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THE PERFORMANCE OF A CONCEPTUAL MULTIMISSION POWER-AUGMENTED-RAM WING-IN-GROUND EFFECT VEHICLE

by

Basil S. Papadales, Jr.

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Results of a conceptual design study of a power-augmented-ram wing-in-ground effect vehicle are presented. The vehicle is designed for sea control operations. Four vertical/short takeoff and landing aircraft are carried for these operations. Alternative payloads designed for transoceanic transport, strategic deterrence, and theater air defense missions are investigated. Vehicle performance for the various operations is shown to provide a unique military capability assuming reasonable advances in power-augmented-ram wing-in-ground effect technology.

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NOTATION

Symbols

C_{D_o}	Drag coefficient
d	Endplate depth (L)
$H_{1/3}$	Significant wave height (L)
$H_{1/1000}$	Height of the average of the 1/1000th highest waves (L)
$H_{1/10,000}$	Height of the average of the 1/10,000th highest waves (L)
h	Endplate clearance (L)
L/D	Lift-to-drag ratio
S	Wing area (L^2)
W_o	Gross weight (M, F)

Abbreviations

MCWL	Mean cruise waterline
SWL	Static waterline
UEW	Unequipped empty weight (M, F)

ABSTRACT

Results of a conceptual design study of a power-augmented-ram wing-in-ground effect vehicle are presented. The vehicle is designed for sea control operations. Four vertical/short takeoff and landing carried for these operations. Alternative payloads designed for transoceanic transport, strategic deterrence, and theater air defense missions are investigated. Vehicle performance for the various operations is shown to provide a unique military capability assuming reasonable advances in power-augmented-ram wing-in-ground effect technology.

ADMINISTRATIVE INFORMATION

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INTRODUCTION

Early in this century it was noted that a wing operating in close proximity to the ground exhibited a reduction in induced drag (Reference 1). For several decades this phenomenon, called the wing-in-ground (WIG) effect, was studied because it complicated the takeoff and landing of low wing aircraft. In the early 1960's, a joint Army/Navy program was initiated to study the feasibility of designing a vehicle which would have exceptional performance by cruising in ground effect over the oceans (Reference 2). These studies showed that to keep wave impact loads during takeoff and landings at acceptably low levels, the WIG effect vehicle would need a low stall speed. This required a low wing loading which resulted in low cruise speeds. Furthermore, since the vehicle was designed to cruise close to the ocean surface, a large vehicle displayed superior performance to a smaller vehicle for a fixed cruise height. Therefore, the WIG effect vehicle designs were for large aircraft and, with the low wing loading, resulted in designs with inefficient structures (i.e., high structural weight fractions). The high structural weight fraction, combined with the low cruise speeds, resulted in vehicles with relatively poor performance.

The poor performance of the conventional WIG effect vehicle was recognized as being the result of takeoff and landing constraints. In the early 1970's a phenomenon was discovered that had the potential to relieve these constraints. This phenomenon involved the directing of the efflux from forward mounted propulsors under a wing which is in ground effect (Figure 1). The efflux could be nearly stagnated by use of wing endplates and a trailing edge flap. A static pressure rise would result under the wing, which could then lift a vehicle out of the water at low speed. This static lift could be increased by designing the propulsion system to entrain ambient air, thereby filling more of the volume under the wing with high energy air. This phenomenon is called the power-augmented-ram wing-in-ground (PAR-WIG) effect.

Early NASA and Navy tests (References 3 and 4) indicated that the PAR-WIG effect could be used as a takeoff and landing aid for a WIG effect vehicle. These early tests showed that lift could be generated with relatively low thrust but with little thrust recovery. Theoretical studies conducted at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) under the sponsorship of the Advanced Naval Vehicle Concepts Evaluation (ANVCE) indicated that significantly better performance could be achieved if the propulsors were better designed for entrainment (Reference 5). Subsequent tests over a solid ground board and over water verified these predictions.* For example, a lift-to-thrust ratio of 6.0 and a height-to-chord ratio of 0.1 resulted in a thrust recovery of 80 percent; this recovery was over 60 percent higher than in the early tests (Figure 1).

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* Reported informally by F. H. Krause and R. W. Gallington ("Static Performance of a Power-Augmented-Ram Wing," DTNSRDC ASED TM-16-76-76, May 1976) and F.H. Krause ("Parametric Investigation of a Power-Augmented-Ram Wing over Water," DTNSRDC ASED TM-16-76-95, Oct 1976).

Encouraged by these promising results, further model testing was conducted at DTNSRDC under ANVCE sponsorship. These test programs demonstrated that the power-augmented-ram (PAR) cushion could be generated at very high wing loadings and in relatively rough sea conditions.* The tests also showed that a vehicle which cruised on the PAR cushion would have excellent transport efficiency (although cruise in ground effect without the cushion would probably be more efficient). The models had exceptionally good ride quality over rough waves, no spray problems were observed, and the PAR-WIG effect demonstrated a natural heave stability.

These tests were conducted in support of ANVCE design studies and were used in determining the military potential of PAR-WIG effect vehicles. Three types of PAR-WIG effect vehicles were investigated (Reference 6):

1. Takeoff and land on PAR cushion and cruise out of ground effect
2. Takeoff and land on PAR cushion and cruise in ground effect (off the PAR cushion)
3. Takeoff, land, and cruise on PAR cushion

The design studies were oriented at specific military operations

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* Reported informally by E. F. McCabe ("Parametric Investigation of a Power-Augmented-Ram Wing with Load Alleviation Devices over Water Waves of Various Sea States," DTNSRDC ASED TM-16-76-97, Dec 1976).

with rigid ground rules which enabled the ANVCE analysts to compare various competing vehicle concepts. These studies were conducted in parallel with the PAR-WIG effect model tests; therefore, the designs did not reflect the most recent test results and design philosophy.

To assess the potential payoff of the most recent PAR-WIG effect technology development, a conceptual design study was initiated at DTNSRDC. The results of this study are presented herein.

MISSION APPLICATIONS

This study was oriented at estimating the performance of a PAR-WIG effect vehicle which was assumed to use the PAR cushion for takeoff and landing and cruise unaugmented in ground effect. This type of vehicle would have relatively high transit speed (200-400 knots) and could loiter for long periods on the ocean surface. Such a capability would be combined with the exceptional range-payload performance possible by use of the WIG effect. Thus missions were selected to take full advantage of these performance characteristics. Furthermore, it was recognized that any PAR-WIG effect vehicle would be large by current aircraft standards and would require a considerable development program. These factors would make the vehicle relatively expensive (per unit). Therefore, to reduce acquisition and support costs, this study was confined to evaluating an airframe which would have a multi-mission capability. Furthermore, because of long term development requirements, the vehicle was designed around projected mission requirements for the 1990-2000 time frame.

TACTICAL SEA CONTROL MISSION

The vehicle design used for this study was sized for a tactical sea control missions using the PAR-WIG effect vehicle as a support carrier of four tactical vertical/short takeoff and landing (V/STOL) aircraft.* The design mission was assumed to have a radius of action of 2000 nm (3700 km) with 5 days on station, including ten 100 nm (185 km) dashes while on station. The design payload of 575,000 lb (261,400 kg) is described in Table 1. In addition to this payload, 200,000 lb (90,900 kg) of fuel was required for V/STOL aircraft operations. A crew of 40 was specified.

The use of V/STOL aircraft provides the PAR-WIG effect vehicle with a high degree of tactical flexibility in the antisubmarine warfare (ASW) environment. Most ASW studies have assumed the use of V/STOL aircraft on advanced marine vehicles for this reason. The PAR-WIG effect vehicle would use these V/STOL aircraft to deliver ASW sensors and weapons to conduct airborne early warning and antiaircraft/missile attack operations.

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* For this discussion the strict definition of V/STOL aircraft is implied, i.e., conventional helicopters and the more advanced V/STOL concepts are included.

For each of these operations, the basic airframe (sized for the sea control mission) was conceptually modified for three secondary missions: transoceanic transport, strategic deterrence and theater air defense.

TRANSPORT MISSION

For the transoceanic transport mission all cargo was assumed to be carried in the fuselage. Operating items weighing 15,000 lb (6800 kg) were assumed (Table 2). For loading, a roll-on, roll-off capability was not specified since a PAR-WIG effect vehicle would probably dock at a coastal pier. Cargo doors on the upper portion of the fuselage were required to permit underway replenishment of surface ships. Cargo could then be transferred using helicopters if sea conditions were acceptable.

STRATEGIC DETERRENCE MISSION

The strategic deterence mission involved carrying four TRIDENT C-4 missiles with a crew of 20. Using a PAR-WIG effect vehicle, ballistic missiles could be carried for limited periods in open ocean areas. The PAR-WIG effect vehicle could be based at secure United States shore facilities and be deployed to remote bases or out to sea for limited periods. PAR-WIG effect vehicle would offer a high degree of launcher mobility without the difficulty of communications that submarine systems experience. Table 3 lists the conceptual payload for this mission. No tactical defensive weapons were specified based on the assumption that the vehicle would use its fast cruise speed as its primary defense.

The use of the PAR-WIG effect vehicle for strategic deterrence missions would provide the United States with a new platform for strategic weapons which has characteristics complementing the projected force of land-based missiles, submarine-based missiles, and manned aircraft. The use of large ballistic missiles (rather than small cruise missiles) can be justified based on the large vehicle size needed to achieve a highly efficient PAR-WIG vehicle. Furthermore, a payload of a large number of smaller cruise missiles with shorter range would require the vehicle to approach enemy defenses and to maneuver in that environment to launch multiple target strikes; this tactic would not be practical.

THEATER AIR DEFENSE MISSION

The theater air defense mission involved the transport and support of a large number of antiaircraft missiles for use in open-ocean theater air defense. In this role the PAR-WIG effect vehicle would be deployed from a shore base and would be deployed for theater air defense under the radar umbrella of an airborne early warning (AEW) aircraft (e.g., AWACS). The AEW aircraft would detect and identify incoming aircraft or missiles. The PAR-WIG effect vehicle would maneuver in ground effect at the command of the AEW aircraft. Missiles could be launched under control and with updated data, from either the AEW aircraft or the PAR-WIG effect vehicle. Table 4 presents the conceptual mission payload; a crew of 20 was specified.

VEHICLE DESIGN

For this study, the vehicle was assumed to be based on technology available in 1990 with operations possible in 1995 (consistent with the mission requirements). The exterior vehicle design was developed from data obtained from towing tank tests conducted at DTNSRDC. Aerodynamic cruise performance was calculated from Lockheed wind tunnel test data (Reference 7). The configuration was based on geometries of known performance and with no attempt at optimization. One of the most critical issues concerning the design of any type of WIG effect vehicle is the structural weight fraction. It is known that significant savings in structural weight can be achieved by the use of high wing loadings and low aspect ratio, thick wings. The magnitude of these savings (compared to conventional aircraft) has not been verified.

Another issue is the validity of the design sea state and, given this condition, the validity of a design rule for the cruise altitude. A lower design sea state or a more optimistic design rule for altitude will result in improved L/D at the cost of utility or structural weight. Since a detailed evaluation of these issues was beyond the scope of the study, the vehicle was designed using reasonable values of unequipped empty weight (UEW) fraction and the design sea state.

The sensitivity of the UEW fraction and design sea state is shown in Figure 2. Performance estimates were based on a 2,090,000-lb (950,000-kg) vehicle with a UEW fraction of 30 percent and design upper state 5 seas ($H_{1/3}$ = 12 ft (3.7m)). This gross weight yielded a vehicle capable of carrying the design sea control mission payload. Military fuel reserves were assumed (a 5-percent increase in fuel consumption and a 5-percent increase in total fuel load). At the design sea state, a reduction of the UEW fraction to 0.25 would result in a 13.7-percent reduction in gross weight; an increase in the UEW fraction to 0.35 would result in a 19.1-percent increase in gross weight. At a UEW fraction of 0.30, an increase in the design sea state to $H_{1/3}$ = 16 ft (4.9 m) would increase the gross weight 9.1-percent; reducing the design sea state to $H_{1/3}$ = 8 ft (2.4 m) would reduce the gross weight by the same proportion.

Figure 3 shows the effect of different design rules for determining the cruise altitude. The rule used for this study (and the ANVCE studies) called for the bottom of the wing endplate to clear the top of the significant wave and for the bottom of the wing and fuselage to clear the bottom of the average of the 1/1000th highest waves. This rule is based on the commonly used truncation of wave height probabilities which assumes the highest expected wave in a given sea condition has the height of the highest wave in 1000. This height is approximately twice the significant wave height. A more conservative design rule would be to have the endplate clear the 1/1000th highest wave and the wing and fuselage clear the 1/10,000th highest wave. Figure 3 shows the 14-percent reduction in cruise L/D caused by the use of the more conservative design rule.

The argument of unacceptable risks associated with cruising very close to the ocean surface is applicable to any type of WIG effect aircraft or high-speed surface effect ship. The risk in such an operation is claimed by some investigators to be the unacceptably high probability of hitting a rogue wave (i.e., a wave of extreme height). Their argument is based on the property of the statistical wave spectra model with very low probabilities at very large wave heights. In general, wave power spectra are modeled by a Rayleigh distribution (e.g., the Pierson-Moskowitz model). This type of model yields a finite, but small, wave probability out to infinitely high waves. Recently, researchers have realized this mathematical model is not accurate at the very large wave heights and have therefore placed a limit on the height of the largest wave that could be expected in a given sea state. Michel (Reference 8) states:

> "One should remember that the Rayleigh distribution is only a convenient mathematical fit to the histogram of actual wave measurements, which do not show extreme wave heights (probably since breakers result from any tendency toward extreme height) ... sound practice indicates a realistic limit should be applied. It is generally accepted that 1000 waves are sufficiently representative of the entire spectrum, and the most probable value of the 1/1000th highest wave represents the maximum."

For a wave spectrum modeled by a Rayleigh distribution, the highest 1/1000th wave is 1.925 times higher than the average height of the one-third highest wave (the significant wave height). Investigators at DTNSRDC have used this factor in determining the highest wave which a WIG effect aircraft must clear while cruising. Performance calculations have been based on the assumption that the bottom of the aircraft wing will cruise at an altitude just above the highest wave crest. This design rule is admittedly heuristic. Further work must be conducted to quantify the relationship between aircraft cruise height, the encounter sea state, and the aircraft speed. The effect of wave heading has not yet been determined.

Characteristics of the PAR-WIG effect vehicle are presented in Table 5; Figure 4 shows the vehicle design. The general arrangement includes a conventional fuselage with forward mounted fans, a tapered, swept-forward trailing edge wing, and a high T-tail. All payload is carried in the fuselage. Fuel is stored in both the fuselage and the wing. Pilot and engineering compartments are located in the forward section of the fuselage. All other crew compartments are located around the center of gravity for ride comfort.

Propulsion is supplied by six 18,300 hp (13,600 kw) gas turbine engines. These engines were assumed to have a stattic specific fuel consumption of 0.35 lb/shp-h (0.21 kg/kw-h) at sea level, generating 440,000 lb (1960 kn) static thrust. These engines drive four 16-ft (4.9-m)-diameter ducted fans, each with a pressure ratio of 1.27; variable blade pitch is used to maintain high propulsive efficiency throughout the flight envelope. The fans have movable ducts to direct the efflux either under the wing or horizontally as needed.

The wing is located to provide adequate proximity to the ocean surface, fuselage clearance, and peak power augmentation from the fans. The wing is swept forward to provide longitudinal stability both in and out of ground effect. Wing planform taper is used to reduce endplate area and endplate impact loads and to permit banked turns while in ground effect. To date, a tapered, swept-forward wing has not been tested in a PAR-WIG effect configuration over water. A. M. Lippisch (Reference 9), however, has developed this configuration with a series of small manned vehicles which cruise in ground effect without power augmentation.

A small flexible endplate is located at each wing tip. The endplates are 6.0 ft (1.8 m) deep (as determined by the assumed design rule). The endplate has a large deadrise angle with chines to break water away from the surface. The endplates are fabricated from elastomeric materials to achieve proper flexibility and hydrodynamic shape. Model tests indicate that both thin rigid endplates and thicker flexible endplates exhibit a ride quality in rough water which is superior to the ride quality of any other type of advanced marine vehicle with the exception of the hydrofoil craft (Reference 10).

No seakeeping model data is currently available for any PAR-WIG effect vehicle. However, seakeeping studies have shown that aircraft of this size would have significantly superior ride quality to conventional smaller seaplanes (Reference 11). The effect of the low wing would probably increase the heave and roll natural frequencies due to the large increase in waterplane area. Seakeeping loads remain an issue.

Longitudinal stability and control is achieved by means of a high aspect ratio horizontal stabilizer located out of ground effect. This configuration has also been successfully demonstrated by A. M. Lippisch (Reference 9) as well as by several other investigators. The horizontal surface is supported by a single vertical stabilizer. The vehicle is neutrally stable longitudinally and is statically stable directionally.

The vehicle fuselage has a circular cross section with some hydrodynamic shaping at the nose and tail to provide hydrodynamic lift and spray control during takeoff and landing. For the sea control and transport versions, two rectangular doors are located atop the fuselage (Figure 4) to permit V/STOL aircraft operations and cargo transfer operations. For the strategic deterrence and antiaircraft operations, vertical missile launch tubes are located along the fuselage (Figure 4).

VEHICLE PERFORMANCE

The vehicle is designed to cruise at an L/D of 18.5 in 12 ft (3.7 m) significant waves (using Reference 7 data). Figure 5 shows the probability associated with achieving better performance (a maximum L/D of 40 is assumed). For world-wide operations, an L/D of 25.5 or greater can be achieved 50 percent of the time; this L/D is reduced to 22.6 in North Atlantic operations. Drag estimates indicate the vehicle could cruise out of ground effect at all weights with an L/D of 9.5. Hence, a substantial L/D improvement is possible when cruising at heights greater than the assumed design heights but still in ground effect.

Figure 6 presents the predicted takeoff run of this vehicle based on early model tests of a similar design.* The model differs from the full scale vehicle in wing aspect ratio and taper; the wing loading and thrust-to-weight ratio (which are the most important parameters) are Froude-scaled. Takeoff on the PAR cushion will accelerate the vehicle to a velocity of 171 knots (88 m/s); in calm water, this speed can be attained with a static thrust-to-weight ratio of 0.35. At this speed, the PAR-WIG effect vehicle would transition to WIG effect flight (unaugmented) by revolving the fan ducts to a horizontal position.

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* Reported informally by G. H. Kidwell and R. W. Gallington ("Effect of Configuration on the Measured Performance of a Power-Augmented, Wing-in-Ground Effect Aircraft," DTNSRDC ASED TM 16-77-115, Mar 1977).

For all cruise performance calculations, the best fuel consumption was achieved by assuming a minimum number of engines operating. A minimum of two engines operating with all four fans running was required. A constant significant wave height was assumed for the entire mission.

Figure 7 presents a performance map for the PAR-WIG effect vehicle with the design sea control aircraft. In 12-ft (3.7 m) significant wave height conditions, this vehicle is designed to have a radius of action of 2000 nm (3700 km) with 10 days on station and to carry four V/STOL aircraft with fuel for 30 missions. Ten 100 nm (185 km) dashes by the PAR-WIG effect vehicle are possible while on station. The radius of action could be increased to 3000 nm (5600 km) if the significant wave height was 6.0-ft (1.83 m). For such long range-endurance missions, a time-averaged significant wave height of 6.0-ft (1.83 m) is equal to the year-round median significant wave height in the North Atlantic (Figure 5).

Figure 8 presents the range-payload performance of the transport version of the PAR-WIG effect vehicle. The PAR-WIG effect vehicle can carry up to 750,000 lb (341,000 kg) of payload based on a payload density of 10 lb/ft (160 kg/m). With this full payload, the PAR-WIG effect vehicle has a range of 4350 nm (8060 km) in 12.0-ft (3.7-m) significant wave height seas; in 6.0-ft (1.8-m) seas, the range is increased to 5600 nm (10,400 km). Three C-5A aircraft could carry the same load 2500 nm (4630 km). Out of ground effect, the PAR-WIG effect vehicle has a ferry range of 6870 nm (12.700 km); for a 750,000-lb (341,000-kg) payload, the range is 2020 nm (3740 km). Cruising out of ground effect would be used only under the most extreme weather conditions. The probability of the seas being continuously too severe for long distance ground effect flight is very low (Figure 5). For this vehiicle, out-of-ground effect cruise would be used only in seas having significant wave heights in excess of 16 ft (4.9 m).

The fuel efficiency of the PAR-WIG effect vehicle is presented in Figure 9. At a range of 4350 nm (8060 km), the vehicle can deliver 1.2 times more payload weight than fuel weight expended in seas with a 12-ft (3.7-m) significant wave height; this factor is increased to 2.0 in 6.0-ft (1.8-m) seas. For comparison, at this range a C-5A can deliver less than one-half its fuel weight in payload.

The strategic deterrence and antiaircraft mission payloads have the same weight (Tables 3 and 4); hence, performance for these two missions is identical. Figure 10 presents this performance. In 12-ft (3.7-m) significant wave height conditions, the vehicle could cruise out 2000 nm (3700 km), loiter ten days with ten 100 nm (185 km) dashes and return; seventeen dashes could be completed with the same time on station if the seas were at a 6.0-ft (1.8-m) significant wave height. Significantly longer times on station are possible with shorter radii of action.

CONCLUSIONS

This study was conducted to show the potential performance of a PAR-WIG effect vehicle, assuming that the PAR-WIG effect technology, as currently projected, will be available about 1990. Several critical technical assumptions have been made:

1. Speed/height/sea state operating limits (which determine the cruise altitude design rule) are not prohibitive.
2. Wave impact loads, ride quality, and handling quality are acceptable in various wind and sea conditions.
3. Unique component development (wing flaps, endplates, etc) is possible.
4. Seakeeping loads and motions are acceptable.
5. On-off PAR Cushion Transition is possible.

Furthermore, the development of light-weight composite materials and large, low pressure ratio variable pitch fans (both capable of long-term exposure in the marine environment) have been assumed. Given these assumptions, the development of a large PAR-WIG effect vehicle would be possible, and the potential performance of such a vehicle would be impressive. That the combination of efficient ground effect cruise and takeoff and landing on a PAR cushion and the ability to loiter afloat in the open ocean can result in a vehicle with broad military application and high energy efficiency.

The performance of a large PAR-WIG effect vehicle has been the only concern of this study. No consideration has been given to development, operational, or support costs other than a qualitative attempt to minimize development costs by using a common airframe. The large size of the vehicle and the development risks associated with this type of vehicle would probably result in relatively high costs for development and operation. Cost-benefit studies must be conducted prior to the large-scale development of a PAR-WIG effect vehicle. These studies can be accurately conducted only when the PAR-WIG effect technology has advanced to a point where performance limits are known and conceptual vehicle component designs are available. To date, PAR-WIG effect technology has not advanced to this extent; therefore further technology development is required before subjecting the PAR-WIG effect vehicle to quantitative cost-benefit analyses.

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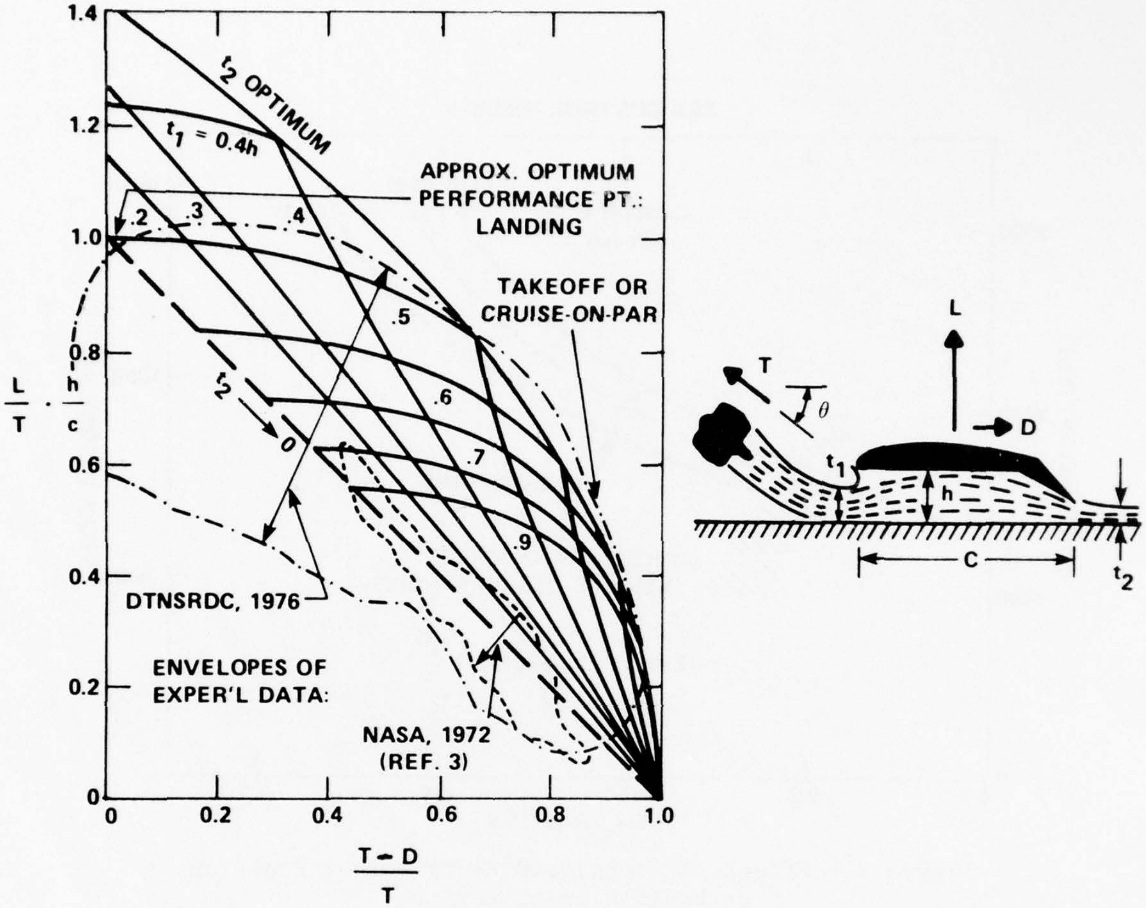


Figure 1 - Power-Augmented-Ram Wing-in-Ground Effect

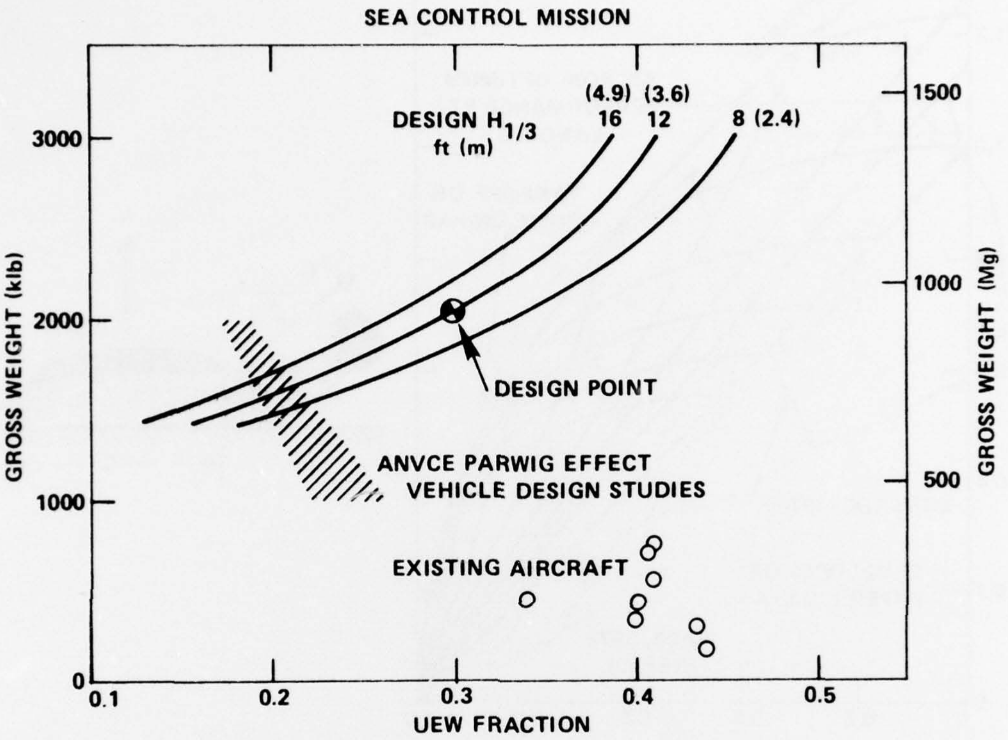


Figure 2 - Effect of Unequipped Empty Weight Fraction on Vehicle Gross Weight

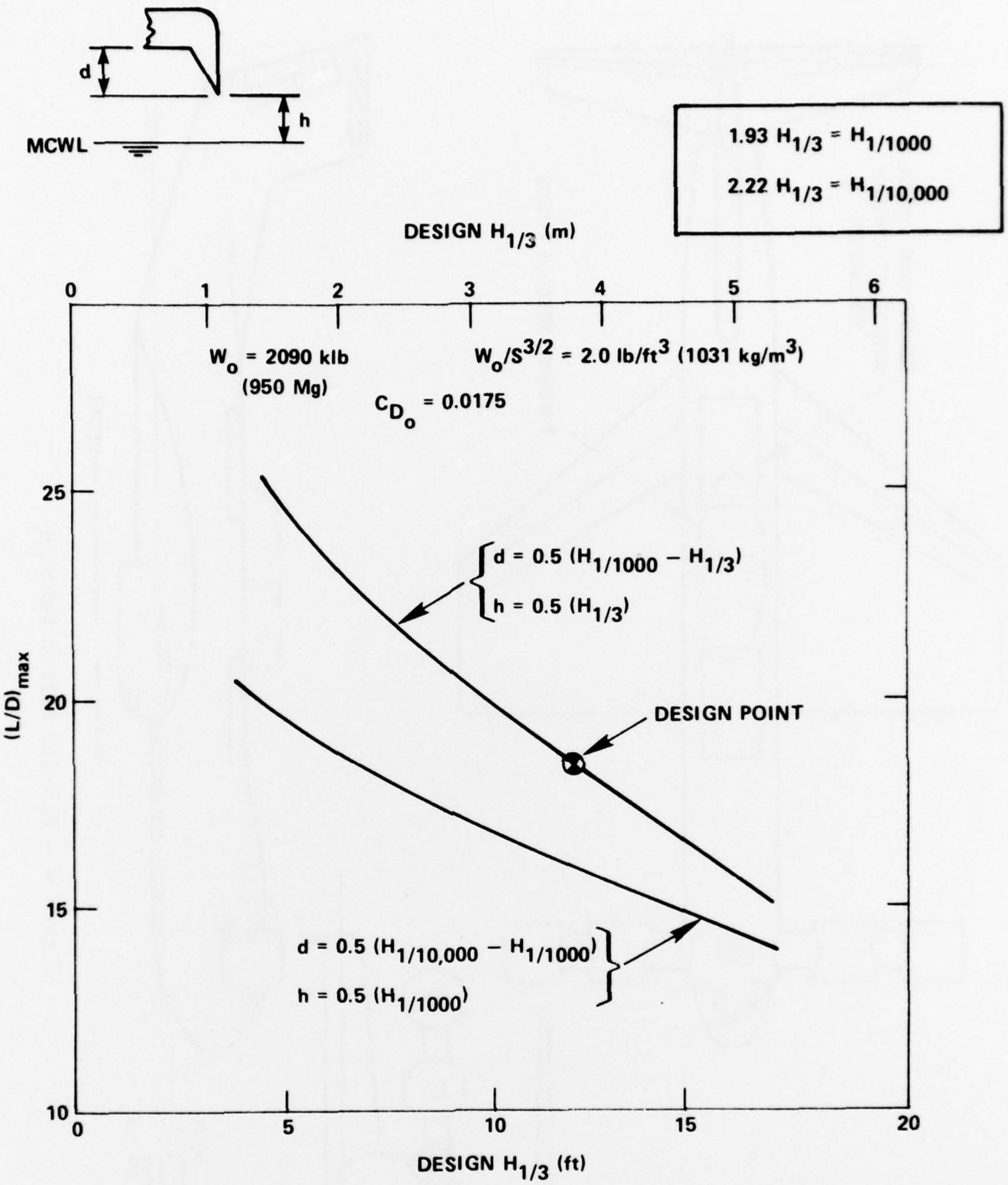


Figure 3 - Effect of Design Sea Conditions and Design Rules on Aerodynamic Efficiency

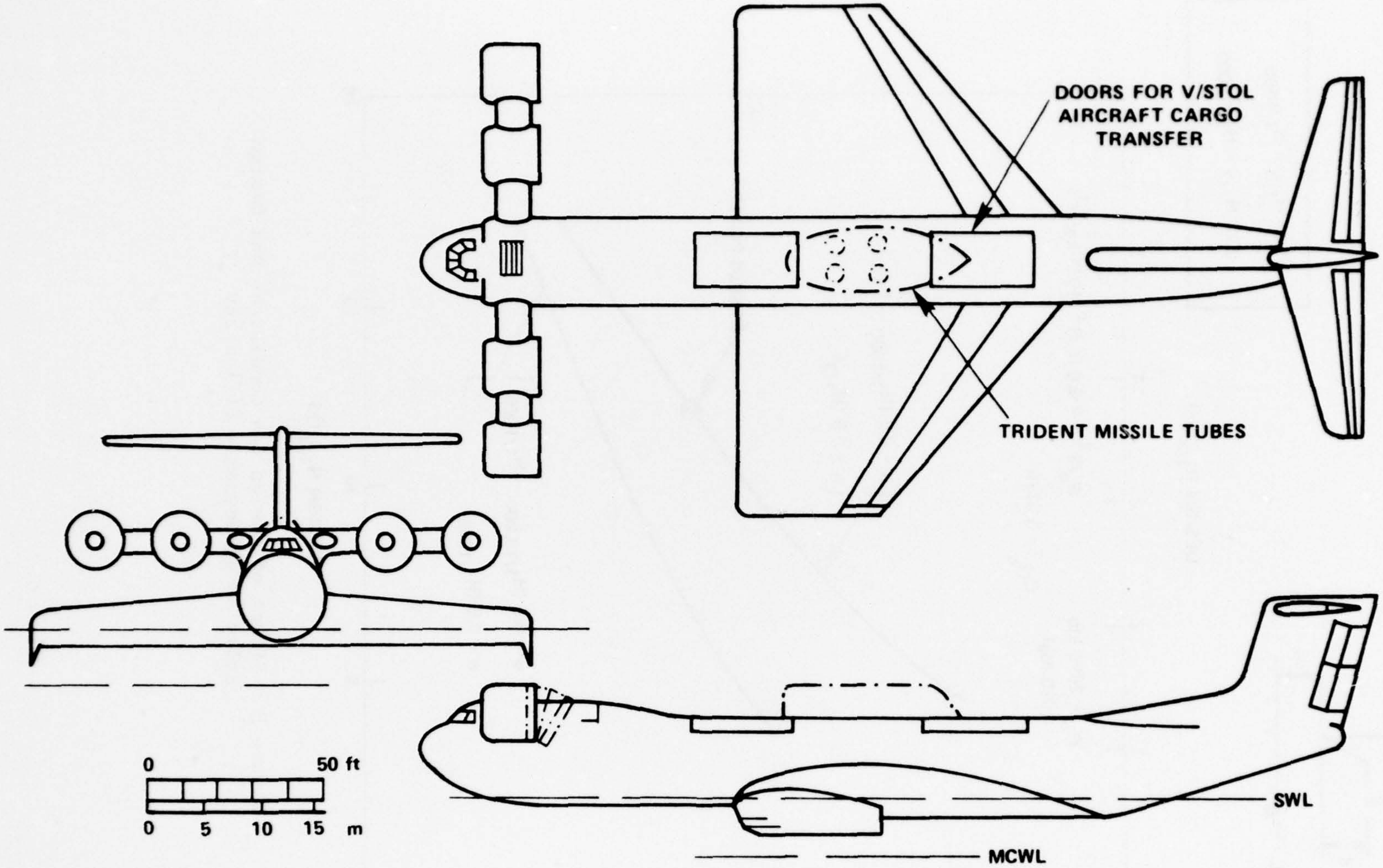


Figure 4 - PAR-WIG Effect Vehicle

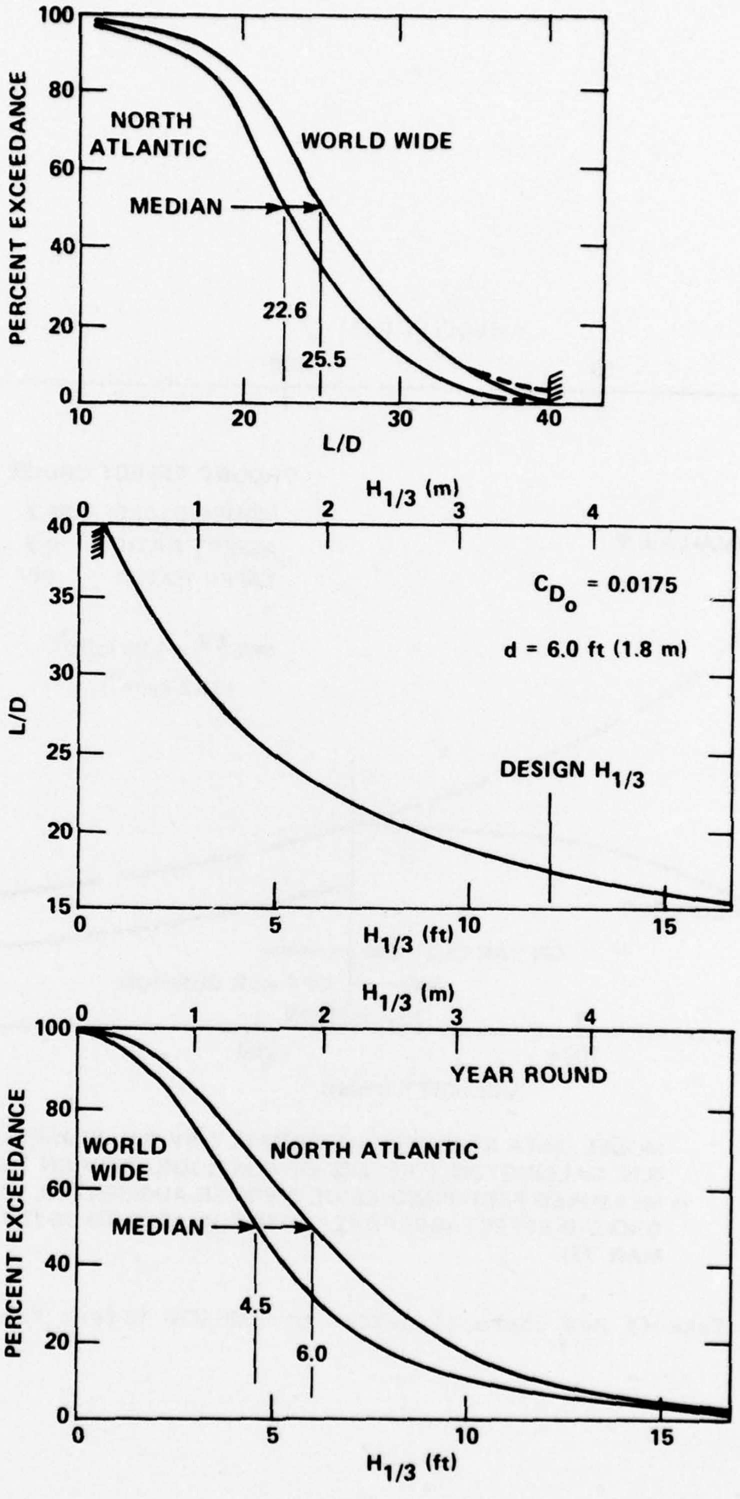
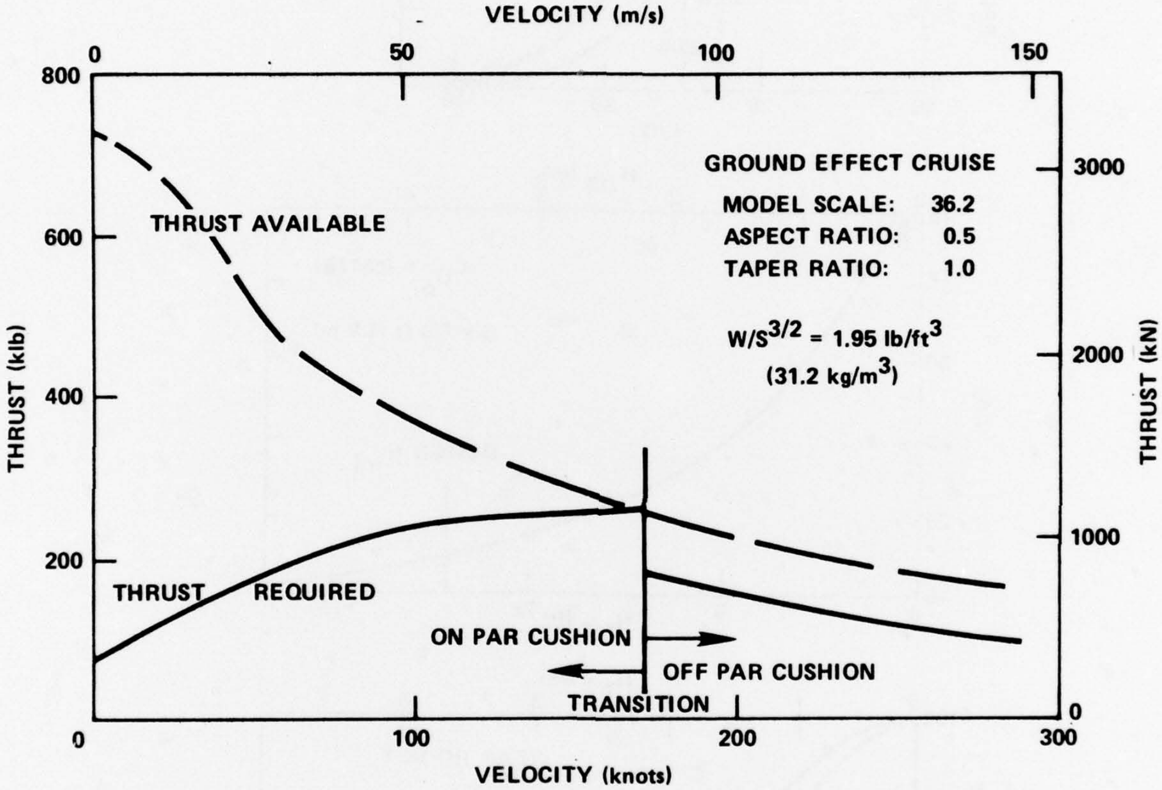


Figure 5 - Effect of Off-Design Sea Conditions on Aerodynamic Efficiency



MODEL DATA REPORTED INFORMALLY BY G.H. KIDWELL AND R.W. GALLINGTON, ("EFFECT OF CONFIGURATION ON THE MEASURED PERFORMANCE OF A POWER-AUGMENTED, WING-IN-GROUND EFFECT AIRCRAFT," DTNSRDC ASED TM 16-77-115, MAR '77).

Figure 6 - Takeoff Run Characteristics of PAR-WIG Effect Vehicles

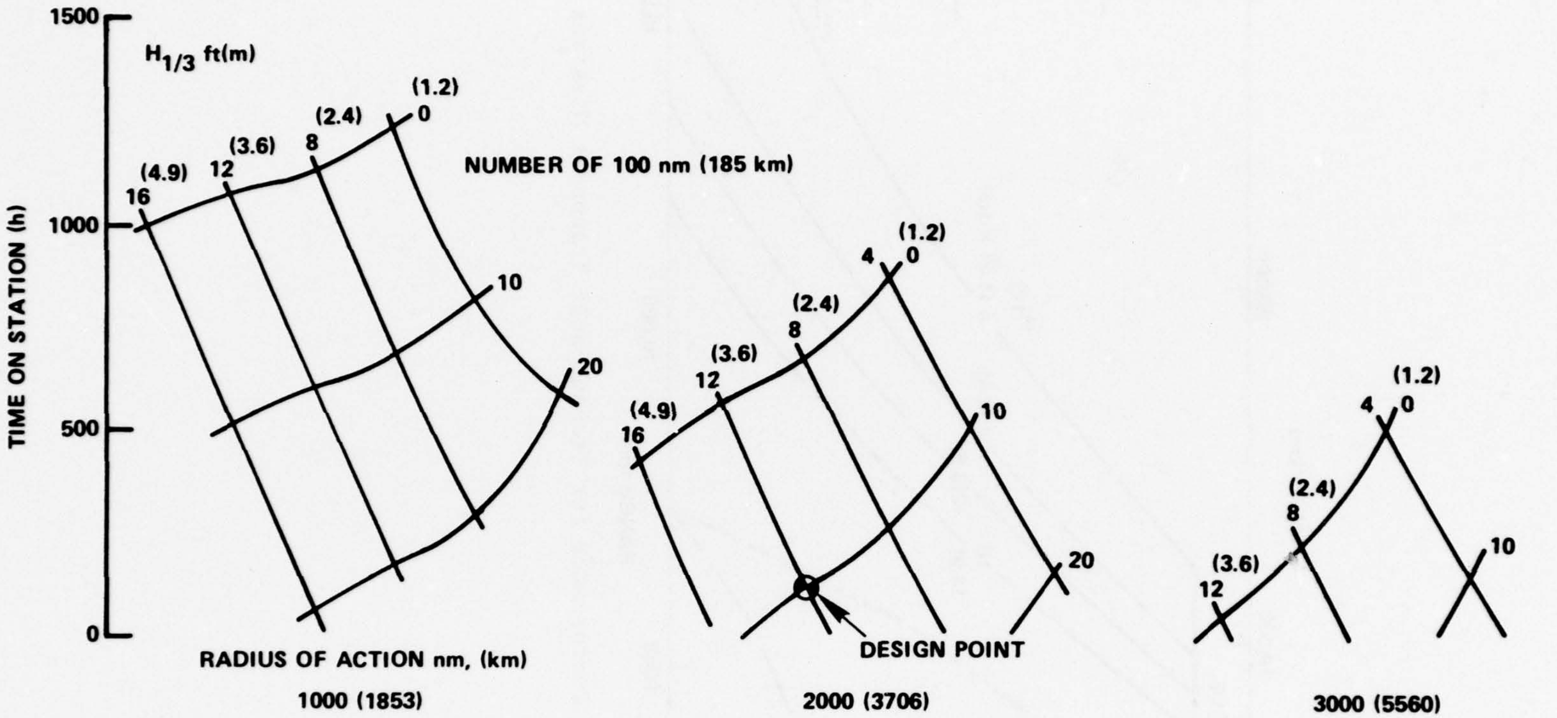


Figure 7 - Vehicle Performance for Sea Control Missions

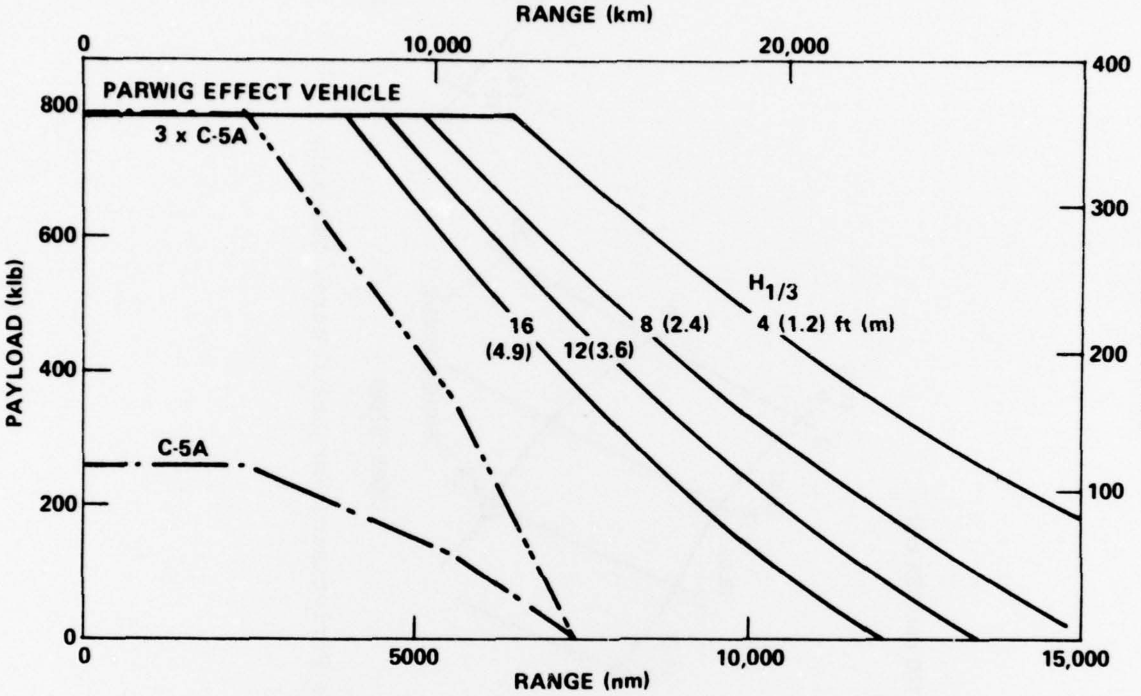


Figure 8 - Vehicle Performance for Transoceanic Transport Missions

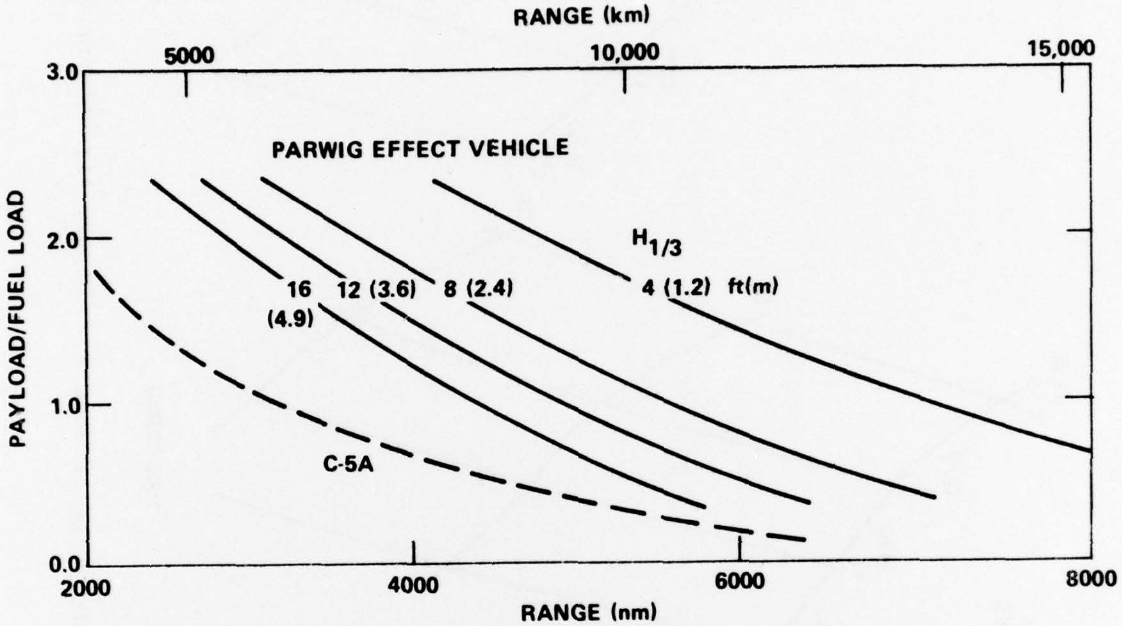


Figure 9 - Vehicle Energy Efficiency for Transport Missions

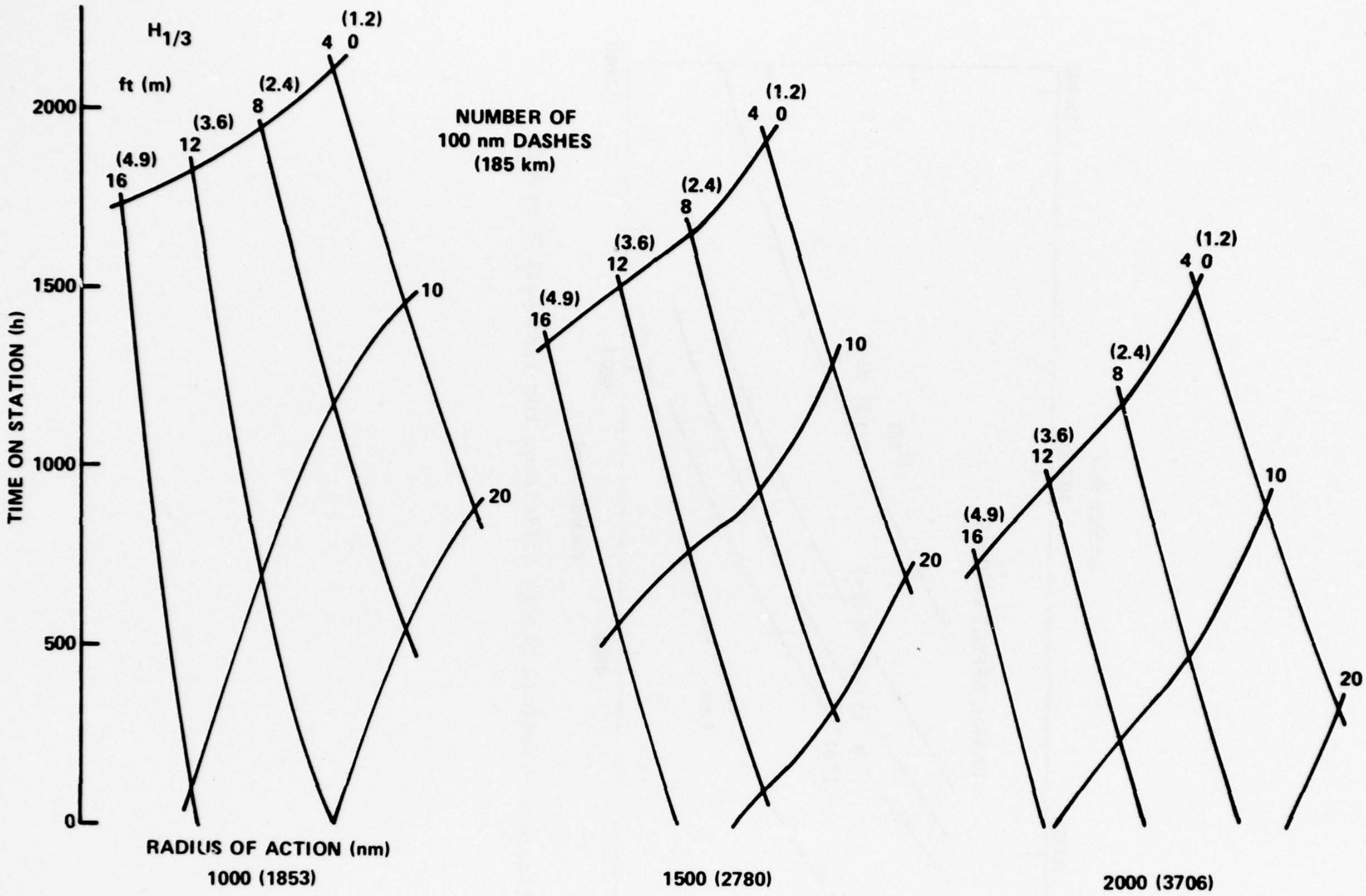


Figure 10 - Vehicle Performance for Strategic Deterrence and Theater Air Defense Missions

TABLE 1 - DESIGN PAYLOAD AND OPERATING ITEMS FOR SEA CONTROL MISSION

		(lb)*	(kg)
Payload	4 V/STOL Aircraft	100.0	45.5
	Aircraft Weapons & Sensors	135.0	61.3
	Aircraft Support	100.0	45.5
	Onboard Avionics	40.0	18.2
		375.0	170.5
Operating Items	Crew (20)	8.0	3.6
	Provisions	10.0	4.5
	Furnishings	40.0	18.2
	V/STOL Aircraft Fuel	200.0	90.9
		258.0	117.2
Total Fixed Weight		633.0	287.7

* All weights are in thousand lb (kg).

TABLE 2 - PAYLOAD AND OPERATING ITEMS FOR TRANSOCEANIC TRANSPORT MISSION

		(lb)*	(kg)
Payload	Avionics	3.5	1.6
		3.5	1.6
Operating Items	Crew (6)	1.2	0.5
	Provisions	0.3	0.1
	Furnishings	10.0	4.5
		11.5	5.1
Total Fixed Weight		15.0	6.7

* All weights are in thousand lb (kg).

TABLE 3 - PAYLOAD AND OPERATING ITEMS FOR STRATEGIC DETERRENCE MISSION

		(lb)*	(kg)
Payload	4 TRIDENT Missiles	280.0	127.3
	Launcher	200.0	90.9
	Avionics	40.0	18.2
		520.0	236.4
Operating Items	Crew (20)	4.0	1.8
	Provisions	33.0	15.0
	Furnishings	30.0	13.6
		67.0	30.4
Total Fixed Weight		587.0	266.8

* All weights are in thousand lb (kg).

TABLE 4 - PAYLOAD AND OPERATING ITEMS FOR THEATER AIR DEFENSE MISSION

	(lb)*	(kg)
Payload		
180 AA Missiles	365.0	166.0
Missile Launcher	50.0	22.7
Missile Support	50.0	22.7
Avionics	55.0	25.0
	520.0	236.4
Operating Items		
Crew (20)	4.0	1.8
Provisions	33.0	15.0
Furnishings	30.0	13.6
	67.0	30.4
Total Fixed Weight	587.0	266.8

* All weights are in thousand lb (kg).

TABLE 5 - PAR-WIG EFFECT VEHICLE CHARACTERISTICS

Gross Weight	2,090,000 lb (950,000 kg)
Unequipped Empty Weight	627,000 lb (285,000 kg)
Wing Area	10,225 ft (950 m)
Wing Aspect Ratio	2.0
Wing Taper Ratio	0.50
Endplate Depth	6.0 ft (1.8 m)
Fuselage Diameter	22 ft (6.7 m)
Static Thrust/Weight	0.35 (sea level)
Installed Power	183,900 hp (137,100 kw)*
Fan Pressure Ratio	1.27**
Cruise Speed	180-330 knots (93-170 m/s)
Maximum Speed	400 knots (206 m/s)
Cruise L/D	18.5
Cruise $H_{1/3}$	12.0 ft (3.7 m)
Maximum Operating $H_{1/3}$	16.0 ft (6.7 m)

* Six engines with 30,650 hp (22,850 kw);

** Four 116-ft (4.9 m) diameter fans