RE-DEFINING SEA LEVEL:
THE HOVERWING WING IN GROUND EFFECT VEHICLE

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By:
Graham Taylor, Hypercraft Associates, England
Mr Klaus Matjasic, Fischer Flugmechanik/AFD Airfoil Development GmbH, Germany

Outline
Like the Hovercraft, development of the Wing in Ground Effect vehicle (WIG) or Ekranoplan (Russian terminology) has suffered because it falls between established pigeonholes. Indeed WIG has suffered particularly from perceptions that it should be classified as an aircraft rather than a boat, and this risks the imposition of inappropriate technology and regulation, as was the case in the hovercrafts' early years. Fortunately as aviation and high-speed marine technologies continue to converge, acceptance of the 'grey area' of no-water-contact marine/surface transport is now becoming more widespread. This paper outlines the work and current direction of FF/AFD's second generation WIG vehicle concept; the Hoverwing.

Introduction – Basic WIG Technology
When Sir Christopher Cockerell adopted the ideas of Mr Latimer-Needham in 1961, he put on the very feature that holds the hovercraft back – the skirt. The skirt determined that the vehicle he developed would forever be supported by a confined static cushion rather than a dynamic one. The skirt limits the hovercraft to a speed of around 80 knots, beyond which it is unfeasible to pressurise the static cushion against the dynamic pressure acting on the front of the craft (indeed, the Hoverwing uses this principle to retract its skirts). For higher speed it is better to remove the skirt altogether (Figure 1).

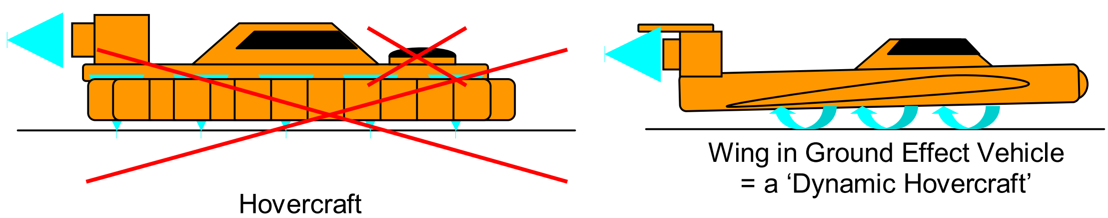

Figure 1. The WIG – a 'dynamic' hovercraft, without skirt or lift engines

What we have left is a ground-effect WIG, a 'dynamic hovercraft' without the need of a heavy skirt, or lift engines. The dynamic self-stable ground effect 'cushion' of lift is created by its own forward passage. Stripped down in this way, WIG is a very simple concept comprising an aerodynamic hull form, an air propulsor and a rudder. Indeed, 'ground effect' can be simply demonstrated by laying a piece of card on a table; given a flick it can be sent skimming on a 'dynamic' cushion of air.

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 effect dramatically increases the lift and reduces the drag compared to that attainable by a wing in conventional flight, and so is the basis of self-stability in cruising height/wave clearance (at about 10% wingspan) and power efficiency. As sea clearance is a function of the scale of the craft, larger craft will have greater sea state capability. When cruising in ground effect, the only noticeable wake is a trace of small surface ripples behind each wing tip created by the action of the confined wing tip vortices (Figure 2). WIGs main attribute is that it should (according to popular theory) be able to carry significantly more load, and at less power, than a conventional aircraft. It also happens that (as long as these craft are not capable of free flight operation) if such vehicles are constructed with appropriate technology (i.e. 'ship' technology) they can be made and operated at considerably lower cost than the equivalent aircraft.

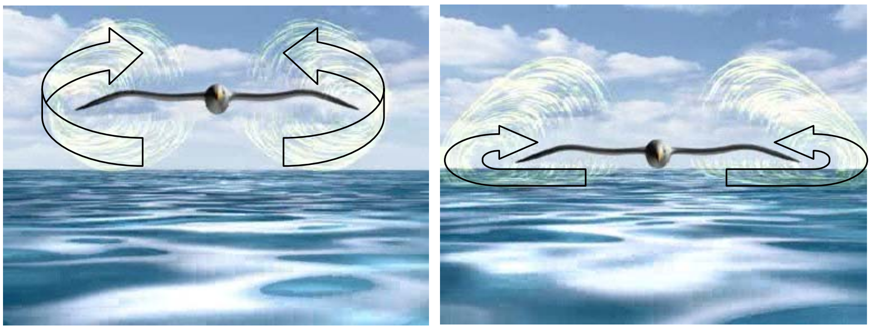

Figure 2. WIG = Distortion of airflow around a wing due to the presence of a surface

The WIG/Ekranoplan was one of the technologies, like the hovercraft and hydrofoil, whose bulk of development took place in the late 1950's - 60's. Behind the Iron Curtain, the USSR's Central Hydrofoil Design Bureau put the ideas of Rostislav Alexeyev through a development process, culminating in the awesome KM 'Caspian Sea Monster' and several other large military vehicles. The KM, weighing 550 tonnes, and travelling at 160 knots, was one of the largest machines ever to get airborne (and some 100 tonnes heavier than an Incat 86m cross channel car ferry). It is worth noting that the 'maiden voyage' of the KM was in 1966, preceding by nearly two years the 165 tonne 60 knot SR.N4 cross-channel hovercraft (Feb. 1968) that seemed so revolutionary in the West at the time.

The other leading school of thought on Ekranoplan/WIG design was founded quite independently by Dr. Alexander Lippisch (the 'father' of delta wing), first in USA (circa 1963) under Collins Radio/Lippisch Research Corp and then in Germany under Rhein-Flugzeugbau GmbH (1967 onward). This work is continued by Fischer Flugmechanik/AFD and is characterised by the 'Lippisch reverse delta' wing configuration.

Development by Fischer Flugmechanik/AFD Airfoil Development GmbH

Through many years of research and practical prototyping, Fischer Flugmechanik/AFD Airfoil Development GmbH have evolved their WIG technology into a marine vehicle that, with the launch of their Airfish AF8(FS8) 8-10 passenger craft in 2001 became the worlds first WIG vessel to achieve a Certificate of Class by Germanischer Lloyd (Dec 2001), and Lloyd's Register (May 2002) (Figure 3). This craft will go into licensed series production. During the course of development the FF/AFD concept has evolved away from an initial sea-skimming aircraft design. The vehicle is not capable of free flight, but offers the power-efficiency, simplicity and economy of a pure ground effect surface vessel, constructed and certified for operation as a boat.

Figure 3: Airfish 8/Flightship 8, eight passenger vessel launched in 2001

FF/AFD have evolved two strands of WIG technology: the first generation 'Airfish' concept and the second generation 'Hoverwing' concept. This paper concerns the Hoverwing concept. FF/AFD are now seeking strategic partners for the construction and operation of 20-passenger and 80-passenger craft based on this technology.

The Second Generation 'Hoverwing' Concept

Getting a WIG craft to cruise efficiently is one thing; getting one to take off efficiently from the water is another. The power required to take off can be significantly larger than that required for efficient cruise. To help overcome this, FF/AFD's research led to the development of the Hoverwing concept. This incorporates a retractable SES type air cushion between catamaran hulls which is used during takeoff (Figure 4).

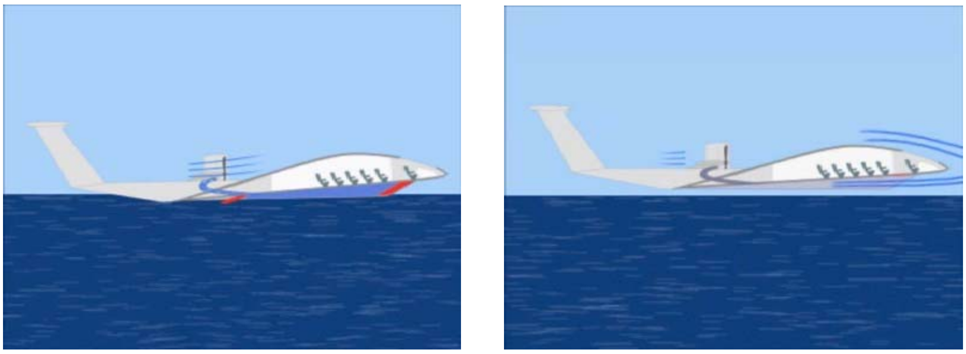

Figure 4: Illustration of retractable SES air cushion as craft makes transition from 'hovercraft'/step-taxi mode (left) to WIG mode (right).

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 5). Initially 7% of the propeller stream is diverted and guided between catamaran hulls to produce a static air cushion that supports 80% of the craft weight. 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 cruise efficiently in 'step-taxi mode' as a wing-assisted high-speed boat at speeds below the takeoff speed.

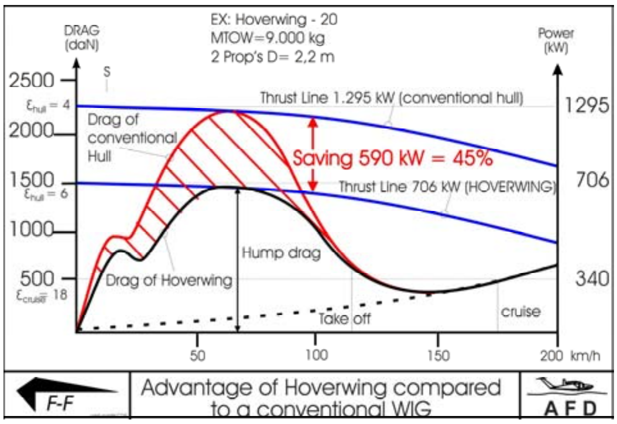

Figure 5: Reduction of Installed Power Requirement due to Hoverwing principle

The Hoverwing Hull

By combining catamaran hulls with a blended body/lifting body shape, the hull of the Hoverwing contributes 40% of total lift in Ground Effect, and at the same time offers a very large internal payload volume. This approach also enables a highly integrated mechanical construction in which masses and lift forces are concentrated together. This minimises bending stresses, which in turn minimises airframe/hull weight. 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 6).

Figure 6: The HW-80 showing the blended/lifting body/hull and folding wings

Manoeuvrability

A single combined flap/rudder control enables the craft to make 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 (Figure 7). This craft underwent extensive trials and has 'flown' more than 3,000 km. Figure 8 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.

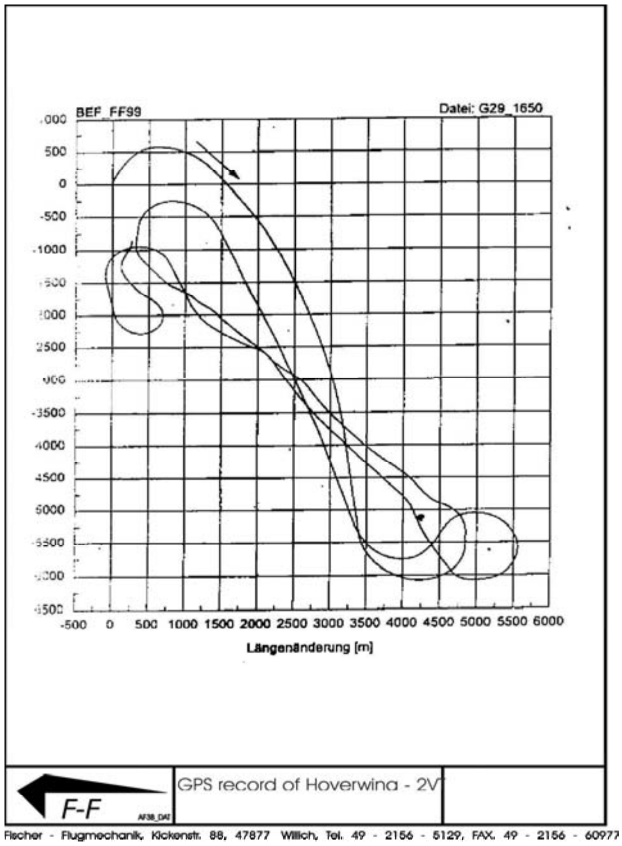

Figure 8. Manoeuvrability - GPS track of HW2VT trials

Figure 7: The HW2VT 2 seat technical demonstrator in 1997.
This was a scale model of an 80 seat concept.

Features, Benefits and Uses

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 well have greater 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.

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 – point to point speed competitive with helicopter/light aircraft
- No water contact Cruise mode:
  - Little sea motion; no seasickness, leading to low crew/personnel fatigue
  - No wake / wash
  - No environmental damage
- Good load carrying capacity (relative to aircraft)
- 'Boat' simplicity:
  - Low maintenance
  - Low training requirement
- Efficiency:
  - Low power consumption
  - Low fuel cost
  - Low maintenance
- Low cost (relative to aircraft/helicopter)
- One craft could do the work of several conventional craft
- Offers a unique passenger experience

Some Applications are suggested below:

- Passenger Ferry/Water Taxi – services between population centres
- Freight/Workboat – e.g. high value/time sensitive freight and mail
- Tour boat – e.g. able to take passengers from cruise liners to remote destinations in short space of time
- Resort boat – ferry passengers from airport to hotel beach
- Dive boat – Reach remote reefs, follow reef activity

The Hoverwing Program

FF/AFD currently propose the development of two types of vessels:

- The Hoverwing HW-20: This is a 20 seat passenger/freight civil craft with a cruising speed of 90 knots in waves up to 2 m and a useful load of 2.5 tonnes (Figure 9).

Figure 8: The Hoverwing HW-20

- The Hoverwing HW-80: The HW-80 will accommodate 80 civilian passengers or up to 10 tonne payload (Figure 10). The craft will have a modular payload system and could be adapted to carry small vehicles (cars, Land Rovers etc.). The HW-80 craft will have a cruising speed of 96 knots in wave-heights up to 2.5 m and takeoff wave-heights up to 1.85 m. A cargo variant is possible for freight operations. Large gull-wing doors facilitate easy access for freight and a dedicated system of purpose built lightweight plastic moulded containers and nylon roller tracks can be installed. FF/AFD have considered scaling the concept to 200 seats

Figure 9: The Hoverwing HW-80

Paramilitary Potential

In addition to the civil applications mentioned in this paper AFD/FF/Hypercraft Associates are also exploring the paramilitary use of the Hoverwing concept. In this field the zero-wash sea-skimming and comfort combine in a vessel that offers rapid response, endurance, stealth (wake is often the most visible sign of ship activity) and the genuine capability to intercept almost all other marine vessels. Potential applications include littoral operations, drug-running interdiction, anti-piracy, border patrol, search and rescue, medevac, pollution/environmental monitoring, transport, covert and special operations.

Figure 10. Hoverwing 20-Mil

WIG and The New Fast Marine Business

In many respects the Hoverwing WIG craft sit between conventional boat and aircraft. The Hoverwing is a marine surface vessel and will be classified as one, but the development and adoption of it serves as an illustration of how the fast ferry business is evolving and beginning to blend together the values of both the marine and aviation industry.

The traditional marine industry is a very incremental one; each boat is built as an increment on the one that went before. There is little fundamental research and development, and the cost of that which does take place is funded from the sale of that particular vessel. The aviation industry is somewhat different. Each new model requires extensive research and development, and this can only be funded through pre-selling series production. In the case of WIG, and some other cutting-edge marine developments, a higher proportion of 'fundamental' R&D investment means that the marine business model must be changed. Beneficially, this brings the possibility of moving from an industry structure that has low barriers to entry and competition, to an industry structure that has high barriers to entry and competition.

Conclusions

This paper presents the Hoverwing as a surface vehicle operating within the grey area of sea/air interface. With no sea motion fatigue and high speed, such craft offer a unique passenger experience.

These craft can be used for ferry, water taxi, resort craft and other applications on new or existing routes, including environmentally sensitive and poorly served areas of the world, wherever the sea conditions permit. They also present new paramilitary solutions. If constructed with the appropriate technology for the operational environment they fit a competitive niche between ship/boat and aircraft. There is still considerable scepticism about WIG within both aviation and marine circles. But if the marine industry were to think less in terms of 'ships' and 'boats', and more in terms of 'vehicles for a marine environment', then the role and potential for WIG would be more obvious to all. What is needed is the clarity of vision to step outside the traditional marine pigeon holes.

WIG is very much a marine craft that travels at sea level. It is just that 'sea level' is a few meters higher than it used to be.

Contacts:

- Graham Taylor, Hypercraft Associates, 23 Wyndham Avenue High Wycombe, Bucks, HP13 5ER, England. Tel: +44 (0)1494 461689. Email: mail@Hypercraft-associates.com
- Klaus Matjasic, AFD Airfoil Development GmbH, Robert Bosch Str. 1141844 Wegberg, Germany. Tel: +49 2431 981680. Fax: +49 2431 891618. Email. Airfoil@t-online.de
- Hanno Fischer, Fischer Flugmechanik, Kickenstrasse 88 47877 Willich, Germany. Tel: +49 2156 5129. Fax: +49 2156 60977. Email: Flugmechanik@t-online.de