	150 400	Normal	All Weather	None	Special Vehicles
607. Mobile ICBM Launcher	STOL	50 - 100	1000 8000	150-350	Out-size	500 - 750	Low Noise Life Support	All Weather	None	Ground system aircraft
U. S. ARMY										
701. Observation & Command & Control	VTOL	5-150	400-800	8	Crew Equip	0.3 - 0.5	Low Noise	All Weather	None	Aircraft, Balloon
702. Artillery Movement	VTOL	5-150	200-400	2 - 5	Out-size	0.5 - 15	Normal	All Weather	None	Helicopter
703. Large Load Lifter	VTOL	5-150	200 - 400	2 - 5	Out-size	25 - 50	Normal	All Weather	None	None/adv helicopter
704. MBT/CEV Lifter	VTOL	5-150	200 - 400	2 - 5	Out-size	50 - 75	Normal	All Weather	None	None/adv helicopter
705. Surveillance Drone	VTOL	5-150	400 - 800	8	Crew + Equip	0.05 - 1.0	Low Noise	All Weather	None	Aircraft
706. Unmanned Logistic Support	VTOL	5-100	200 - 400	3 - 5	Normal Cargo	0.5 - 2.0	Low Noise	All Weather	None	Air drop None

speeds, inspecting items from the air, and transferring personnel at sea. For many missions, range is an important parameter while for others endurance is the most important parameter.

The user of a system has many requirements, and three were selected and listed under pax/cargo requirements. The size refers to either maximum passenger or cargo weight capacities. Passenger size values were estimated considering the published results of many studies covering different types of aircraft (RTOL, STOL, and VTOL) and different advanced ground systems. The vehicle sizes tend to be the minimum size consistent with desired operating costs and the maximum size consistent with still being able to supply the desired frequency of service for the passenger. The cargo weights follow the same general philosophy. The environment for the passenger or cargo is important to attract customers. Passengers prefer a comfortable and safe trip. Their acceptance of the environments associated with present forms of transportation can be a guide to their acceptance of the environment for new forms of travel. The term "comfortable" implies an environment somewhere between riding in an automobile and riding in present jet CTOL aircraft at cruise altitude.

The third category is transportation effectiveness and includes schedule frequency and reliability, what additional transportation modes the passenger or cargo interfaces with to use the MAV system, and what transportation modes it would be competing with. The term "schedule" denotes whether it is a regular carrier or an unscheduled carrier. Adequate frequency and availability is implied for regular carriers. The heading "interfaces with" includes both the loading and unloading functions. For instance, surface transportation (private automobile, taxi, rail, or bus) normally will be used to interface with MAV passenger terminals of a regular carrier, while the transportation of workers to and from an off-shore platform will have transportation interfaces on only one leg. Vehicles carrying large indivisible loads will have no other transportation interfaces when the mission is from a factory to a site. The heading "competes with" implies the user has other choices that may not be as desirable because of availability, comfort, speed, safety, or cost.

Scheduled and Unscheduled Civil Passenger and General Cargo Transportation Missions

The scheduled and unscheduled civil passenger and general cargo transportation missions are listed in Table 41. The missions are listed in numerical order, using the code numbers and mission categories for potential missions.

Unique Missions

These missions are given in Table 42 and include transporting heavy/outsize cargo (100 series), agricultural transportation missions (200 series), platform missions (300 series), and transportation missions from remote regions (400) series).

The heavy/outsize cargo missions (100 series) require MAV's with VTOL capabilities for most of the missions and STOL capabilities using unprepared surfaces for the others. Speed of transport can be low compared with other air systems, because the distances normally are relatively short, and the potentially competitive conventional forms require long periods of time to construct a right-of-way for surface movement of these items. Endurances are associated with the cruise speed, ranges, and cargo transfer times. The cargo is outsized and overweight for conventional ground systems. Cargo environmental requirements during transport can be easily met by MAV designs. The transportation effectiveness should be high using unscheduled carriers; interfacing with ships, rail, or no other transportation mode (directly with the factory); and competing with right-of-way costs and special ground vehicles for essentially one-time shipments.

The agricultural transportation missions (200 series) require MAV's with VTOL capabilities from unprepared surfaces to operate in the difficult terrain usually associated with such missions. Speed, range, and endurance requirements are moderate. The cargo requirements are moderate except for the possible size of the timber and the low noise requirements for transferring cattle. The transportation effectiveness should be high because the MAV's will be private or chartered for availability, and the transportation interfaces with special ground equipment or ground vehicles with limited right-of-way. Potential competition consists of rotary wing vehicles, special fixed wing vehicles, and special all-terrain vehicles and trucks.

A large number of missions are listed under platform missions (300 series). These missions require VTOL or STOL capabilities from unprepared surfaces. Endurance is the important parameter for these missions, with the larger vehicles being airborne for up to 360 hours. The speed requirements are less than 51.34 m/s (100 knots) except for the Coast Guard missions, which require higher speeds in emergencies. Range requirements can be met with low cruise speeds for the required endurance. The platform missions require sufficient room for the crew members, special oversized equipment for many missions, and a room-type environment for crew efficiency on most missions. Most of the vehicles would be chartered or owned by the user for ready availability, will interface with no other transportation forms, and may have some limited competition from rotary wing aircraft, special ships, or combinations of these.

Transportation of resources from remote regions (400 series) requires specific market sizes or other constraints for viability. VTOL or STOL capabilities from unprepared surfaces are required for these unique markets. Speeds and range are associated with bulk-commodity low-transportation costs. Private or unscheduled carriers can provide the availability required for this mission. The MAV's will interface with no other forms of transportation except for one terminal of the first mission that connects with a ship. The competition to MAV's for these missions requires a right-of-way for other systems, creating a right-of-way without disturbing the present natural environment, or creating a large cost processing plant to liquefy gas and creating special ships for transporting the liquified gas.

Military Missions

These missions are given in Table 43 and include U.S. Navy missions (500 series), U.S. Air Force missions (600 series), and U.S. Army missions (700 series).

The U.S. Navy missions include heavy lift/outsize cargo missions, short and long haul; platform missions for patrol, sea control, command and control, escort, and mine sweeping; flight training missions; and as a platform to test and demonstrate new equipment.

Many of the Navy missions would use the MAV as part of a total weapon system. Coordination with other weapons systems consisting of several (different) vehicles such as aircraft and ships may be required. The MAV's competitive advantage should increase with the requirements for large payloads, long endurance, and/or long range while providing the required crew environment.

The U.S. Air Force missions (600 series) include VTOL and STOL heavy lift/outsize cargo, transportation, and platform missions. The heavy lift/outsize cargo missions include large missiles and outsize cargo. The platform missions include carrying RPV's or ICBM missiles for long periods (150 to 350 hours). These missions have more stringent requirements for a low noise and spacious crew member and equipment stations. Competition by other forms is limited, considering the VTOL or STOL capabilities.

The U.S. Army missions (700 series) include heavy lift/outsize cargo, normal cargo, and platform missions using small MAV's. Low noise is a stringent requirement for many of the missions. All-weather capabilities are required for all missions. No interfaces with other transportation systems generally are anticipated for these missions, because they are associated with field use. The competition to the MAV's for these missions ranges from none for heavy lift to balloons, helicopters, or airdrop for the other missions.

EVALUATION OF MAV'S FOR POTENTIAL MISSIONS AND SELECTED MISSION PECULIAR FIGURES OF MERIT

General

These missions were selected taking into account the effect of modern technology on increasing past LTA capabilities relative to size, payload percentages, speed, and improved low-speed control for improved ground handling as well as aerodynamic or propulsive lift for additional capabilities such as payload, buoyancy management, and ground handling. Mission selections and evaluation criteria are based on factors associated with past systems, present competing systems, and technological forecasts. Past capabilities of airships also were considered: VTOL-type qualities, low power requirements, long endurance, low fuel consumption for low-flight velocities with buoyant configurations, and low-altitude operations for maximum payloads. The past commercial missions were basically VTOL-type operations; the vehicles flew at low speeds compared with present aircraft to provide ranges beyond the capabilities of aircraft of that day and even beyond present aircraft capabilities. They also flew at low altitudes for maximum payloads. The military airship proved most worthwhile in detached scouting and surveillance. The function remains today as one of the most attractive uses for large airships. The ability of the Akron and Macon to carry and operate aircraft became a significant element of their military worth. With the emphasis today shifting toward relatively inexpensive remotely piloted vehicles for many aircraft operations, the large airship becomes attractive as a RPV carrier.

The evaluation criteria selected for the civil missions are based on the criteria for present systems and assume that MAV's are possible with desired performance capabilities. The evaluation criteria for the military missions are focused on the military worth of the various candidates in light of the known operational requirements and deficiencies of existing systems. The latter factor is most important and receives the heaviest weighting. Performance qualities were evaluated in quantative terms by the parametric performance analysis (Reference 10).

MAV's for potential missions and mission peculiar figures of merit were evaluated relative to the interests of the different groups associated with a transportation system; that is, the operator, the user, the local community, and the nation as a whole (see Tables 44, 45, and 46).

Operators normally must be able to forecast a sufficient market with a sufficient competitive advantage to risk the large capital investment associated with a competitive-size transportation system. They are concerned with the investment cost associated with right-of-way costs, vehicle investment cost (including amortization and maintenance), and the operating cost associated with its use (including labor, materials consumed, and administration). The right-of-way cost is a sunk cost, and a large right-of-way cost normally requires large rates of utilization of the system for long periods time to recover the costs. The operator's other costs impose less risk because a portion of the vehicles normally can be used elsewhere or sold, if the market doesn't develop as planned, and the use costs are related to operating levels.

The user is interested in the availability and amount of service (locations, frequency, and whether it includes door-to-door provisions), the speed (block or door-to-door), the cost (¢/PM or ¢/TM for transportation missions), reliability of schedule, comfort, safety, and any restrictions (size, weight, type of cargo). The users will trade off these elements with their needs and determine which one of the many conventional or unique systems is most acceptable.

The community consists of the people located near a transportation system and affected by the system. The community interests include the income associated with creating the system, income for maintaining and operating the system, secondary new business resulting from the system, the change in land use (taxes, housing, industry), and the change in the environment (noise and air quality).

National interests in a conventional or unique system are broad and include the system's effect on energy consumption, gross national product, balance of international payments, subsidy requirements, national prestige, and security.

TABLE 44 - SCHEDULED AND UNSCHEDULED POTENTIAL CIVIL PASSENGER AND GENERAL CARGO MISSIONS AND SELECTED MISSION PECULIAR FIGURES OF MERIT

Missions	Operator: Minimizes Sunk Investment Dollars	Operator: Competetive Advantage	User: Availability	User: Minimizes Door-to-Door Time	User: Minimizes Cost	User: Passenger Comfort	User: Lack of Cargo Restrictions	Community: Minimizes Impact on Environment	Community: Minimizes Change in Land Use	Community: Attracts Business	National: Energy Efficiency	National: Security	National: GNP	National: BP	National: Minimizes Subsidy Requirements	Total	Mission Peculiar Figures of Merit
	← 30 →		←	40			→	←	20	→	←		10		→		
Scheduled Passengers																	
001 Between City Centers	20	5*	8	16	2*	12	–	10	6	2*	1*	–	2*	–	2*	86	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
002 Between Minor Airports	20	5*	16	6*	4*	4	–	4	6	5*	1*	–	4	–	2*	77	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
003 Airport Feeder	10	20	12	16	4*	4	–	10	6	2*	1*	–	2*	–	4	91	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate ◁**
Scheduled Cargo																	
025 Between City Centers	20	5*	12	16	4*	–	4	10	6	2*	1*	–	2*	–	2*	84	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
026 Shipper/Customer	10	20	12	16	4*	–	4	10	6	2*	1*	–	2*	–	4	91	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate ◁
027 Very Long Range	10*	5*	12	4*	2*	–	16	10	6	2*	1*	–	2*	1*	1*	72	$V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
Unscheduled Passenger																	
050 Off-Shore Platforms	20	10	16	6*	4*	4	–	8	12	–	1*	–	1*	2*	2	86	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
051 Remote Regions	20	10	16	6*	4*	4	–	4	10	6	2*	–	2*	–	2	86	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
052 Emergency Service	20	5*	16	6*	2*	8	–	8	12	–	3*	–	–	–	2*	82	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
Institutional Passenger																	
060 Forest Service	20	10	12	16	4	8	–	10	10	–	1*	–	2*	–	4	97	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate ◀
061 Fire Fighting	20	10	12	16	4	8	–	10	10	–	1*	–	2*	–	4	97	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate ◀
062 Rescue	20	10	12	8*	4*	8	–	10	10	–	2*	–	–	–	7	91	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate ◁
Unscheduled Cargo																	
075 Cargo Between Plants	20	10	12	16	4*	–	4	10	6	2*	1*	–	2*	–	4	91	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate ◁
076 Cargo to Customer	10	20	12	16	4*	–	4	10	6	4	1*	–	2*	–	4	93	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate ◁
077 Very Long Range	10*	5*	12	4*	2*	–	16	10	6	2	1*	–	2*	1*	1*	72	$V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate

*1/2 of maximum value

**See text for definition of ranking methodology

TABLE 45 - MAV'S FOR POTENTIAL UNIQUE MISSIONS AND SELECTED MISSION PECULIAR FIGURES OF MERIT (HEAVY LIFT/OUTSIZE, AGRICULTURAL, AND PLATFORM)

Missions	Operator: Minimizes Sunk Investment Dollars	Operator: Competetive Advantage	User: Availability	User: Minimizes Door-to-Door Time	User: Minimizes Cost	User: Passenger Comfort	User: Lack of Cargo Restrictions	Community: Minimizes Impact on Environment	Community: Minimizes Change in Land Use	Community: Attracts Business	National: Energy Efficiency	National: Security	National: GNP	National: BP	National: Minimizes Subsidy Requirements	Total	Mission Peculiar Figures of Merit	
HEAVY LIFT - OUTSIZE																		
Commercial	30		40					20			10							
101. Power generating equipment	10	20	8	4	12	-	16	6	10	4	2	-	5	-	3	100	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate	◀
102. Large industrial equipment	10	20	8	4	12	-	16	6	10	4	2	-	5	-	3	100	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate	◀
10?. Mining equipment - remote	10	20	8	4	12	-	16	4	6	10	2	-	5	-	3	100	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate	◀
104. Prefabricated buildings	20	5*	8	2*	6*	-	16	6	10	4	2*	-	2*	-	1*	82	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate	
105. Large aerospace vehicles	10	10*	12	8	2*	-	16	7	13	-	3*	-	-	-	2*	83	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate	
Institutional	10		40					20			30							
106. Coast Guard aids to navigation	6	4	8	12	2*	-	16	7	13	-	10	20	-	-	-	98	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate	◀
107. Coast Guard MEP	6	4	8	12	2*	-	16	7	13	-	10	20	-	-	-	98	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate	◀
AGRICULTURAL TRANSPORTATION																		
Commercial	30		40					20			10							
201. Timber harvesting	20	5*	16	12	4*	-	4	4	6	10	2	-	5	-	1*	89	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate	
202. Chemical seeding	10	10*	12	4*	8*	-	4	6	10	2*	2*	-	5	-	1*	74	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate	
203. Crop harvesting, remote	20	5*	16	8	6*	-	4	4	6	10	2*	-	5	-	1*	87	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate	
204. Livestock Transfer	10	10*	12	4	4*	-	16	6	10	2*	2*	-	5	-	1*	82	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate	
PLATFORM MISSIONS	30		40					20			10							
Commercial																		
301. Pipeline/Powerline patrol	10	20	12	4	8	16	-	12	8	-	2	-	2*	-	4	98	VTOL, $V_C \cdot P_L$	◀
302. Aerial survey	10	10*	8	2*	6*	16	-	12	8	-	1*	-	2*	-	2*	77	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate	
303. Advertising	10	20	10	-	5*	-	20	9	7	4	4	-	2*	-	2	93	STOL, P_L/Fuel Rate	◁
304. Sightseeing	10	20	10	-	5*	20	-	4	6	5*	6	-	-	-	4	90	STOL, P_L/Fuel Rate	◁
305. Seismographic Surveys	10	20	8	-	4	12	16	8	12	-	1	-	4	3	2	100	VTOL, P_L/Fuel Rate	◀
306. MAV Cruise	10	20	12	2*	4*	16	-	4	6	5*	2*	-	-	2*	2	85	STOL, $V_C \cdot P_L$/Fuel Rate	

*1/2 of maximum value.

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TABLE 45 - (CONTINUED)

Missions	Operator: Minimizes Sunk Investment Dollars	Operator: Competetive Advantage	User: Availability	User: Minimizes Door-to-Door Time	User: Minimizes Cost	User: Passenger Comfort	User: Lack of Cargo Restrictions	Community: Minimizes Impact on Environment	Community: Minimizes Change in Land Use	Community: Attracts Business	National: Energy Efficiency	National: Security	National: GNP	National: BP	National: Minimizes Subsidy Requirements	Total	Mission Peculiar Figures of Merit
PLATFORM MISSIONS (Continued)																	
<u>Institutional</u>	← 10 →		← 40 →					← 20 →			← 30 →						
307. Police Surveillance	6	4	12	4*	4	16	–	12	8	–	10	20	–	–	–	96	VTOL, P_L/Fuel Rate
308. Border Patrol	6	4	12	4*	4	16	–	12	8	–	10	20	–	–	–	96	VTOL, P_L/Fuel Rate
309. Coast Guard (SAR)	6	4	4	2*	4	16	12	8	12	–	10	20	–	–	–	98	VTOL, P_L/Fuel Rate
310. Coast Guard (ELT)	6	4	4	2*	4	16	12	8	12	–	5	15	5	5	–	98	VTOL, P_L/Fuel Rate
311. Coast Guard Drone (SAR)	6	4	24	4	12	–	–	12	8	–	10	20	–	–	–	100	VTOL, P_L/Fuel Rate
312. Coast Guard (ATN)	6	4	8	6*	2*	16	–	8	12	–	10	20	–	–	–	92	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
313. Coast Guard (MPE)	6	4	8	6*	2*	16	–	8	12	–	10	20	–	–	–	92	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
314. Air Pollution	4	6	12	4	4*	16	–	12	8	–	30	–	–	–	–	96	VTOL, P_L/Fuel Rate
315. Water Resources	4	3*	12	4	4*	16	–	12	8	–	30	–	–	–	–	93	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
316. Crop Surveillance	4	3*	12	4*	2*	16	–	12	8	–	8*	–	5	10	–	84	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
317. Fish Monitoring	4	6	12	4	4*	16	–	12	8	–	15	–	5	10	–	96	VTOL, $V_C \cdot P_L$/Fuel Rate, P_L/Fuel Rate
318. Hospital-Disaster	6	2*	12	8	2*	2	2	8	12	–	15*	–	–	–	–	81	VTOL, $V_C \cdot P_L$/Fuel Rate
TRANSPORTATION - REMOTE REGIONS																	
<u>Commercial</u>	← 30 →		← 40 →					← 20 →			← 30 →						
401. Ore/Ore Pellets	10	20	12	8	16	–	4	4	10	6	1*	–	2	4	2	99	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
402. Petroleum	20	5*	4	12	4*	–	16	4	10	6	1*	–	2	4	1*	89	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
403. Gaseous	20	5*	4	12	4*	–	16	4	10	3*	1*	–	2	4	1*	86	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate

*1/2 of maximum value.

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TABLE 46 - MAV'S FOR POTENTIAL MILITARY MISSIONS AND SELECTED MISSION PECULIAR FIGURES OF MERIT (ARMED SERVICES)

Code	Missions	Operational Factors (60)						Economic Factors (30)							Institutional Factors (10)			Total	Mission Peculiar Figures of Merit
		Fills Major Operational Deficiency	Improves existing capability-endurance	Improves existing capability-stability	Improves existing capability - low/hover speed	Provides unusual mission combinations	Provides airborne replenishment/ remanning	Comparatively low operating costs	Draws on other funded technologies	Lowers platform maintenance costs	Requires fewer personnel	Lower training costs	Comparative acquisition cost	Fits Lo side of Hi-Lo Mix	Energy Efficiency	Minimizes impact on environment	Reduces defense expenditures significantly		
	MAXIMUM RATINGS	15	10	5	10	10	10	5	5	5	5	←	10	→	5	3	2		
501	LOTS	15	10	5	5	5		5	5	5	5	5	5		5	3		78	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
502	Sea Control	15	10	5	5	10	10	5	5	5	5		5	5	5	3	2	95	VTOL, $V_C \cdot P_L$/Fuel Rate, P_L/Fuel Rate
503	VP Patrol		10	5	5	10	10	5	5	5	5		5	5	5	3	2	80	VTOL, P_L/Fuel Rate
504	Heavy Lift	15		5	5	5			5			5	5					45	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate
505	Airborne C/C		10				10	5	5	5	5	5		5	5	3		58	VTOL, P_L/Fuel Rate
506	Arctic Operations	15	10	5	5	10	10	5	5	5	5		5		5	3		73	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
507	NOAA Support		10				10	5	5	5	5		5		5	3		53	VTOL, P_L/Fuel Rate
508	Minesweeping		10	5	10	10	10	5	5	5	5	5		5	5			80	VTOL, $V_C \cdot P_L$/Fuel Rate
509	Ocean Escort		10	5	5	10	10	5	5	5	5		5	5	5	3	2	80	VTOL, P_L/Fuel Rate
510	Flight Training	15	10		10	10		5	5	5	5	5	5		5	3		83	VTOL, P_L/Fuel Rate
511	Demonstration Platform	15	10	5	10	10		5	5	5	5	5	5		5	3		88	VTOL, P_L/Fuel Rate
601	Bare Base Transport.		10		10		10	5	5	5	5	5			5	3		63	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
602	Intra Theatre Trans.		10		10	10	10	5	5	5	5	5			5	3		73	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
603	Remote Station Trans.	15	10		5		10	5	5	5	5		5		5	3		73	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
604	TOA/DME Station		10	5	10		10	5	5	5	5		5		5	3		68	VTOL, P_L/Fuel Rate
605	RPV Carrier	15	10	5		10	10	5	5	5	5		5		5	3		83	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
606	Mobile ICBM Trans.		10	5	10		10	5	5	5	5				5	3		63	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
607	Mobile ICBM Launcher		10	5	10		10	5	5	5					5	3		58	STOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate

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TABLE 46 - (CONTINUED)

Code	Missions	Operational Factors (60): Fills Major Operational Deficiency	Operational Factors (60): Improves existing capability-endurance	Operational Factors (60): Improves existing capability-stability	Operational Factors (60): Improves existing capability - low/hover speed	Operational Factors (60): Provides unusual mission combinations	Operational Factors (60): Provides airborne replenishment/ remanning	Economic Factors (30): Comparatively low operating costs	Economic Factors (30): Draws on other funded technologies	Economic Factors (30): Lowers platform maintenance costs	Economic Factors (30): Requires fewer personnel	Economic Factors (30): Lower training costs	Economic Factors (30): Comparative acquisition cost	Economic Factors (30): Fits Lo side of Hi-Lo Mix	Institutional Factors (10): Energy Efficiency	Institutional Factors (10): Minimizes impact on environment	Institutional Factors (10): Reduces defense expenditures significantly	Total	Mission Peculiar Figures of Merit
701	Observation, C/C		10	5	10		10	5	5	5	5				5	3		63	VTOL, P_L/Fuel Rate
702	Artillery Mover		10	5		5		5	5	5	5				5	3		48	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate
703.	Large Load Lifter	15	10	5	5	5		5	5	5	5	5	5		5	3		78	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate
704	MBT/CEV Lifter	15	10	5	5	10		5	5	5	5	5	5		5	3		83	VTOL, P_L, $V_C \cdot P_L$/Fuel Rate
705	Surveillance Drone	15	10	5	10	10		5	5	5			5	5	5	3		83	VTOL, P_L/Fuel Rate
706	Unmanned Log	15	10	5	10			5	5	5			5	5	5	3		73	VTOL, $V_C \cdot P_L$, $V_C \cdot P_L$/Fuel Rate

The columns in Tables 44, 45, and 46 contain estimates of how pertinent groups might weigh the various mission attributes. Mission peculiar quantitative figures of merit also are presented where applicable. The mission attributes are labeled so that a high or a medium rating is possible. From an investor's standpoint, a system receives the highest rating if it (1) minimizes sunk investment costs and (2) has a competitive advantage over conventional transportation modes. From a user's standpoint, a system provides (1) VTOL capability for availability, (2) is faster than its competition, (3) costs less to use than its competition, (4) is more comfortable, and (5) has less restrictions (size or weight) than its conventional mode competition. From a community standpoint, a system receives the highest rating if it (1) has the least effect on the environment or present land use and (2) attracts new business or provides new jobs. From a national standpoint, a system receives the highest rating if it has high energy efficiency compared with its conventional competition, (2) provides more security, (3) increases the gross national product or improves the balance of payments, and (4) minimizes subsidy requirements.

The missions were evaluated in two independent steps. First, all items in the tables were rated for each mission as high, medium, or not applicable. Second, a numerical weighing approach was created for the different groups and the items within each group. A value of 100 was divided between the four different groups (operator, user, community, and national). For commercial missions, the distribution was operator 30 points, user 40 points, community 20 points, and national 10 points. The distribution of points was changed for institutional and military missions. The points assigned to the four groups were further distributed within the applicable items listed under each group for each mission.

These two independent evaluations were combined by assigning the full point value for each item to items with high ratings and one-half the full point value to items with medium ratings. Tables 44, 45, and 46 are the result of this combination. The point values marked with an asterisk are items that received a medium rating and reflect one-half of the point weighing for that item.

The total points as a result of the evaluation are summed in the last column. Point values of 95 and greater have solid flags; values of 90 and greater have open flags.

The mission peculiar figures of merit are mission dependent and include:

1. VTOL or STOL capability from unimproved or improved surfaces
2. $V_C P_L$ is cruise velocity times payload, which relates to productivity (ton-miles per hour or passenger miles per hour)
3. $V_C P_L$/fuel rate, which relates to the amount of fuel required to transport items a given distance (ton-miles per pound of fuel or passenger miles per pound of fuel)
4. P_L relates to absolute payload capability (pounds)
5. P_L/fuel rate is the ratio of the amount of payload airborne to the amount of fuel required for given time periods (payload pounds per pound of fuel).

Potential Conventional Passenger and Cargo Missions

This market consists of the scheduled/unscheduled passenger carriers and regulated/unregulated cargo carriers. The results of the preliminary evaluation are presented in Table 44.

High ratings are given to systems with VTOL capability for they minimize the operator's sunk cost. High ratings are also given under competitive advantage when time is important and the only apparent competition is the high-cost helicopter or a high sunk cost ground system. When the competition is trucks, the rating is tentatively M (depending on the results of future time/costs tradeoffs). Ratings under the user are high for availability because of VTOL capability, high for speed when the competition is ground, M when the competition is the helicopter, and M when aircraft with transfers are involved. Ratings for minimizing cost are M when comparing with ground systems and general aviation.

Comfort for passengers and lack of restrictions for cargo are rated high because of the lower power requirements and the larger size and spaciousness of MAV's than competitive VTOL systems. The ratings from the standpoint of the community are high because the VTOL systems will have the least effect on the present environment and present land use. Ratings for attracting business or providing jobs are dependent on the system's functions and its comparison with other systems and whether the system potentially provides unique services. From a national standpoint, energy efficiency was compared with possible competing forms (surface and air) and possible energy required to create the ground systems; that is, to remote regions. Several of these systems contribute to national security and many to the gross national product; that is, missions to support off-shore platforms and to open up remote areas. Many of the missions received high ratings for minimizing subsidy payments because large system right-of-way sums for sunk investment costs are not required, MAV's have a competitive advantage, or the missions fall into the general aviation category.

Only three mission peculiar figures are required to cover these conventional missions; that is, capability of vehicle (VTOL or STOL), a productivity index ($V_C P_L$), and a fuel efficiency index, $(V_C P_L)$/fuel rate.

Potential Unique Missions and Selected Mission Peculiar Figures of Merit

Heavy Lift/Outsize Cargo

These missions are listed under commercial and institutional missions in Table 45. High ratings generally occur because of an MAV's VTOL/STOL capability and its greater payload/size capabilities than other VTOL, aircraft, or even ground systems for most missions. Energy efficiency is rated high because of the comparative energy required to create special ground systems right-of-way for moving these large items. For the two coast guard missions, the fuel use of a large ship was compared with the fuel use of MAV's for these short missions.

Agricultural Transportation

These missions basically are to regions of difficult terrain or where improved landing areas are not available. High ratings are given from the operator's standpoint for low sunk cost and for the MAV's VTOL or STOL capability. The competitive advantage over helicopters or special general aviation aircraft are tentatively listed as medium. High user ratings reflect the capabilities for door-to-door service. The costs relative to special air or ground vehicles are tentatively listed as medium. Community ratings are mostly high because the system has little impact on the environment, preserves the land for agricultural use, and attracts or increases agricultural business or output. From a national standpoint, the MAV's are energy efficient because they save energy compared with single-purpose ground systems. Improving agricultural output should improve the gross national product, and the systems have high ratings. The mission peculiar figures include vehicle capability (VTOL or STOL for unimproved surfaces), productivity ($V_C P_L$), and fuel efficiency in terms of transporting items between points ($V_C P_L$/fuel rate).

Platform Missions

These civil missions include commercial and institutional missions that require airborne platforms for crews and special equipment, as contrasted to the prior transportation-type missions. The commercial missions receive medium or high ratings from an operator's standpoint based on the VTOL/STOL capabilities and low sunk investment portions for the MAV systems and the limited competition provided by present VTOL vehicles. Ratings from a user standpoint also are medium or high because of the vehicle's VTOL capabilities, the potentially lower costs for operating MAV's for these missions than for present VTOL vehicles, comfort for the crew (much lower noise and vibration levels), and the alleviation of size constraints for special equipment.

High ratings are indicated from a community standpoint for minimum environmental impact and preserving present land use; medium or high ratings are indicated for attracting business.

National considerations are rated for energy efficiency, effect on gross national product, balance of payments, and subsidy requirements. Energy efficiency ratings are medium or high and are based on the energy use of competitive modes. There is some effect on GNP and balance of payments for some missions that find new resources. High ratings for not requiring subsidy are also indicated for these missions.

The mission peculiar figures of merit include vehicle capability (VTOL and STOL), an energy index for suspending the crew and equipment for time periods (P_L/fuel rate), $V_C P_L$ for portions of some missions, and $V_C P_L$/fuel rate for portions of some missions.

The institutional platform missions are rated under the same column headings as the commercial missions for convenience and completeness since the operator and the user usually are the same person. High ratings from operator and user standpoints are common because of the vehicle VTOL capability, its relatively low sunk costs, its competitive advantage over other VTOL vehicles, its relative comfort (low noise and low vibration), and lack of restrictions for large equipment. Ratings less than high are indicated for some missions when the competitive forms include ships or fixed wing aircraft. The community considerations are mostly related to the impact on the environment and present land use. High ratings are indicated because of the low power requirements of MAV's for these missions and the relatively small new land use requirements. From a national standpoint, the energy efficiency is high compared to competitive systems, security is rated high for the relevant missions, and GNP and balance of payments are rated as high for a few relevant missions.

The mission peculiar figures of merit for platform missions include vehicle capability (VTOL and STOL), an energy index for suspending the crew and equipment for extended time periods (P_L/fuel rate), and $V_C P_L$/fuel rate for portions of some missions.

Transportation to Remote Areas

These missions are commercial transportation missions that fulfill some unique requirements, such as economic, environmental, or balance of payments. The ratings from an operator's standpoint in terms of sunk cost are high, and the competitive advantage ratings are tentatively medium or high because of the favorable operating cost ratios relative to the competitive forms that they could replace. From a user's standpoint, the ratings are high except for transportation cost for the last two missions, which must be offset by reductions in the user's own fixed costs. The ratings from the community standpoint are high for minimizing impact on the prior environment or present land use and for attracting local business for all but the last mission which avoids local investment for liquefication plants.

Ratings from a national standpoint are relative to the GNP and the balance of payments. High ratings are indicated as new resources become available with the use of these MAV systems.

The mission peculiar figures of merit for remote area missions include: system capability (VTOL/STOL), a relative index of productivity ($V_C P_L$), and a relative index of fuel use efficiency ($V_C P_L$/fuel rate).

Potential Military Missions and Selected Military Mission Peculiar Figures of Merit

A substantially different array of factors was used to analyze the military mission potential of MAV's. The evaluation factors and results are presented in Table 46.

Operational factors comprise 60 percent of the total factor worth. These factors relate specifically to those special features of MAV's that would enhance the operational effectiveness of each service or that fills an obvious operational deficiency - the most militarily worthwhile criteria.

Those systems exhibiting this capability are noted in Table 46. The sea control concept appears to be an ideal mission for an ultra-large MAV with great endurance. A vehicle of that class also would find use in remote area transportation, such as the Arctic, or to emplace Bare Bases in unprepared areas; and to serve as a carriage, launch, and control platform for many kinds and quantities of RPV's. The military need for heavy-lift capability much greater than the HLH specification has been repeatedly expressed. A critical deficiency in the planning for and development of MAV capability is the lack of a platform for technology proof and demonstration and flight training. Resurrection of a ZPG-3W from existing components is a near-term possibility.

Small unmanned MAV's would be practical, cost effective answers to the needs for small quiet surveillance drones and unmanned logistics support capability for detached ground troops.

The MAV's exceptional endurance capability is of considerable importance for most missions. Other improvements inherent in MAV's such as motion stability and the ability to hover economically add varying degrees of interest to particular missions. Because of the large lift available in some categories of MAV, a multiple-mission potential is available not found in other platforms. Combining the long endurance and hover capability brings out the need for and performance required to reman and replenish, without large fixed base support, a singular potential for a MAV.

Economically, the MAV can prove to be relatively inexpensive to operate and maintain including training for the flight crews but not mission equipment operators. Total personnel required to operate and support the MAV systems should be less than their primary operational competitors, particularly surface ships.

As noted in the historical overview, MAV acquisition costs compare favorably with competing systems except where those systems have been built and operating.

Institutional factors include an estimate of a particular MAV falling within the LO segment of the HI-LO weapons mix philosophy. For instance, a mission capable force consisting of more expensive platforms (HI) with higher performance in certain categories such as speed supplemented by less expensive MAV's (LO) with more endurance and special sensor capability would be sensible combinations.

Compared with other methods of accomplishing these missions, all MAV's are considerably less demanding on the petroleum-based fuel reserves.

Where noise and effluents are important, the MAV's have a decided advantage. The more critical missions that will demand the more expensive equipment could have significant impact on the defense budget. In most cases, the cost of acquisition and ownership of competitive MAV's is a decided plus.

POTENTIAL MISSIONS BY VEHICLE SIZES AND TYPES

General

The potential missions were investigated for commonality of vehicle requirements to determine which vehicle sizes and types have the most potential for further investigation. Six gross lift ranges were selected to categorize vehicle requirements for all civil missions (commercial plus institutional) and for all military missions (see Tables 47 and 48, respectively). The smallest MAV class has a total lift capability (static plus aerodynamic plus propulsion) of 4536 kg (10,000 lb) or less.

Civil Missions

All civil missions requiring the smallest size vehicles are unique; they will be conducted by other than scheduled or regulated carriers (see Table 47). Some of the missions are short-range transportation missions; however, the majority are platform missions where endurance is the important performance parameter. Other important performance parameters are the speed and range capability of the vehicle for its availability at many small landing regions and for performing specific mission requirements. From a user standpoint, low noise is a very important factor for mission efficiency.

The gross lift range of the next smallest vehicle size is between 4536 kg and 22,680 kg (10,000 and 50,000 lb). Vehicles of this size can perform almost

TABLE 47 - POTENTIAL CIVIL MISSIONS
(COMMERCIAL AND INSTITUTIONAL)

Vehicle Size	Civil Missions (000, 100, 200, 300, 400's)	Reference Number	Speed* (kts)	Range (mi)	Endurance Hours	Payload Size	Payload Weight (tons)	Flag
Smallest MAV (Total Lift 10,000 lbs)	Agricultural Applications							
	Timber harvesting	201a	5-50	2.5-20	4	Normal	5	
	Chemical/seeding applications	202	5-75	20-50	2	Bulk	1-2	
	Crop harvesting transport	203	5-50	20-50	2	Bulk	2	
	Platform Applications							
	Patrolling pipe/electrical lines	301	5-75	50-200	4-6	Crew & Equip	0.5-1.0	◀ **
	Aerial surveying	302	25-100	50-200	4-6	Crew & Equip		
	Advertising	303	5-50	50-200	4-6	Crew & Equip	1-2	◁
	Sightseeing	304	5-50	50-200	4-6	Passengers	2-5	◁
	Police surveillance	307	5-75	50-200	6-8	Crew & Equip	1	◀
	Border Patrol	308	5-75	400-600	8-16	Crew & Equip	2	◀
	Small drone	311	5-35	50-200	2-6	Equipment	0.1-0.3	◀
	Air pollution monitoring	312	5-50	50-200	6-8	Crew & Equip	1	◀
	Water resources monitoring	313	5-50	50-200	6-8	Crew & Equip	1	◁
	Crop surveillance	314	25-100	50-200	4-6	Crew & Equip	0.5-1	
	Fish monitoring	315	5-50	50-200	6-8	Crew & Equip	0.5-1	◀
Small MAV (Total lift 10,000 - 50,000 lbs)	Scheduled Passenger							
	Between minor airports	002	5-150	50-200	2-4	30-50 Pax	10	
	Airport feeder	003	5-100	20-50	1-2	30-50 Pax	10	◁
	Scheduled Cargo							
	Between city centers	025	5-100	20-50	1-2	Normal	5-10	
	Between shipper/customer	026	5-100	50-400	2-8	Normal	10-15	◁
	Unscheduled Passenger							
	Service to off-shore platforms	050	5-150	50-200	2-4	30-50 Pax	10	
	Service to remote regions	051	5-150	200-500	4-8	10-30 Pax	3-5	
	Emergency Service	052	5-100	20-50	1-2	5-10 Pax	2-3 with equip.	
	Institutional Passenger							
	Forest Service Transport	060	5-100	20-50	1-2	10-30 Pax	2-4	◀
	Fire fighting	061	5-100	100-200	2-4	30 passengers	4-6	◀
	Rescue	062	5-150	100-200	2-4	10-30 Pax	2-4	◁
	Unscheduled Cargo							
	Cargo between plants	075	5-100	50-400	2-6	Normal	5-10	◁
	Cargo to customer	076	5-100	20-400	2-6	Normal	5-10	◁

* 1 knot = 0.51389 m/s, 1 mile = 1.609 km, 1 ton = 907.2 kg

** Flagged missions from Tables 44, 45, and 46

TABLE 47 - (CONTINUED)

Vehicle Size	Civil Missions (000, 100, 200, 300, 400's)	Reference Number	Speed (kts)	Range (mi)	Endurance Hours	Payload Size	Payload Weight (tons)
Small MAV (Total lift 10,000 - 50,000 lbs) (Continued)	Agricultural Application						
	Timber transport from yard	201B	5–50	20–50	4	May be outsize	25
	Chemical/seeding applications	202	50–75	50–200	4	Bulk	3–5
	Platform Applications						
	Sightseeing	304	5–50	50–200	4–6	Passenger	2–5
Medium MAV (Total lift 50,000 to 100,000 lbs)	Platform - Institutional						
	Coast Guard ATN	312	5–200	2000	24	Crew & Cargo	10 + crew ◁
	Coast Guard MEP	313	5–200	2000	24	Crew & Cargo	10 + crew ◁
	Agricultural Applications						
	Timber Harvesting	201b	5–50	20–50	4	May be outsize	25
	Livestock transfer	204	50–75	50–200	6	Animals	25–100
	Platform Applications						
	Seismographic Surveys (water)	305	5–75	1000–3000	200	Crew, Outsize equip	20–30 ◀
	Hospital-disaster care	316	5–75	50–400	6–16	Patients, + cargo	25
	Resources from remote regions						
	High value bulk	401	5–75	200–400	3–6	Bulk	20 ◀
	Scheduled Passenger						
	Between city centers	001	5–100	20–50	–	100–150 Pax	(25)
Medium/Heavy MAV (Total lift 100,000 to 750,000 lbs)	Heavy Lift/Outsize Transportation						
	Power generating equipment	101	5–50	20–200	3–6	Outsize	50–500 ◀
	Large industrial equipment	102	5–50	20–200	3–6	Outsize	50–250 ◀
	Mining equipment (remote sites)	103	5–50	200–1000	16–40	Outsize	50–100 ◀
	Prefabricated buildings	104	5–50	20–200	3–6	Outsize	25–100 ◁
	Large aerospace equipment	105	50–100	200–1000	8–20	Outsize	25–100 ◁
	Agricultural Applications						
	Livestock transfer	204	50–75	50–200	6	Animals	25–100
	Platform Applications						
	MAV Cruises	306	25–75	1000-3000	200	100-300 Pass.	25-75

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TABLE 47 - (CONTINUED)

Vehicle Size	Civil Missions (000, 100, 200, 300, 400's)	Reference Number	Speed (kts)	Range (mi)	Endurance Hours	Payload Size	Payload Weight (tons)
Heavy MAV Total lift 750,000 - 2,000,000 lbs	Heavy lift/outsize transportation						
	Power generating equipment	101	5-50	20-200	3-6	Outsize	50-500
	Large industrial equipment	102	5-50	20-200	3-6	Outsize	50-250
	Coast Guard ATN	106	5-30	200-400	24	Outsize	300
	Coast Guard MEP	107	5-30	200-400	24	Outsize	300
	Coast Guard SAR	309	5-150	1000-2000	240-360	Some Outsize	25-50
	Coast Guard ELI	310	5-150	1000-2000	240-360	Some Outsize	25-50
	General Cargo Applications						
	Scheduled very long range	027	75-150	3000-5000	50-100	Containers	300-500
	Unscheduled very long range	077	25-150	3000-5000	50-100	Containers	300-500
	Resources from Remote Regions						
	Petroleum	402	25-75	1000-3000	20-60	Liquid	100-500
	Natural Gas	403	25-75	1000-3000	20-60	Gas	100-500
Very Heavy MAV - Total Lift 2,000,000 to 6,000,000 lbs	General Cargo Applications						
	Scheduled very long range	027	75-150	3000-5000	50-100	Containers	500-1000
	Unscheduled very long range	077	25-150	3000-5000	50-100	Containers	500-1000
	Resources from Remote Areas						
	Petroleum	402	25-75	1000-3000	20-60	Liquid	500 plus
	Natural gas	403	25-75	1000-3000	20-60	Gas	500 plus

all the potential civil passenger transportation missions (the only passenger mission requiring a larger vehicle is the mission between city centers). Potential cargo missions that compete with scheduled helicopters, short-range trucks of all categories, and general aviation vehicles also can be performed using MAV's of this size.

The medium size MAV has a gross lift capability of 22,680 kg to 45,360 kg (50,000 lb to 100,000 lb). The only scheduled passenger mission requiring this size class is the mission between city centers. The balance of the very many missions requiring this vehicle size are unique missions consisting of carrying cargo or acting as airborne platforms.

The medium/heavy size MAV has a total lift capability of 45,360 kg to 340,200 kg (100,000 lb to 750,000 lb). The majority of missions requiring this vehicle size provide heavy lift/outsize cargo transportation. The remaining two missions using this size vehicle are commercial and consist of livestock transfer or MAV cruises.

The heavy size MAV has a total lift capability of 340,200 kg to 907,200 kg (750,000 lb to 2,000,000 lb). Heavy lift/outsize cargo missions from developed or remote areas require vehicles of this size.

The very heavy size MAV has a total lift capability of 907,200 kg to 2,721,600 kg (6,000,000 lb). These vehicles are required for general cargo missions from developed or remote areas only if they have significantly lower operating cost than the prior heavy size vehicles.

Military Missions

Three U.S. Army missions require the smallest size vehicle (see Table 48). The small size MAV is required by only one U.S. Navy mission, crew training.

The medium size MAV is required by many missions, including flight training, demonstration of new equipment, and the listed operational missions for all three services.

TABLE 48 - POTENTIAL MILITARY MISSIONS*

Vehicle Size	Military Missions (500, 600, 700's)	Reference Number	Speed (kts)	Range (mi)	Endurance Hours	Payload Size	Payload Weight (tons)
Smallest 10K lb	Observation & Command/Control	701	5-150	400-800	8	Crew/Equip.	0.3-0.5
	Surveillance Drone	705	5-150	400-800	8	Equipment	0.05-1.0
	Unmanned Logistics Support	706	5-100	200-400	3-5	Cargo	0.5-2.0
Small 10-50K lb	Flight Training	510	5-50	50-200	4-6	Crew/Equip.	2-4
Medium 50-100K lb	Airborne C&C	505	5-75	1-3K	200	Crew/Equip	5-10
	NOAA Support	507	5-75	1-3K	200	Crew/Equip	10-20
	Minesweeping	508	5-50	400	6-16	Outsize	20-30
	Flight Training	510	5-100	1-3K	100	Crew	5-10
	Demonstration Platform	511	5-100	400	6-16	Crew/Equip.	50-100
	TOA/DME Station	604	5-75	1-3K	200	Crew/Equip.	10-20
	Artillery Movement	702	5-150	200-400	2-5	Outsize	0.5-15
Medium-Heavy 100-750 K lb	LOTS	501	5-50	20-200	3-6	Outsize	100-200
	Intra-Theatre Trans	602	50-100	200-1K	8-20	Military	25-100
	Mobile ICBM Trans	606	5-75	20-400	4-10	Military	150-400
	Large Load Lifter	703	5-150	200-400	2-5	Military	25-50
	MBT/CEV Lifter	704	5-150	200-400	2-5	Military	50-75
Heavy 750-2M lbs	Bare Base Transportation	601	5-150	1-8K	120-720	Military Cargo	500-1M
	RPV Carrier	605	5-150	1-8K	150-350	Crew/Equip.	250-750
	Mobile ICBM Launcher	607	50-100	1-8K	150-350	Crew/Equip.	500-750
	SEA Control	502	5-150	1-8K	240-720	Crew/Equip.	500-750
	VP Patrol	503	5-150	1-8K	240-720	Crew/Equip.	500-750
	Heavy Lift	504	5-150	1-8K	120-720	Military Cargo	500-1M
	Ocean Escort	509	5-150	1-8K	240-720	Crew/Equip.	500-750
Very Heavy 2M - 6M	Remote Station Support	603	5-150	4-20K	100-200	Military Cargo	500-2M
	Arctic Operations	506	5-150	4-20K	100-200	Military Cargo	500-2M

*1 knot = 0.51389 m/s, 1 mile = 1.609 km, 1 ton = 907.2 kg

The medium-heavy size MAV is required by operational missions for all three services; the missions include heavy lift-outsize cargo and general cargo.

The heavy size MAV is required for operational missions by the U.S. Navy and the U.S. Air Force. These missions include platform and transportation missions. The platform missions include the important patrol, escort, sea control, weapons platform, and RPV carrier missions. The transportation missions include Bare Base transport and heavy lift.

The very heavy vehicle is required for two very long-range military cargo missions to remote stations.

EVALUATION AND SELECTION FACTORS

Missions

The mission analysis results indicate a number of specific areas where a MAV becomes attractive, particularly for a number of the platform missions for service type functions. Since this study is primarily directed toward the transportation mode, those highly rated civil mission areas involving conventional or unique transportation were given priority for recommended Phase II study. Additionally, the highest-rated DOD mission area is considered sufficiently important to warrant further investigation. If such a capability were developed by the military, in all probability a number of commercial applications would evolve.

A high rating in both the civil and military mission analysis for a particular function, such as the medium heavy lift and the medium lift size requirement, immediately qualifies the mission for detailed further study.

Both the civil and military mission analysis developed high ratings for drone-type MAV's for surveillance and logistics. Since the concept is somewhat remote from the main theme of this study, further study under this contract is not recommended. However, these drone-type mission and candidate MAV's should be further developed under other auspices.

One mission factor that emerged toward the end of this study concerns the impact of the proposed railroad consolidation and the abandonment of six thousand miles of secondary trackway. If this occurs, an enormous need for short-haul cargo transport will emerge. This demand could be partially filled with a medium-size airship in the 22, 680 kg to 45, 360 kg (50, 000 lb to 100, 000 lb) gross lift category.

Parametric Analysis

Various types of lighter-than-air (LTA) vehicles from fully buoyant to semibuoyant hybrids are examined in the parametric analysis (Volume II). Geometris were optimized for gross lifting capabilities from 1360.8 kg to 2, 721, 600 kg (3000 lb to 6, 000, 000 lb) for ellipsoidal airships, modified delta planform lifting bodies, and a short-haul, heavy-lift vehicle concept.

Various types of lighter-than-air (LTA) vehicles from fully buoyant to semibuoyant hybrids are examined in the parametric analysis (Volume II). Geometries were optimized for gross lifting capabilities from 1360.8 kg to 2,721,600 kg (3000 lb to 6,000,000 lb) for ellipsoidal airships, modified delta planform lifting bodies, and a short-haul, heavy-lift vehicle concept.

Neutrally buoyant airships employing a rather conservative update of materials and propulsion technology offer significant improvements in productivity. Advanced fabric applications for non-rigid airships offer great potential for improved performance.

Propulsive lift for VTOL and aerodynamic lift for cruise can significantly improve the productivity of low to medium gross weight ellipsoidal airships. For large gross weights, neutrally buoyant flight maximizes productivity.

For the CTOL lifting body hybrid, no optimum ratio of buoyant lift to gross weight, β, was found, based on productivity, between 0.1 and 0.6. For all but very large ranges the productivity of the $\beta = 0.1$ hybrid exceeds that of the $\beta = 0.6$ hybrid. Depending on gross weight and range, semibuoyant lifting body hybrid vehicles can offer improved productivity relative to ellipsoidal airships, particularly at the large gross weights. However, in comparison with commercial cargo aircraft at equal gross weight and range, their productivity appears to be significantly lower.

The short-haul, heavy-lift vehicle, consisting of a simple combination of an ellipsoidal airship hull and existing helicopter componentry, offers significant potential for low-cost, near-term applications for ultra-heavy lift missions. Results indicate useful load-to-empty weight ratios of approximately 1.0 can be maintained to gross weights of approximately 907,200 kg (2,000,000 lb).

Selected Combinations

Table 49 summarizes the highest rated transportation-oriented missions for potential MAV application by gross lift category. Other highly rated nontransportation missions that could be performed by the MAV configuration design are included. The DOD missions for the same gross lift categories are identified in the right-hand column and are segregated into highest rated and other.

For the largest gross lift category, the importance of the DOD missions (sea control and RPV carrier) far overshadows any possible civil transportation mission.

TABLE 49 - HIGHEST RATED TRANSPORTATION MISSIONS

High Rated Transportation Mission Codes	Other Important Mission Codes	Lift Category (Lb)	Max Range or Endurance	Speed (Knots)	VTOL/ STOL/ CTOL/ RTOL	DOD High Rated Missions	Other Important DOD Missions	Recommended for Phase II Study
003 026 075 076	060 061	10-50K	400 NM	100	VTOL	None	None	Yes
401	305	50-100K	400 NM or 24 Hrs	75	VTOL	510 511	604 508 505 507	No
101 102	103 309 310	100K- 750K	200 NM	50	VTOL	704	703 501 602 606	Yes
None**	106 107 402 403	750- 2M	720 Hrs	150	VTOL	502* 605	503 509 601 607 504	Yes

*DOD mission dominates lift category

**A DOD MAV obviously would have civil application

Note: 1 lb = 0.4536 kg, 1 knot = 0.51389 m/s, 1 nautical mile = 1.853 km

MAV/Mission Combination 1

General

This combination provides both a passenger and cargo service in the short- to medium-range market. Of particular interest is the major airport feeder capability now being handled by helicopters and small STOL fixed wing aircraft. In Phase II, GAC will analyze the potential of this capability in the context of the Lake Erie Regional Transportation Authority (LERTA) plans currently under development for placing a large international airport in the lake off Cleveland. This plan has provoked severe criticism in terms of noise and a requirement to provide much greater roadway access, some of it through downtown Cleveland.

Studying the combination as a major feeder of both passengers and cargo in this elaborate LERTA scenario will be extremely useful for planners in both groups. The MAV has the potential for minimizing the noise problem, air-space, and runway use by the feeders and should substantially reduce the ground traffic.

The spectrum of potential applications of small VTOL aircraft is immense in the urban transportation systems of the future. Applications range from the multitude of specialized tasks currently performed by today's small helicopter, through passenger and utility transport within a megalopolis, to intercity transport between city centers.

The baseline vehicle recommended for Phase II study is based on the requirements for mission Codes 003, 026, 075, and 076, which are listed below.

1. Baseline vehicle - Conventional shape and rigid construction, semibuoyant airship
2. Alternate - Pressurized metalclad 2 from Task III
3. Baseline mission/performance requirements (Table 49)
    a. Lift capability - 4536 to 22,680 kg (10,000 to 50,000 lb)
    b. Range - 643.6 km(400 statute miles)
    c. Speed-51.4 to 77.1 m/s (100 to 150 knots)
    d. VTOL
4. Recommended baseline vehicle design characteristics
    a. Gross weight = 18,144 kg (40,000 lb)
    b. Static lift/gross weight = 0.2
    c. Volume = 4511.4 cu m (159,300 cu ft)
    d. Length = 57.9 m (190 ft)
    e. l/d = 4.7*
    f. Useful Load - 10,206 kg (22,500 lb)
    g. Tilting tuboprop propulsion for VTOL,conventional propellers - 6.83 m (22.4 ft) diameter
    h. Four engines - 8000 SHP at sea level
    i. Cruise power required at altitude - 5450 SHP
    j. 1524 m (5000 ft) design altitude
5. Baseline vehicle performance characteristics
    a. Design range = 643.6 km (400 statute miles)
    b. Cruise speed = 82.2 m/s (160 knots)
    c. Fuel required = 2268 kg (5000 lb)

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*l/d = 4.7, slightly larger than optimum.

d. Payload (including crew and avionics) = 7930 kg (17,500 lb)
e. Productivity (ton-miles per hour) = 1510
f. Payload ton-miles/hour/ton EW = 184
g. Payload ton-miles/hour/pound of fuel = 0.322
h. Payload/empty weight = 1.0
i. Empty weight/gross weight = 0.44
j. Installed horsepower per ton gross weight = 400
k. Estimated noise level* at 500 ft = 101 db**
l. Estimated passenger capacity = 50

Primary Civil Missions

Primary civil missions are:

003 Major airport feeder operation from outlying or satellite airfields
026 Scheduled cargo delivery system between shipper and customer
075 Unscheduled cargo deliveries between industrial plants
076 Unscheduled cargo deliveries between shipper and customers

Primary DOD Missions

No DOD missions rate high in this lift category.

Secondary Civil Missions

Secondary civil missions are:

060 Forest Service logistics support system
061 Fire fighting system

*Assumes all engines at same location in space, 244 m/s (800 ft/sec) tip speed.

**95db noise level can be achieved with same tip speed and β = 0.65 vehicle or slightly lower tip speeds with the baseline vehicle using only a small performance degradation.

Secondary DOD Mission

There are no secondary DOD missions in this lift category.

Rationale for Selection: Vehicle type

Rationale for selection of vehicle type is as follows:

1. Rigid vehicle offers more flexibility for engine installation/location options for noise, performance, and stability requirements.
2. Pressurized metalclad may offer slightly improved structural efficiency and productivity if acceptable engine installation can be accomplished.
3. Pressurized fabric airships (particularly if Kevlar technology is developed); also potentially competitive subject to same engine installation requirements.
4. Lifting body hybrid configuration as studied in Phase I not competitive due to low structural efficiency.

Other Factors Relative to Vehicle Selection

Other factors relative to vehicle selection are:

1. Configuration derivative may satisfy performance requirements for mission Code 401.
2. Small size of configuration provides potential for low-cost, near-term operational capability via flight research vehicle program (baseline vehicle volume is comparable to Goodyear advertising airships).
3. Stability, control, vehicle dynamics, handling, and flying qualities data obtainable from near-term flight research vehicle program applicable to mission Code 401 as well as 101 and 102 vehicles.

MAV/Mission Combination 2

General

This combination is not recommended for Phase II study. It presumes that a unique market would emerge in the medium-haul market for transporting high-value bulk cargo up to 18, 144 kg (20 tons). This mission conceivably could be satisfied by a derivative of the combination 1 baseline vehicle or with a conventional airship of the ZPG-3W type. The more immediate mission interest lies in the DOD category since this size MAV (ZPG-3W configuration) is ideal for the test beds and flight trainers that will be required to initiate a MAV development program. Also, there are several current DOD operational missions that could be performed with the ZPG-3W configuration represented by this size MAV. Therefore, it is recommended that the flight research vehicle/test bed program be pursued and developed under other auspices.

Primary DOD Missions

Primary DOD missions are:

510 Provides a flight training platform for ultimate MAV's

511 Provides a test bed for demonstration and proof of MAV subsystems, propulsion, buoyancy management, ground handling, and several important classified military sensor and weapon systems

Primary Civil Missions

Primary civil missions are:

401 High-value bulk transporter such as precious-metal ores from remote areas

Secondary DOD Missions

Secondary DOD missions are:

604 TOA/DME reconnaissance and weapon control platform
508 Minesweeping
505 Airborne command and control platform
507 NOAA support as weather station

Secondary Civil Missions

Secondary civil missions are:

305 Ocean seismographic survey for petroleum, etc.

MAV Parameters

The vehicle for this mission will be defined as a short-haul, heavy-lift derivative of the baseline vehicle for mission/vehicle combination 1.

MAV/Mission Combination 3

General

This combination is directed toward the unique and immediately required market for a medium heavy-lift VTOL MAV capable of transporting large, heavy indivisible payloads comparatively short distances-371 km (200 naut mi). It also has a near-term DOD requirement for all three services plus the Coast Guard.

Primary Civil Missions

Primary civil missions are:

101 Short-haul transport of outsize heavy power-generating equipment (up to 453,600 kg, or 500 tons)

102 Short-haul transport of other outsize, heavy industrial equipment

Primary DOD Missions

Primary DOD missions are:

704 Main battle tank/combat engineer vehicle lifter

Secondary Civil Missions

Secondary civil missions are:

103 Transportation of mining equipment to remote sites

309 Coast Guard search and rescue

310 Coast Guard ELT

Secondary DOD Missions

Secondary DOD missions are:

703 Large load lifter (general)

501 Logistics over-the-shore (LOTS) requirements

602 Intratheater transporter

606 Mobile ICBM equipment transporter

MAV Parameters

The vehicle for this mission is a larger version of the Heli-Stat concept currently being studied by the Piasecki Aircraft Company under Navy contract. The Heli-Stat concept can be expanded to include the mission performance requirements that have evolved from this study's mission analysis and selection process. Goodyear Aerospace is supporting Piasecki Aircraft Company in the development of the Heli-Stat modern airship vehicle concept.

The parametric studies in Volume II suggest that a vehicle of this type can be built utilizing proven helicopter lift systems mounted on a current state-of-the art (even 1930 vintage) rigid airship hull with a useful load-to-empty weight ratio on the order of unity. Realization of this performance level depends on a number of factors relating to the intended use and are spelled out as requirements. Among these factors are endurance requirements, pressure ceiling and safety requirements with respect to power failure, loss of lifting gas, etc.

In the preliminary design suggested for further study, the pressure ceiling and endurance are taken as a reasonable estimate of what might be required in a heavy cargo lift and transport mission of relatively short range or a shuttle service carrying heavy cargo units one way with empty return. Referring to the preliminary design data, it is evident that the 226,800 kg (250 ton) payload could be increased to 272,000 kg (300 tons) or more on a minimum-fuel, short-haul mission.

It is also evident that reducing the pressure ceiling requirement would result in even more lift, 36,288 kg (40 tons), available for payload. This mode of operation would require that the helicopter rotors exert down thrust to balance the excess buoyant lift in the empty condition, and the vehicle would have to be anchored to substantial weights before the power was shut down.

This mode of operation could possibly be carried further by providing additional hull volume and additional buoyant lift to where the helicopters are barely able to hold down the vehicle in the empty condition. One would need to be very careful not to run out of fuel with a vehicle designed for this mode of operation since large quantities of lifting gas would need to be valved very rapidly to avoid disaster. Thus, a large number of tradeoffs need to be made to determine the best combination of parameters for a vehicle of this type.

Postulated requirements for a 226,800 kg (250-ton) heavy lifter are:

1. Sea level vertical lift capacity with full fuel load 226,800 kg (500,000 lb)
2. Endurance on short-range shuttle service (one way loaded, return with no payload) at an average power of two-thirds maximum continuous rated power (per hour)
3. Pressure ceiling 1524 m (5000 ft)
4. No helicopter down thrust required in empty condition

Preliminary design requirements are:

1. Aerostatic lift
   a. Gross volume, 446,040 cu m (15.75×10^6 cu ft)
   b. Gas volume at sea level at 85 percent - 379,488 cu m (13.4×10^6 cu ft)
   c. Gross static lift* - 376,488 kg (830,000 lb)
2. Helicopter lift (10 CH-53E's)
   a. 10 at 30,800 kg (68,000 lb) - 308,000 kg (680,000 lb)
   b. Gross lift - 684,936 kg (1,510,000 lb)
3. Weights
   a. Aerostatic at 0.031** - 221,000 kg (488,000 lb)
   b. 10 CH-53E's*** - 154,050 kg (340,000 lb)

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* Helium lifting gas at 94 percent purity.

** Aerostatic weight is taken conservatively high to allow for cargo handling and storage provisions, structural reinforcements to support helicopter/out-rigger loads and deliver lift to a central cargo hoisting system or sling. Fuel system, crew accommodations, control system, alighting gear, and all other systems other than helicopter lift system and outrigger weight are intended to be covered by this weight allowance.

*** CH-53E's are stripped of all nonessential components. This weight is intended to include outriggers to deliver the helicopter rotor forces to the airship hull.

c. Crew - 907.2 kg (2000 lb)

d. Fuel - 81,550 kg (180,000 lb)

e. Payload-226,800 kg (500,000 lb)

Gross weight - 684,936 kg (1,510,000 lb)

Less payload and fuel - 308,000 kg (680,000 lb)

Minimum weight - 376,936 kg (830,000 lb)

4. Power and fuel consumption

   a. Total installed maximum horsepower (30 × 4330) - 130,000

   b. Continuous rated horsepower (30 × 3665) - 110,000

   c. Fuel consumption at continuous rated horsepower - 24,900 kg/hr (55,000 lb/hr)

   d. Endurance at continuously rated horsepower - 3.28 hr

   e. Endurance at two-thirds continuously rated horsepower - 4.92 hr

5. Dimensions

   a. Hull diameter - 56.4 m (185 ft)

   b. Hull length - 216.4 m (710 ft)

   c. Rotor diameter - 21.95 m (72 ft)

   d. Rotor spacing - 24.4 m (80 ft)

   e. Width C to C motors - 80.9 m (265 ft)

   f. Width overall - 102.7 m (337 ft)

MAV/Mission Combination 4

General

This combination has no high-rated civil transportation mission. However, it may well be the most important DOD mission area. If a MAV of this capability were developed and operated in satisfaction of the military missions described, a commercial market would evolve.

Primary Missions

The 502 sea control concept requires a 77.1 m/s (150 knot), 907,200 kg (two-million pound) gross lift MAV capable of 720 hours of sustained flight. The MAV is capable of most sea control functions.

The 605 RPV carrier concept requires a MAV with the performance described above to serve an an air mobile RPV carrier capable of carrying, launching, and controlling large numbers of multiple-purpose RPV's for strike, reconnaissance, and deception.

Secondary DOD Missions

This MAV could accomplish the following additional missions:

1. 503 VP patrol
2. 509 Ocean escort
3. 601 Bare Base transporter
4. 607 Mobile ICBM launcher
5. 504 Heavy lifter

Secondary Civil Missions

Specialized derivatives of this MAV could possibly accomplish the following additional civil missions:

1. 402 Petroleum carrier (long haul)
2. 403 Natural gas carrier (long haul)
3. 106 Coast Guard ATN
4. 107 Coast Guard MEP

The recommended vehicle baseline for the heavy-lift military endurance vehicle is as follows:

1. Baseline - Conventional rigid, neutrally buoyant airship
2. Alternate - Sandwich shell monocoque

3. Baseline mission/performance requirements
   a. Lift capability - 340,000 kg to 907,200 kg (750,000 to 2 million pounds)
   b. Endurance - 720 hours into 20-knot head wind
   c. Cruise speed - 79.5 m/s (155 knots), still air
   d. VTOL
4. Recommended baseline vehicle design characteristics
   a. Neutrally buoyant vehicle, $\beta = 1.0$
   b. Gross weight - 907,200 kg (2 million pounds)
   c. Volume - 1,127,136 cu m (39.86×10^6 cu ft)
   d. Length - 504.75 m (1656 ft)
   e. l/d = 7.6
   f. Useful load - 353,868 kg (780,000 lb) at 1524 m (5000 ft) altitude
   g. Turboprop propulsion/conventional propellers
   h. 14 cruise engines - 80,000 SHP at sea level
   i. Two loiter engines - 860 SHP at sea level
   j. VTOL inherent since vehicle operates continuously in neutral buoyancy
5. Baseline vehicle performance characteristics
   a. Payload, crew, provisions - 226,800 kg (500,000 lb)
   b. On-station endurance - 720 hours
   c. Still air range* at 79.5 m/s (155 knots) - 360 naut mi
   d. Still air range at 51.4 m/s (100 knots) - 740 naut mi
   e. Still air range at 35.95 m/s (70 knots) - 1400 naut mi
6. Rationale for recommendation
   a. Rigid construction offers best structural efficiency at large gross weights
   b. Access and use of internal volume allows greater flexibility in mission equipment requirements and utilization

*Range to station maximum range is twice value shown.

7. Alternatives

   a. Sandwich monocoque metalclad airship

   b. Buoyancy control system:

      (1) First choice is water pickup. Potentially lowest cost/lowest complexity method of maintaining neutral buoyancy and is compatible with endurance mission characteristics.

      (2) Alternate choice is by consumption of internally stored lifting gas (hydrogen the preferred candidate) with or without water recover from combustion products. This method could additionally supply some APU requirements.

PHASE II RECOMMENDATION

Goodyear Aerospace recommends that MAV/mission combinations 1, 3, and 4 be further studied and analyzed.

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