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THE HOVERWING CONCEPT
-
A NEW GENERATION OF HIGH SPEED MARINE CRAFT

Nato Conference
RTO-AVT Symposium
April 7 – 11. 2003
"Novel and Emerging Vehicle and Vehicle Technology Concepts"

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Summary
A WIG craft is a high-speed 'dynamic hovercraft' surface/marine vehicle. Fischer Flugmechanik have undertaken research and development of a second generation Lippisch based concept, the patented 'Hoverwing'. The ability of this type of vehicle to take off in waves of 5% of wingspan in height and cruise efficiently at a height of 10% of wing span makes it feasible that large craft of this configuration can be designed for virtually any operational area. Fischer Flugmechanik/AFD developments now concentrate on the next vessel, the Hoverwing HW-20, which is offered as a paramilitary variant with a cruising speed of 90 knots, a useful load of 2.5 tonnes, and potential to carry up to 13 troops. In addition FF/AFD have also explored concepts for small Interceptor craft and larger craft to carry 50 troops and useful load of 10 tonnes.

The four major innovations embodied in the Hoverwing concept are: (1) The patented lift-off aid, (2) the reduction of 'installed power', (3) the 'blended body' rather than 'stick-with-wings' configuration, (4) the ability to use foldable wings. These innovations combine to enable a heavier load to be carried than would otherwise be possible. They also provide a volume capacity that has the capability to accommodate loads that would not fit into a conventional aircraft, and so would be otherwise difficult to move at high speed.

This paper covers the potential of Hoverwing craft for paramilitary applications, feasibility regarding technical and operational issues, military applications and time schedules to bring the first unit into service.

Introduction

Wing in Ground Effect vehicles (WIG) are an emerging technology that provide a surface transport utility that is between aircraft and existing marine craft, in terms of speed, cost (capital and running) and load carrying capacity. With a cruising speed of circa 90+ knots they are faster than almost all other seagoing craft and over short/medium distances they provide journey times comparable with helicopter and aircraft. Yet they can be built, certified and operated as boats. Skimming above the water but without water contact, they provide efficient long endurance, with no sea motion fatigue, no wake, and have natural stealth. Such vehicles are of potential use in both civil and paramilitary fields.

The joint companies Fischer Flugmechanik/AFD Airfoil Development GmbH (FF/AFD) are one of the pioneers of WIG technology and can trace their heritage back to the 1960s'. FF/AFD have inherited the

ground-effect stabilisation technology originally put forward by the renowned German scientist and aerodynamicist Dr Alexander Lippisch. Other major pioneers in this technology have been the Soviet/Russian Central Hydrofoil Design Bureau which explored from 1960's an 'Ekranoplan' concept for military assault and transport which culminated in the construction and testing of prototype vehicles up to 550 tonnes. Elsewhere in the world other WIG projects include several Chinese and USA based initiatives – including the current Boeing 'Pelican' 1,400 tone payload military transport concept.

The principle differences between FF/AFD concept and the Soviet/Russian ekranoplan concept is the use of Lippisch reverse delta wing together with a patented air cushion lift off aid, within an integrated composite hull design. This gives the FF/AFD concept improved sea clearance, manoeuvrability, simplicity and power/load carrying capability over the ekranoplan concept.

Technical Development History

In 1971 Mr Fischer (founder of Fischer Flugmechanik) worked with Dr Lippisch to German Navy specifications for a manned prototype ground effect aircraft capable of flying below enemy radar detection. Fischer Flugmechanik have acquired the rights and intellectual property of that early work and, since that time seven manned prototype vehicles have been built, culminating in the Airfish AF8(FS8) 8-10 passenger seat WIG vehicle launched in 2001. This craft is currently undergoing certification trials for passenger service in Australia, and is going into licensed series production.

During the course of development the concept has evolved away from the ultra-low altitude aircraft design. The capability for free flight has been removed, to be replaced by the power-efficiency, simplicity and economy of a pure ground effect surface vessel, constructed and certified for operation as a boat. In the course of their research and development Fischer Flugmechanik have evolved two strands of WIG technology: the first generation 'Airfish' concept and the second generation 'Hoverwing' concept. This paper concerns the Hoverwing concept.

Technical Background

A WIG vehicle is a 'dynamic' hovercraft. Unlike a conventional hovercraft that generates a static cushion which is dragged around within a skirt, the WIG generates a 'dynamic cushion' between itself and the surface below it by virtue of its own forward passage. The WIG utilises 'wing-in-ground effect', a phenomenon that relates to the airflow around a wing when it flies in close proximity to a surface, wherein the presence of the surface distorts the downwash from the wing and inhibits the formation of vortices. This results in two beneficial effects. There is a pressure increase on the lower surface of the wing due to the conversion of the dynamic pressure of the forward motion to static pressure, which results in a substantial increase in lift. At the same time there is a substantial reduction in (lift-induced) drag because the vortices and downwash are less, so there is less energy stored in them.

The combined effects lead to a higher Lift/Drag ratio for a wing in ground effect than could be achieved in free flight, and hence higher efficiency. Indeed heavy seabirds use this 'ground effect' to save their energy on long distance flights. However, birds have a natural automatic height and longitudinal stabilisation system. Dr Lippisch regarded aircraft as "frozen birds" that needed special methods for self-stabilisation. He solved this by using a reversed Delta wing, flying in ground effect, in combination with a high T-Tail, which flies out of ground effect. This configuration guarantees a safe stability at all heights from the surface. The 'ground effect' gets stronger as the surface is approached and efficient cruise height is a balance between the wave clearance and the optimum power-efficiency, and generally equates to a cruise height of equivalent to 10% of wingspan.

Despite the technical nature of the concept, at its core WIG is a fundamentally simple concept comprising little more than four elements: aero/hydrodynamic body, propulsion, rudder, and stabiliser. This can result in rugged craft with stubby wings that need be no more complex than a conventional high speed boat, as illustrated in Figure [1].

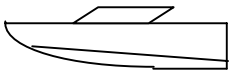
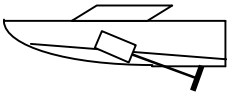
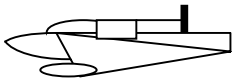
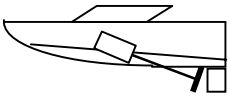
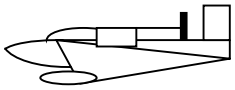
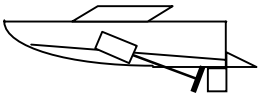
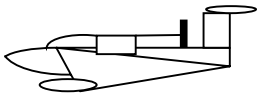
	Hydrodynamic body / Aerodynamic body	
	Engine and propeller	
	Rudder	
	Trim tabs/ Stabiliser	

Figure 1. The fundamentally simple nature of WIG; no more complex than a conventional boat

Technical Discussion – Hoverwing Features

Although the dynamics of WIG flight are very efficient, one issue facing the development of WIG craft is the imbalance between takeoff and cruise power requirements. It takes considerably more power to overcome the drag of water than is needed in cruise mode. To overcome this, various forms of lift-off aid have been explored, in particular 'Power Assisted Ram' (PAR) or 'power augmentation' wherein part of the stream from the propulsion is deflected below the wings. This creates a primitive air cushion and results in a lift that decreases the displacement of the craft. Even so, such an approach can still suffer from excess installed power as highlighted by the Soviet KM ('Caspian Sea Monster') of whose ten engines only two were needed for cruise.

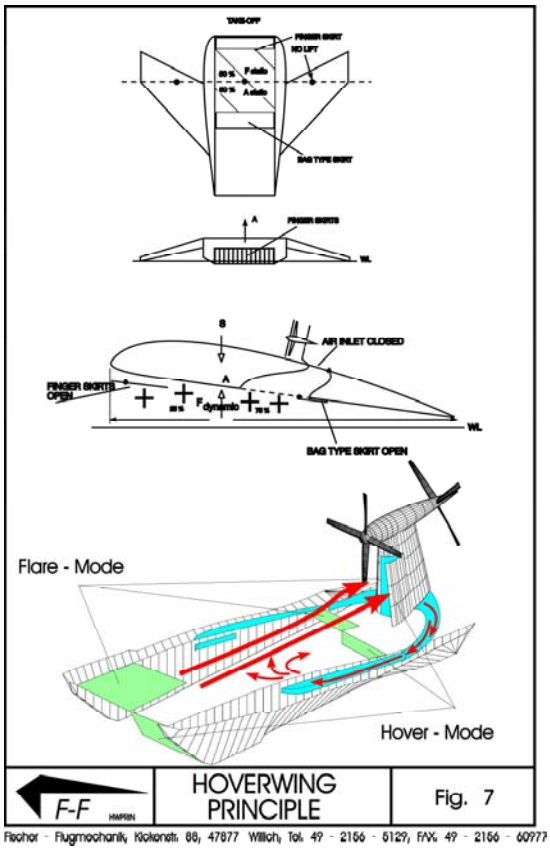


Figure 2. The Hoverwing Principle

By contrast the patented Hoverwing technology developed by Fischer Flugmechanik diverts 7% of the propeller stream and guides it between catamaran hulls to produce a static air-cushion, which reduces displacement of the craft by 80%. By means of skirts, as used on SES craft, the static pressure can be maintained until take-off. [Figure 2]

The lift/drag increase afforded by this system minimises the mismatch between takeoff and cruising power and so reduces the installed power requirement by 45%. [Figure 3]. As the vehicle accelerates during takeoff, the dynamic air pressure replaces the static air-pressure, the sealing skirts are retracted automatically, the diversion duct is closed and the craft makes a seamless transition to ground effect cruise mode. This system also allows the craft to operate efficiently in 'step-taxi mode' as a wing-assisted high speed boat at speeds below the takeoff speed.

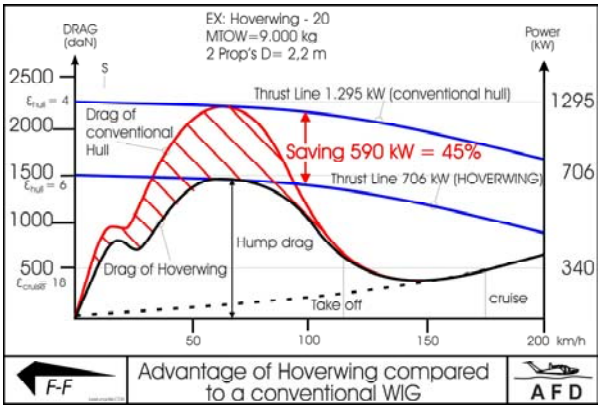
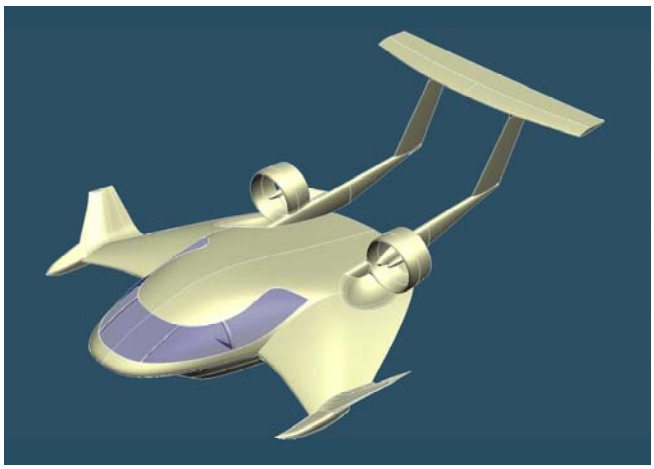


Figure 3. Reduction of Installed Power Requirement due to Hoverwing principle

Benefits of Blended Body

The Hoverwing concept features a blended body/lifting body configuration whereby the main hull/fuselage has an airfoil shape that contributes 40% of total lift in Ground Effect, while offering a large payload volume compared to that of a conventional 'stick with wings' aircraft configuration. This approach also enables a highly integrated mechanical construction in which masses and lift forces are concentrated together, rather than being distributed about conventional aircraft airframe. This minimises bending stresses, which in turn minimises airframe/hull weight. The resultant craft is a rugged vehicle that is well suited to a marine environment.

Because bending stresses have been minimised in this way the wings and tail of the Hoverwing can be made to fold (for docking) using simple mechanisms. [Figure 4]



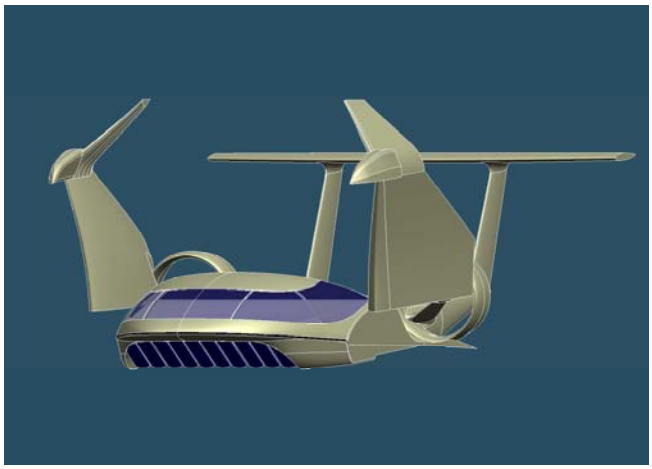


Figure 4. HW-20 showing blended/lifting body and wings folded

Manoeuvrability

By a single combined flap/rudder control the craft is capable of making co-ordinated banked turns of less than 300m radius while cruising at 90 knots. Such banked turns do not subject the passengers/crew to uncomfortable G forces. In 1997, as part of a project funded by the German Ministry of Research and Development, a two-manned 'proof of concept' test craft, the Hoverwing 2VT, was built. This craft underwent extensive trials and has 'flown' more than 3,000 km. [Figure 5] shows the GPS track of a Hoverwing 2VT flight, where several turns with less than 300m radius were recorded. In addition, by using the kinetic energy in cruise mode, it is also possible to give the vehicle the ability to jump up for vertical obstacle avoidance.

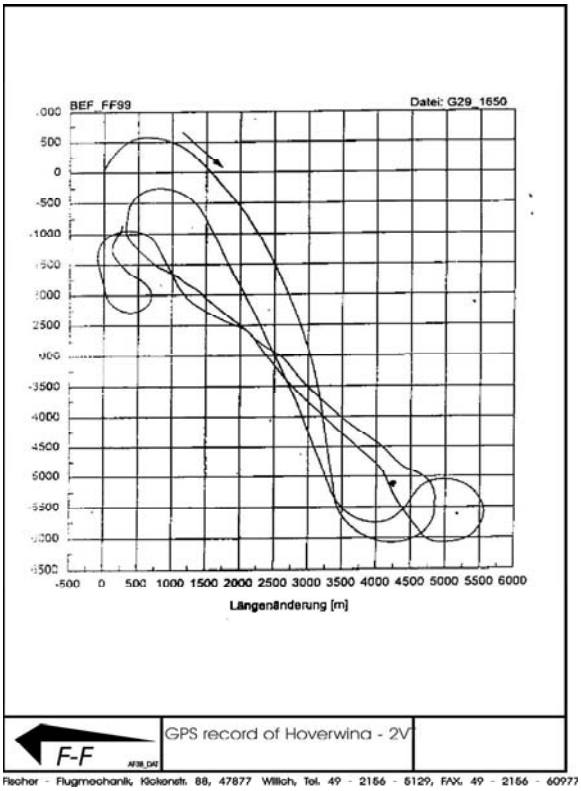


Figure 5. Manoeuvrability - GPS track of HW2VT trials

The New Generation of Hoverwing Paramilitary WIG craft - Operational Applications

The Hoverwing concept is aimed at medium / short-range applications such as river, coastal, inter-island, delta/estuary transport in parts of the world where the sea-state permits. The relationship between span and wave clearance makes the extent of these operational areas dependent on the size of the craft (future large craft may have all-weather capability). Examples of such areas include the Gulf of Mexico, the Caribbean, East Asia and the Mediterranean, as well as the thousands of miles of major rivers in each continent. Paramilitary applications include littoral operations, drug-running interdiction, anti-piracy, border patrol, search and rescue, medevac, pollution/environmental monitoring, transport, covert and special operations. In addition, subject to further research, these craft may be difficult to detect by mines or sonar, making them suitable for crossing minefields, mine clearance or ASW work.

The principle advantages offered by the Hoverwing concept are:

- High cruising speed – circa 90 – 100 knots:
  - Ability to cover a wide area within a short time
  - Rapid response capability
  - Genuine capability to intercept almost all other marine vessels.
- No water contact Cruise mode:
  - No seasickness, leading to low crew/personnel fatigue
  - No wake-wash: Stealth (wake is often the most visible sign of ship activity), no environmental damage
  - Sea skimming: High radar stealth
- High load carrying capacity (relative to aircraft)
- 'Boat' simplicity:
  - Low maintenance
  - Low training requirement

- Efficiency:
  - Low power consumption
  - Low fuel cost
  - Low maintenance

The features of high speed, crew comfort, endurance, efficiency and stealth combine to produce a viable paramilitary proposition:

- By virtue of the geographic dispersion of suitable sea conditions this technology is equally applicable to First, Second and Third world nations.
- One can expect the technology to evolve with operational development. Technology, techniques and skills learned through this field may be transferred to more conventional vessels.
- One vessel can cover the territory of several conventional vessels, and can be easily re-deployed.
- Crew comfort is an important feature; with reduced fatigue, crew/personnel will be in better condition to perform their duties effectively.
- The high interception speed combined with stealth means that persons undertaking illegal activities can be caught red-handed, leading to more effective enforcement; especially applicable to areas with high incidences of piracy or smuggling.

Cost/Efficiency/Effectiveness Savings - Summary

In comparison to Aircraft the WIG offers several benefits:

- Lower capital cost compared to equivalent aircraft, due to reduced 'aerospace' content and simplicity
- Lower maintenance cost due to simplicity and rugged airframe/hull
- Lower fuel cost due to power/efficiency
- Reduced staffing costs; WIG does not require a trained aircraft pilot
- Point to point speed roughly equal to that of light aircraft or helicopter
- Low infrastructure cost; ability to operate from a beach.

In comparison to Conventional Boats:

- High speed and comfort gives longer range and faster response time
- One WIG craft could cover the territory of several conventional boats, saving capital, fuel and crew costs

The Hoverwing Program

FF/AFD currently propose the development of three vehicles for paramilitary applications:

- The Hoverwing HW-20 (Mil)
- The Hoverwing HW-80 (Mil)
- The Hoverwing Interceptor

Hoverwing HW-20 Mil

This is a military variant of the 20 seat passenger/freight civil craft, having a useful load of 2.5 tonnes, with the capability to carry 12 fully armed troops, and be fitted with an assortment of weaponry or special equipment. As a paramilitary craft the HW-20 creates new possibilities. It will be able to offer some of the utility of more expensive rotary or fixed wing aircraft. Much of the craft will be manufactured from sandwiched composites. This gives good potential to incorporate radar and thermal image reduction and local armour as necessary, without excessive cost.

Figure 6. Hoverwing 20-Mil

The illustration in Figure 6 depicts the HW-20MIL equipped with a Boeing .50 cal chain gun on a stabilised mount, backed by a remote targeting system which will enable the gun to be accurately brought to bear while the vehicle is performing a 90-knot banked turn, at night. [See also Appendix 1]

Hoverwing HW-80 Mil

This is a paramilitary variant of the civil HW-80 proposal [Figure 7]. This would accommodate 80 civilian passengers or up to 10 tonne payload. In military application this craft could be adapted to carry 50 troops or 'Low Vehicles' (Land Rovers etc.) up to 6.7m x 1.9m x 2.7m. The craft would have a cruising wave-height of 5m and takeoff wave-height of 1.85m.

Figure 7. Hoverwing HW 80 civil variant

Interceptor Craft

FF/AFD put forward a small craft HW 4 Interceptor, with crew of four, that combines high surface speed, comfort and long endurance for communications, surveillance, medevac and maritime patrol, with capabilities that exceed those of conventional 'interceptor' fast boats. [Figure 8]

Figure 8 HW-4 Interceptor

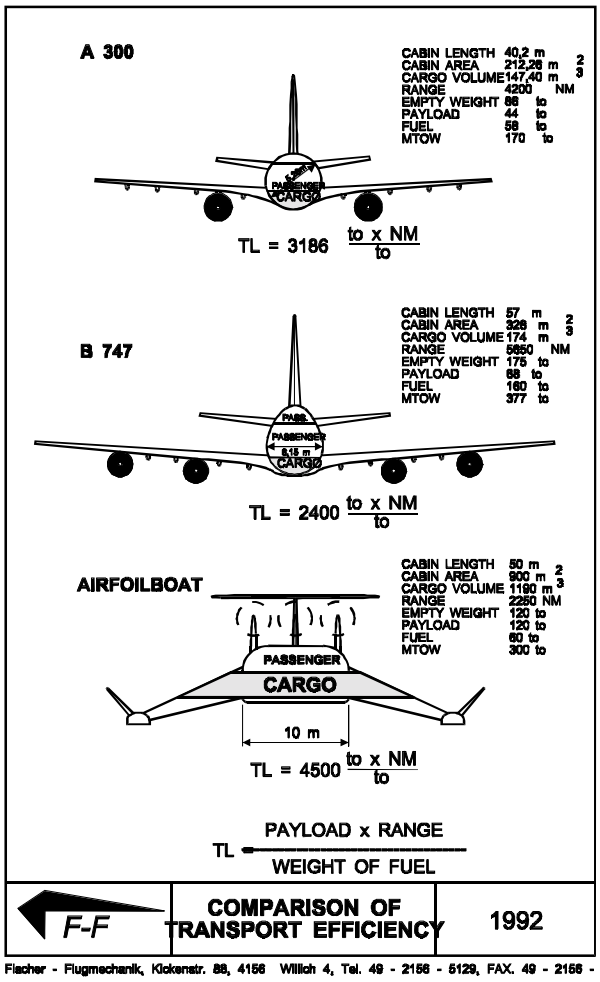
Discussion: Amphibious Assault

Recent reassessment of amphibious assault capabilities by First World navies has considered the possibility that support ships be stationed further offshore. This implies that the final journey to the shore in traditional slow landing craft will be longer, more arduous for personnel, and with greater vulnerability. As a potential solution for this FF/AFD have explored adaptation of the proposed HW 20 Mil and HW 80 Mil with folding wings, to fit within the welldock or LCAC dock of a LPD(R) mother ship. In both cases, the cruising speed of 90 knots will enable these craft to make the ship-to-shore run in a matter of minutes, with greater stealth than traditional craft, and deliver personnel in better condition to perform their functions.

Hoverwing and Large Scale Wingships.

Since 1960s there have been many proponents for, and studies on, the development and operation of very large scale ground effect vehicles. Military interest in this field has been rekindled by the announcement last year that Boeing were undertaking outline design for their land-based 'Pelican' WIG/aircraft project. This concept is a long-range vehicle with capacity to carry 1400 tonnes of vehicles and logistics, and will run in ground effect for most of its journey. FF/AFD also have considered the application of the Hoverwing concept at large scale. The Figure 9 illustrates how a vessel of Hoverwing layout (HW 1200 - 120 tonne payload) offers more load capacity both in terms of payload weight and payload volume, than would a conventional aircraft of similar gross weight (MTOW). Such craft could accommodate large loads that could not currently be moved at high speed.

The relationship between wingspan, take-off wave height (about 5% span) and efficient cruise height (about 10% span) means that the scale of craft larger than the HW-80 will enable greater sea clearance to be achieved, moving towards 'all weather' capability. Our studies indicate that the Hoverwing concept can be scaled to



Right: Figure 9. Illustration of cargo volume available from Hoverwing concept

(passenger) craft in excess of 200 seats. The 200 seat craft ('HW 200') would have a takeoff wave height of 2.2m and cruise height of 4.4 m, while the 120 tonne payload craft (mentioned above) would have a takeoff wave height of 3.5 m cruise height of 6.9m.

FF/AFD are taking an incremental approach to large craft development. Operational development of the HW-20 and HW-80 craft will provide valuable data for a realistic assessment of the demand for, and manufacture and operation of, large scale WIG craft.

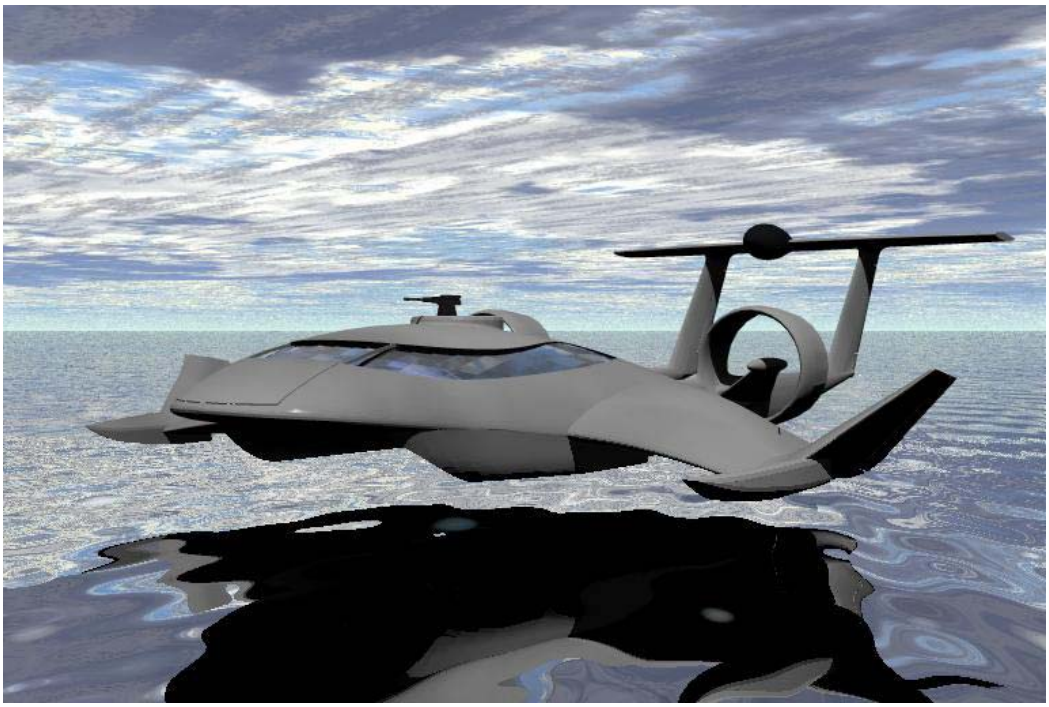
Time Scales

FF/AFD is actively pursuing the development of the HW-20 vehicle and are currently working to establish strategic partners for manufacture, finance and operation of the craft. Given support from para/military organisations the first craft of this type would be available within three years. This would be followed by a period of close cooperation with the customers operational evaluation/trials/development unit. With such experience the concept could be upgraded from patrol/surveillance vehicle to develop into a more war-fighting vehicle.

Conclusions

The development of the second-generation Hoverwing concept is a significant improvement on previous WIG concepts and enables the application of WIG type vehicles to a range of paramilitary duties. The combination of lift off aid and blended body technology, together with other features, enables the Hoverwing to be applied to a range of para/military tasks, both in terms of new capabilities and as a replacement for existing conventional boats, helicopters and aircraft in many situations.

APPENDIX 1 - HOVERWING 20 MIL
Second Generation Paramilitary WIG Vehicle from AFD Airfoil Development GmbH



Hoverwing 20 Mil
Hoverwing technology has been developed by AFD's sister company Fischer Flugmechanik under sponsorship of the German Ministry for R & D.

Outline Specifications:
This sea-skimming craft will have a cruising speed of 90 knots. The vehicle can carry a dozen fully armed troops, can be fitted with an assortment of weaponry or equipment, and has stealth possibilities. Paramilitary applications include anti-drug running, anti-piracy, border patrol, interception, search and rescue, pollution / environmental monitoring, covert and special operations. The high speed no-water-contact, zero wake cruise mode provides high crew comfort and genuine ability to intercept almost all other vessels.

Performance:		**Specifications:**	
Cruise Speed	175 km/h	Length	22.44 m
.. ..	94 knots	Width	17.34 m
Range (no Reserves)	500 km	(wings folded)	6.30 m
Efficient Cruise height	1.75 m	Height	4.94 m
Max wave height take-off	0.75 m	Payload	2,460 kg
Max wave height cruise	2.50 m	Take-off weight	8,994 kg
		Cruise power	465 hp