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The remotely piloted seaplane (RPS) for antisubmarine warfare (ASW) is a small, relatively inexpensive, unmanned water-based aircraft that provides excellent time-on-station performance, tactical flexibility, and energy efficiency. In the 1980's, command, control, and communications ($C^3$) technology will be available which will permit a seaplane to be

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designed with no crew on board. Such a vehicle would be capable of performing military ASW operations in open ocean areas while taking full advantage of its waterborne capability. The removal of a crew from the seaplane has a substantial impact on the aircraft design. A RPS having a 1200 n mi radius of action and 72 hr time-on-station would weigh only 34,800 lb (15,764 kgm) and would incorporate a 5300 lb (2400 kg) ASW payload.

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# ABSTRACT

The remotely piloted seaplane (RPS) for antisubmarine warfare (ASW) is a small, relatively inexpensive, unmanned water-based aircraft that provides excellent time-on-station performance, tactical flexibility, and energy efficiency. In the 1980's, command, control, and communications ($C^3$) technology will be available which will permit a seaplane to be designed with no crew on board. Such a vehicle would be capable of performing military ASW operations in open ocean areas while taking full advantage of its waterborne capability. The removal of a crew from the seaplane has a substantial impact on the aircraft design. A RPS having a 1200 n mi radius of action and 72 hr time-on-station would weigh only 34,800 lb (15,764 kgm) and would incorporate a 5300 lb (2400 kg) ASW payload.

# INTRODUCTION

Seaplanes were first designed with hydrodynamically shaped hulls in order to provide basing flexibility and an emergency landing capability for long over-water flights. In these early days of aviation these types of aircraft, called seaplanes, were limited to operations in calm water except in emergencies. The addition of the hull resulted in higher structural weight and higher aerodynamic drag compared to land-based aircraft. As aeronautical technology advanced, airfields became more numerous and aircraft systems became more reliable. Aircraft performance also improved making the penalties for waterborne operation proportionally greater. These factors led to the demise of the seaplane in the 1950's.

At that time, the Navy began to investigate more innovative seaplane applications. Studies showed that seaplanes would be very useful in tactical naval applications if operations could be conducted in rough water and if the aircraft could loiter afloat for extended periods of time. An extensive research and development effort was initiated to achieve this capability. High-lift aerodynamics, refined hull designs, and hydroskis (and foils) were found to permit routine takeoffs and landings in relatively rough water. Vertical (small waterplane area) floats which supported the seaplane hull above the ocean surface were developed; seakeeping motions with this arrangement were found to be substantially lower than could be achieved with a more conventional hull arrangement. These advances, however, required further compromises in aircraft performance and studies showed that seaplanes using this advanced technology would still not be competitive with land-based aircraft. For this reason, the Navy terminated its seaplane research and development effort in the late 1960's.

In 1975, the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) initiated studies to assess the impact of evolving technologies on the potential performance of advanced manned seaplanes. This effort was supported as part of the Advanced Naval Vehicle Concepts Evaluation (ANVCE). The seaplane hydrodynamics data base was expanded and several advanced seaplane designs were generated and evaluated. Results from these studies showed that the manned seaplane is, and will remain by most measures, uncompetitive with land-based aircraft for tactical naval operations.[1*]

A review of the data generated for the ANVCE program revealed that the limited performance characteristic of all seaplane designs was a result of the design constraints imposed by the presence of a crew aboard the aircraft. The presence of a crew limits the time-on-station performance of a seaplane while afloat. Habitability requirements for vehicle motion limit the duration a seaplane with a single crew can remain on station. The addition of a second crew can allow the seaplane to loiter for longer periods, but a severe design penalty is incurred to support the extra personnel.

In the 1980's, command, control, and communications ($C^3$) technology will be available which will permit a seaplane to be designed with no crew on board. Such a vehicle, called a remotely piloted seaplane (RPS), would be capable of performing military operations in open ocean areas while taking full advantage of its waterborne capability. The removal of a crew from the seaplane has a substantial impact on the aircraft design. Figure 1 shows the reduction in vehicle size which can result from employing the RPS concept. In the figure, both aircraft have the same performance (1200 n mi radius of action and 72 hr time-on-station) and both have similar payloads. The manned seaplane, using advanced technology, would

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*A complete listing of references is given on page 19.

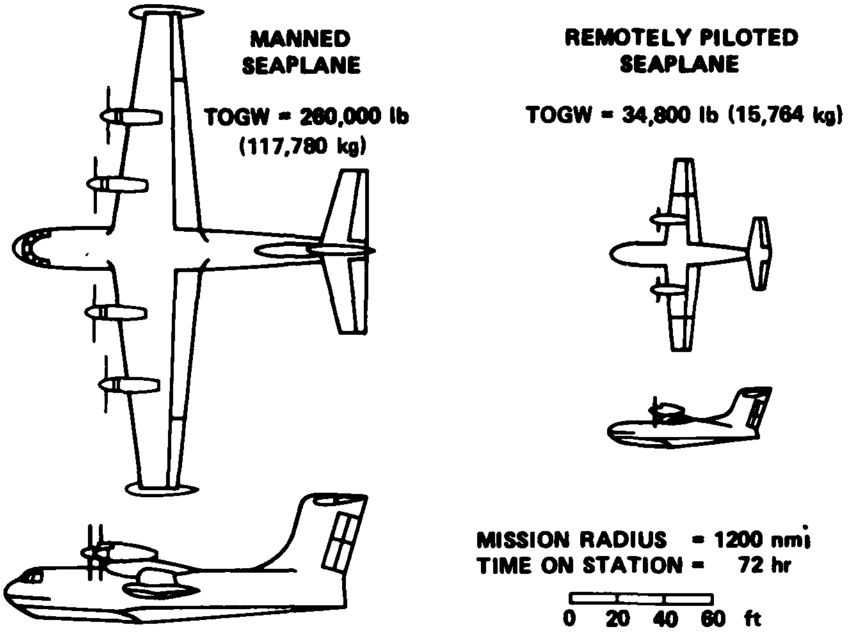


Figure 1 - Advanced Antisubmarine Warfare Seaplane Concepts

weigh approximately 260,000 lb (117,780 kg); an RPS with similar capability would weigh only 34,800 lb (15,764 kg). This reduction in size is solely a result of incorporating remote piloting capability.

The remote piloting capability results in an aircraft with excellent time-on-station performance; this performance being limited by reliability of the aircraft systems. An RPS would be small, compared to most Navy aircraft and would probably be procured in large numbers, thus reducing acquisition costs. Increased tactical flexibility would also result. Since an RPS would loiter on the sea surface, a reduction in fleet fuel requirements would result. This sea loitering capability makes the RPS an ideal sensor platform for submarine sensors. Better usage of highly skilled personnel (e.g., sensor operators) would be possible with the RPS because information from aircraft located large distances apart could be presented to a single individual. With these features, the RPS concept is an attractive candidate to perform tactical naval ASW operations in remote ocean areas.

# ANTISUBMARINE WARFARE APPLICATIONS

A review of the potential military applications of advanced manned seaplanes showed that the potential benefits of seaplane operation could not be fully exploited because of the constraints imposed by the presence of the crew aboard the aircraft. This situation led to the formulation of the remotely piloted seaplane (RPS) concept.

The RPS is viewed as a sea control vehicle which would be used in conjunction with manned aircraft loitering at high altitude and/or ground controllers communicating via satellite.

The features of the RPS concept make it attractive for operations where military payloads need to be placed on station for extended periods. Table 1 lists the seven tasks which are required for a complete sea control capability. In that list, only three tasks: airborne early warning (AEW); surface ship surveillance; and command, control, and communications ($C^3$) require a vehicle which has a continuous high altitude loiter capability. All prosecution tasks, independent of the nature of the threat (e.g., submarine versus aircraft), only require an intermittent airborne capability. The RPS is well suited for these operations. The submarine surveillance and contact identification task requires the vehicle (or at least the sensor) to be in continuous contact with the water. The RPS is a prime candidate vehicle for this operation.

Using this vehicle philosophy, a sea control system can be envisioned in which a fleet of ASW equipped RPS aircraft can be deployed under the cover and control of a long endurance AEW/$C^3$ aircraft. For most operations it seems practical for this aircraft to be manned and to have all RPS control functions. This manned aircraft could pass off control of the RPS fleet (which would be loitering on the ocean surface) to a replacement aircraft as required by crew or fuel limitations. The arrangement of using a fleet of RPS aircraft with a manned AEW/$C^3$ aircraft in the theater of operations would be practical during periods of near or open hostility. A sea control system would involve substantial reductions in fuel requirements since the primary weaponry would be aboard the RPS aircraft burning little fuel while loitering.

TABLE 1 - REQUIRED SEA CONTROL TASKS

| | |
|---|---|
| Command, Control, and Communications ($C^3$) | Continuous High Altitude Loiter<br>or<br>Secure Long Range RF Link |
| Airborne Early Warning (AEW)<br>Surface Surveillance | Continuous High Altitutde Loiter |
| Antiaircraft Attack<br>Antiship Targetting and Attack | Intermittent Airborne Flight |
| Antisubmarine Surveillance | Continuous Sensor Contact with Water |
| Antisubmarine Contact Investigation | Intermittent Airborne Flight, Sensor Contact |

In peacetime operations, the primary sea control task for the Navy is to maintain surveillance of enemy submarines and ships in order to insure consistent favorable initial conditions to any conflict. For this operation, the RPS could be used as a long range submarine surveillance vehicle. The RPS aircraft would be deployed singly or in small numbers to maintain contact with an enemy submarine. The RPS could be controlled via satellite; sensor information could be transmitted through the same data link or recorded. Acoustic submarine intelligence can also be gathered in this manner. Ship surveillance could be accomplished in a similar manner; the RPS provides a means of identifying surface and subsurface vessels. The use of an RPS for identification and targeting would permit the potential of long-range weapons to be fully realized.

## CONCEPTUAL REMOTELY PILOTED SEAPLANE DESIGNS

In order to quantify the potential benefits of the RPS concept, a preliminary design has been developed. The design is based upon the aforementioned operational concept in which the RPS would perform prosecution tasks against submarine threats or perform submarine surveillance. For operations in a hostile environment, the RPS fleet is assumed to be controlled by a manned AEW/$C^3$ aircraft loitering at high altitude. In a benign environment, shore-based control via satellite control could be employed.

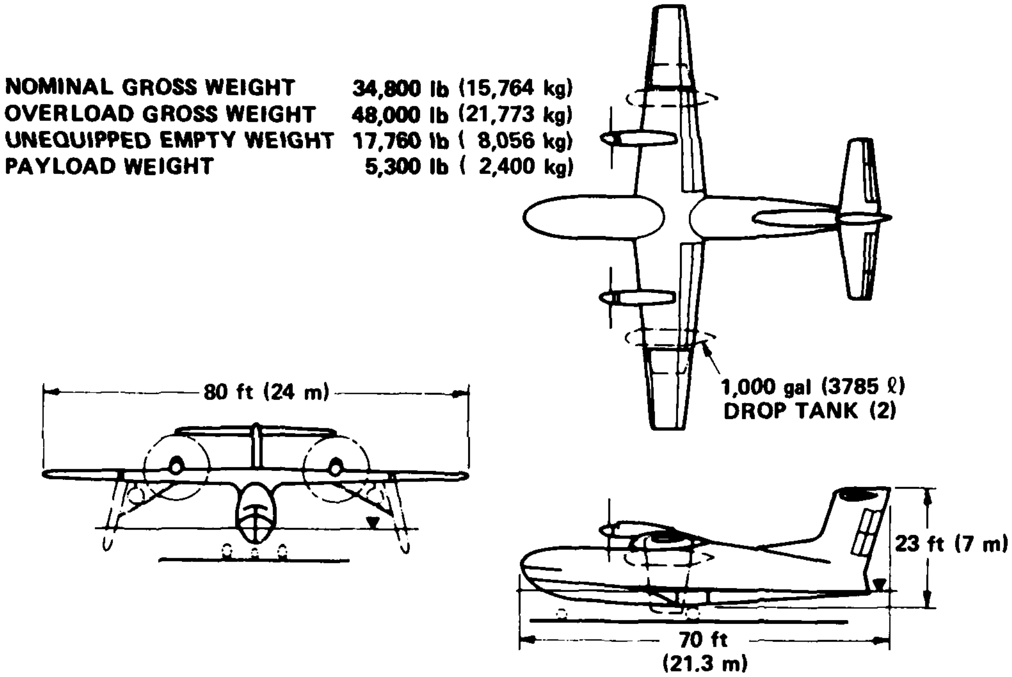
Table 2 presents two candidate RPS payloads for ASW. The missions are contact investigation (ASW/CI) which include 40 sonobuoys, 4 advanced lightweight torpedoes, and a surface surveillance (ASW/SURV) system including a towed acoustic array. A maximum payload of 5300 lb (2400 kg) was assumed.

The ASW aircraft was designed for a radius of action of 1200 n mi with 72 hr time-on-station (loitering on the water); while on station the aircraft is required to takeoff and dash 200 n mi three times. The design assumes land basing and control from either overhead aircraft or ground stations. A technology freeze in 1985 is assumed with an initial operational capability in 1992-1994.[2]

### TABLE 2 - CANDIDATE REMOTELY PILOTED SEAPLANE PAYLOADS FOR ANTISUBMARINE WARFARE MISSIONS

| | ASW/CI (lb) ((kg)) | ASW/SURV (lb) ((kg)) |
|---|---|---|
| $C^3$/NAV | 300 (136) | 300 (136) |
| ASW/CI Equipment | 300 (136) | |
| ASW/SURV Equipment | | 1600 (725) |
| Radar | 100 (45) | 100 (45) |
| FLIR/VIDEO | 100 (45) | 100 (45) |
| ESM/ECM | 100 (45) | 200 (90) |
| Acoustic Array (Retrievable) | | 1500 (680) |
| Sonobuoys | 40-1200 (544) | |
| Advanced Lightweight Torpedo | 4-3200 (1450) | |
| Total Payload Weight | 5300 (2401) | 3800 (1721) |

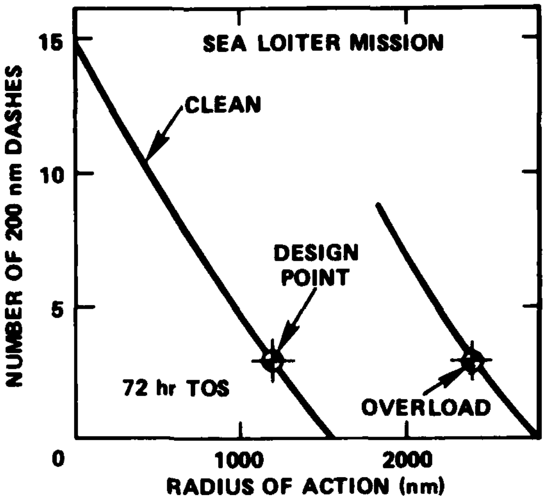
Figure 2 shows the general arrangement of the RPS aircraft. The seaplane weighs 34,800 lb (15,764 kg) with a wing loading of 55 $lb/ft^2$ (268 $kg/m^2$). Two turboprop engines mounted on the wings provide thrust; the static thrust-to-weight ratio is 0.6. The RPS has an advanced flap system for high lift during takeoff and landing. The aircraft stall speed is 45 knots. Two 1000-gal (3785 liters) drop tanks are provided to permit overload operations. The aircraft is amphibious and is assumed to be shore-based and supported.



| | |
|---|---|
| **NOMINAL GROSS WEIGHT** | **34,800 lb (15,764 kg)** |
| **OVERLOAD GROSS WEIGHT** | **48,000 lb (21,773 kg)** |
| **UNEQUIPPED EMPTY WEIGHT** | **17,760 lb ( 8,056 kg)** |
| **PAYLOAD WEIGHT** | **5,300 lb ( 2,400 kg)** |

Figure 2 - General Arrangement Remotely Piloted Seaplane

Figure 3 presents the RPS performance. The aircraft fuel can be allocated to permit greater on-station capability at the cost of range. The time-on-station of 72 hr is considered a function of avionics reliability and has little impact on airborne performance. Power while on station (i.e., afloat) is supplied by a diesel powered system. This system offers low inlet airflow requirements and low fuel consumption. The radius of action can be increased to 2,400 n mi by using the drop tanks with the RPS at a takeoff weight of 48,000 lb (21,773 kg).



**OVERLOAD GROSS WEIGHT 48,000 lb (21,773 kg)**
**NOMINAL GROSS WEIGHT (CLEAN) 34,800 lb (15,764 kg)**

Figure 3 - Remotely Piloted Seaplane Performance

A comparison of a conceptual RPS force and other more conventional sea control forces is presented in Table 3. The comparison is based on a tactical situation in which a barrier must be maintained for a relatively short period. The RPS force is assumed to constantly require a manned AEW/$C^3$ aircraft (a conservative assumption). For this example, an advanced version of the P-3 ASW aircraft has been hypothesized. The threat is assumed to be of low density but of unknown character (surface ship or submarine). To counter this threat, an RPS force of five aircraft and one Lockheed P-3 aircraft are required on station continually. An extra RPS is deployed (i.e., six in total) to account for the unknown availability while loitering.

Equally capable forces include a group of three surface ships (one AEGIS ship with two escorts) or a P-3 force with four aircraft continually on station. For this example, the P-3 aircraft are assumed to be different versions (AEW/$C^3$--air, surface, and submarine attack, in order to provide

TABLE 3 - POTENTIAL COST AND MANPOWER SAVINGS WITH REMOTELY PILOTED SEAPLANE/P-3 FORCE

Short-Term Barrier against Air, Surface, and Submarine Threats
50 n mi × 200 n mi
1200 n mi from Base

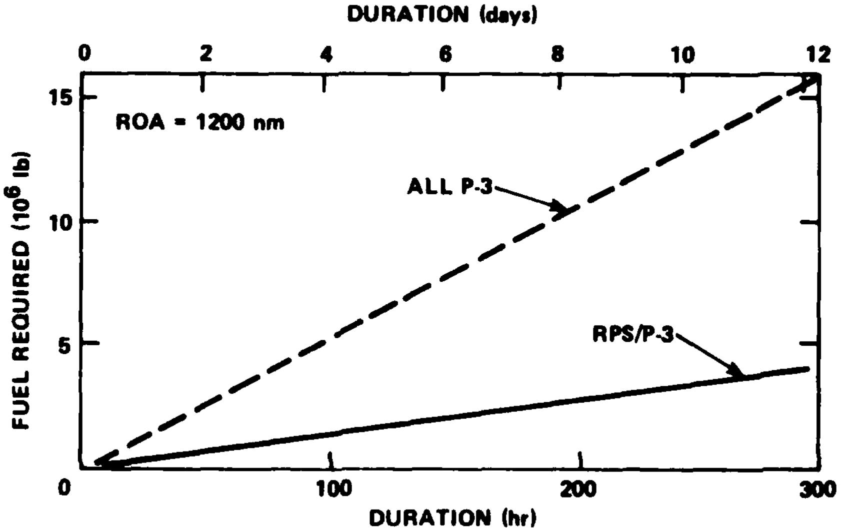
| | Possible Sea Control Forces | | |
|---|---|---|---|
| | Surface Ships | All P-3 Force* | RPS/P-3 Force** |
| Forces on Station | 1 CG-47<br>1 DD-963<br>1 FFG-7 | 4 P-3 | 6 RPS |
| Total Force Required (No Attrition) | 1 CG-47<br>1 DD-963<br>1 FFG-7 | 16 P-3 | 12 RPS<br>4 P-3 |
| Total Manpower Required | 742 | 648 | 408 |
| Total Acquisition Cost (Millions of Dollars, 1977) | 1280 | 480 | 156 |

*Mixture of advanced P-3 aircraft types (AEW/$C^3$, ASW, SUW, and AAW).

**All advanced AEW/$C^3$ P-3 aircraft, 5 RPS and 1 reserve RPS on station, includes 360 ground support personnel.

defense against any anticipated threat). Table 3 shows that the RPS/P-3 force has an acquisition cost (all aircraft) of one-third that of the P-3 force and one-eighth that of the surface ship force. The RPS force, including ground support personnel requires two-thirds the personnel of the all P-3 force and one-half that of the ship force. Figure 4 shows that the RPS/P-3 force would consume 73 percent less fuel than the comparable P-3 force. These figures suggest that the RPS force would have lower life cycle costs than comparable sea control forces provided the RPS aircraft operates as anticipated. The aircraft is designed with low stall speed and high thrust; operation in 16 ft significant wave heights should be possible. This rough water capability will permit operations 90 percent of the time.

| | FORCE MIX | |
|---|---|---|
| | ALL P-3* | RPS/P-3** |
| AIRCRAFT ON STATION | 4 P-3 | 6 RPS†<br>1 P-3 |
| TOTAL REQUIRED AIRCRAFT | 16 P-3 | 12 RPS<br>4 P-3 |



* MIXTURE OF ADVANCED P-3 AIRCRAFT TYPES (AEW/C$^3$, ASW, SUW, AND AAW); ONE OF EACH

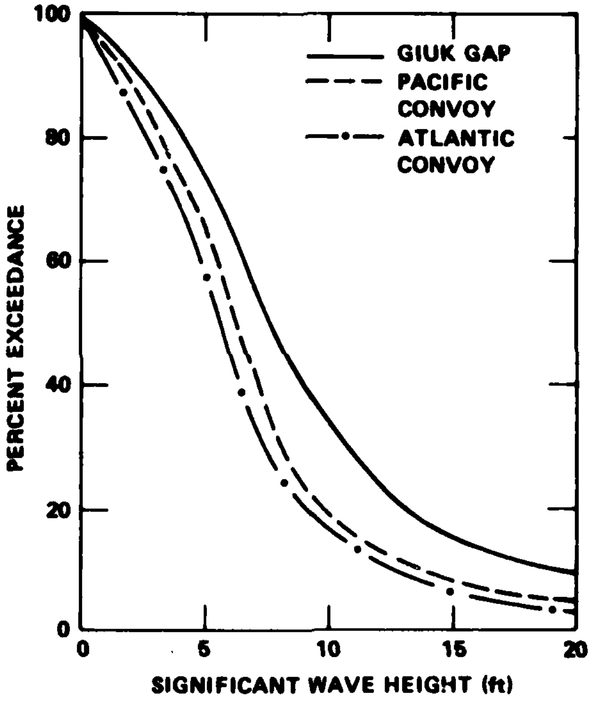
** ALL ADVANCED AEW/C$^3$ P-3 AIRCRAFT

† 5 RPS AND 1 RESERVE RPS ON STATION

Figure 4 - Energy Comparison of Remotely Piloted Seaplane versus P-3 Forces

## TECHNICAL CONSIDERATIONS

The feasibility of the RPS concept depends, in large part, on improvements in hydrodynamics and flight control technologies which would permit routine operations in rough water to be conducted with relatively small seaplanes. For reasonable utility, an RPS would have to be capable of operations in upper State 5 seas ($H_{1/3}$ = 12 ft) (3.66 m). Figure 5 shows that with this capability an RPS would be capable of waterborne operations more than 90 percent of the time. Increased utility can be achieved by further increases in sea state rough water capability.



**FROM: PRINCIPLES OF NAVAL ARCHITECTURE, PP 624-625**

Figure 5 - Open Ocean Wave Statistics

### PLANING-OFF

In general terms, the maximum wave heights in which a given seaplane can takeoff or land are a function of the seaplane size, stall speed, and thrust-to-weight ratio. Figure 6 shows the relationship between these

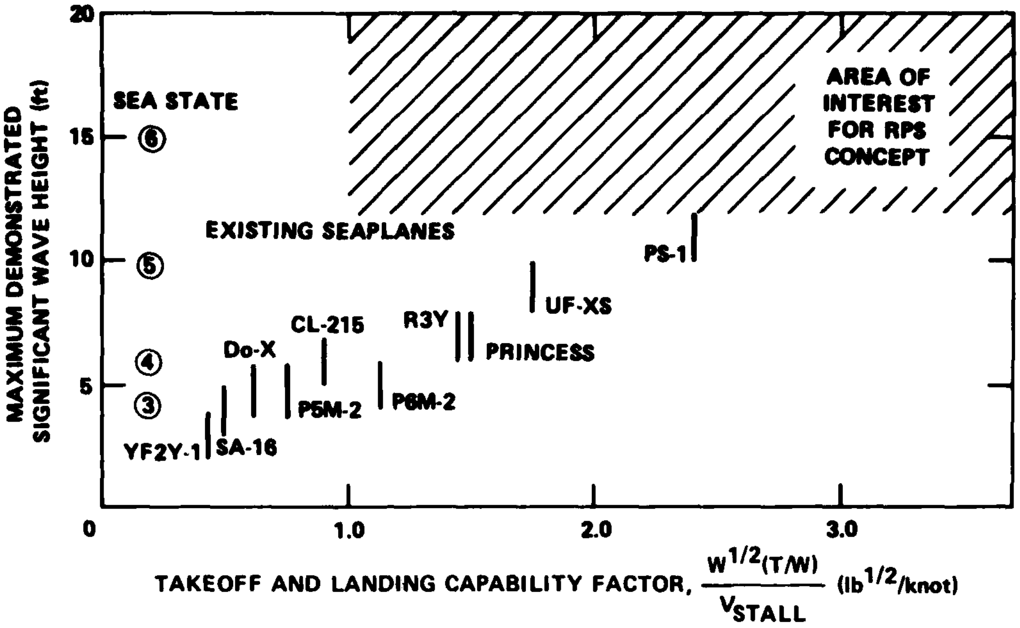


Figure 6 - Seaplane Capabilities in the Open Ocean

variables and the maximum demonstrated significant wave height of several existing manned seaplanes. No seaplane has ever achieved operationally the rough water takeoff and landing capability required for an RPS. To achieve this capability, it is proposed to compensate for the small RPS size with increases in thrust and a reduction in stall speed. An RPS with performance similar to a manned seaplane will be capable of operating in higher waves because of the removal of human habitability considerations. For small RPS aircraft (between 5,000 (2,268) and 50,000 lb (22,680 kg)) an operational capability of upper State 5 seas would require stall speeds between 35 and 60 knots and thrust-to-weight ratios of 0.5 to 0.8.

There is no experience with seaplanes of this size and performance operating in waves characteristic of State 5 seas. Figure 7 presents a numerically predicted takeoff of a relatively large (34,800 lb (15,764 kg)) RPS in a State 4 sea. The seaplane with this high thrust and lift capability takes off in less than 6 seconds. During the takeoff, the aircraft actually becomes airborne at a speed below the stall speed, accelerates,

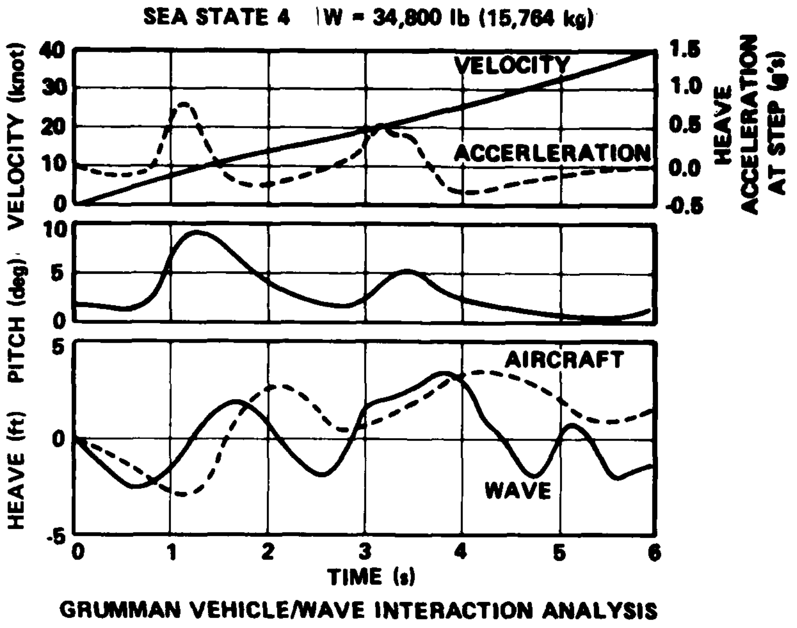


Figure 7 - Planing-Off Dynamics

and finally achieves sufficient speed to climb. This takeoff procedure is called planing-off; it has been demonstrated, to a limited extent in manned seaplane UF-XS (a modified HU-16) and PS-1 STOL seaplanes.[2,3]

The dynamics of the planing-off phenomenon, however, are not well understood. The existence of any limits on maximum sea state as a function of lift and thrust performance must be determined. The benefits of taking off in short distances (and time) have not been fully demonstrated. For instance, the short takeoff (or landing) run would permit hull porpoising stability requirements to be relaxed; the extent to which these requirements can be relaxed must be determined. There is also a considerable technology base of advanced seaplane hull designs and load alleviation and lift augmentation devices which could reduce the RPS lift and thrust requirements.

## FLIGHT CONTROL SYSTEM

The development of an RPS flight control system is essential to the development of the RPS concept. The capability of the control system to perform the takeoff and landing tasks and control the aircraft in flight, has a substantial impact on the overall effectiveness of the RPS concept. It is highly desirable to minimize the information that must be exchanged between the RPS controller and the RPS itself. Minimizing this information exchange will improve system reliability and security.

Current digital flight control technology will permit the RPS to perform airborne tasks with little real-time data exchanged. During takeoff and landing, the information exchange requirements are unclear. Improved understanding of the dynamics of the vehicle during takeoff and landing is needed prior to the design of a flight control system. The RPS takeoff and landing problem is substantially different than automated landings of conventional land-based aircraft. For a seaplane the exact point of touchdown (or lift-off) is not critical, as it is with operations from airfields.

## SEA LOITER

The RPS concept requires the capability of the aircraft to loiter for extended periods afloat in rough water. As with the takeoff and landing situation, an ability to operate in upper State 5 seas is necessary for acceptable RPS utility. Studies have shown that small vehicles can loiter in such high sea states with acceptable motions and load.[1] This capability is achieved by designing the vehicle to follow the wave contours in phase; this can be achieved by a design with large waterplane area (i.e., shallow draft) and low moments of inertia. The effect of these characteristics, along with the relatively low vehicle weight, is to increase the vehicle's natural frequencies to a point where the encounter sea conditions cannot resonate the vehicle (Figure 8). For RPS applications, this wave surface following results in motions which do not produce slamming conditions. Computer simulations have confirmed this concept.[4]

Figure 9 presents numerically predicted motions of an RPS while afloat. The motions would be intolerable for a human crew for periods longer than a few hours. The RPS, however, has no habitability constraint and seakeeping loads would be low enough to allow loitering for periods as

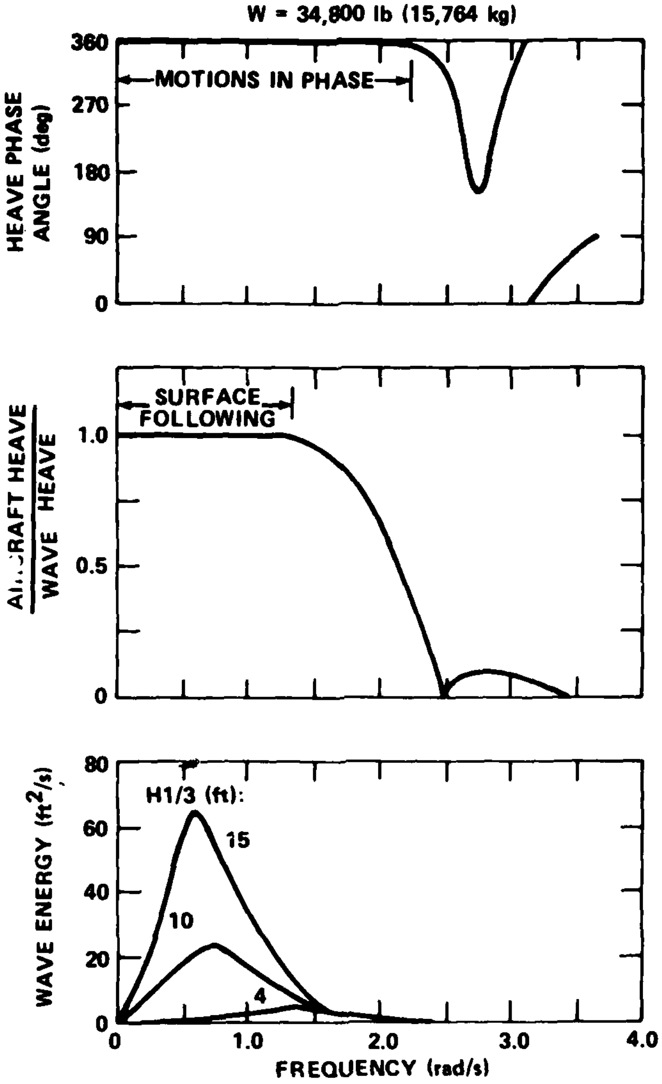

W = 34,800 lb (15,764 kg)

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Figure 8 - Seaplane Seakeeping Motions

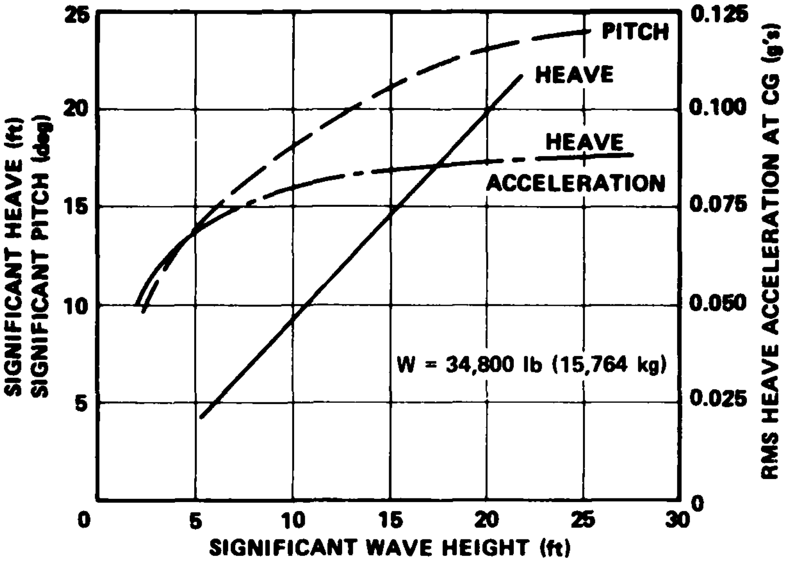

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Figure 9 - Seaplane Dynamics While Wave Following

long as needed. There is little analytical or experimental background with this approach to seakeeping, and further work is required to define hydrodynamic design requirements and operational limitations; nevertheless, this does not pose a high risk technical challenge.

## SUMMARY

The RPS is viewed as a sea control vehicle which would be used in conjunction with manned aircraft loitering at high altitude and/or ground controllers communicating via satellite. The RPS is useful in areas where sea control forces are required to counter low density threats. Early analyses have shown substantial cost, fuel, and manpower savings possible with an RPS force.

The RPS offers an ideal vehicle to conduct ASW missions. Its long sea loiter capability provides very high time-on-station for ASW surveillance. Coupling this with the capability to move from one loiter point to another at aircraft speeds provides a versatile vehicle for ASW.

In order to realize these benefits, however, the RPS must be capable of routine operations in at least State 5 seas. Although this capability does not currently exist, recent studies have shown the combination of high thrust and lift, and advanced hull designs can provide this capability. Several critical technical issues have been identified which involve the feasibility of the RPS concept. These issues all involve the ability of the RPS to operate in rough water.

An RPS adapted to the ASW role provides an inexpensive vehicle with excellent time-on-station performance, tactical flexibility, and high energy efficiency.

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