INNOVATION DYING OF APATHY:

WIG – A CASE STUDY

Paper for the RINA International Conference

"High Speed Craft, ACV's, WIG's and Hydrofoils"

The Royal Institution of Naval Architects, London
31 October – 1 November 2006

By Graham K Taylor,

Director
Hypercraft Associates Ltd.
23 Wyndham Avenue
High Wycombe
Bucks HP13 5ER
England
Tel: +44(0)1494 461689
Email: mail@hypercraft-associates.com
Web: www.hypercraft-associates.com

INNOVATION DYING OF APATHY: WIG – A CASE STUDY

Paper for the RINA International Conference on High Speed Craft, ACV's, WIG's and Hydrofoils.
The Royal Institution of Naval Architects, London 31 October – 1 November 2006

G K Taylor, Hypercraft Associates Ltd. UK

SUMMARY
The author has been actively involved in promoting the commercialisation of WIG for ten years. He is often asked "If WIG is so good, why has it not happened earlier?" The answer is that there is no technical reason why WIG has not taken off – only apathy. The condition of WIG may be symptomatic of a level of apathy regarding innovation which is endemic in the marine transport industry, and most likely affecting the development of other technologies presented at this conference.

In management rhetoric, much issue is made of the importance of innovation as a strategic tool and a source of strategic and competitive advantage. However, WIG serves as a case study to show that innovation is not getting the attention it deserves in the marine transport industry. Certainly WIG has been put in front of worthy potential players, who should know better, yet have taken no interest.

This paper focuses on the technical and commercial niche for WIG, outlining the state of current technology, the market opportunities and global potential. This is juxtaposed and discussed against the low level of take-up and the wider issue of embracing innovation within our industry.

WIG is an endangered species. Some believe that WIG may still materialise in the near future; it would be nice to think so. But the pioneers who have mastered WIG are getting old; some are dying and there is little succession. Will WIG die of apathy? – that is what this paper will explore.

NOMENCLATURE

WIG: 'Wing in Ground' effect vehicles and the underlying principles thereof. Often known by alternative names: 'ekranoplan' (Russian term), 'WISE' (wing in surface effect), 'GEM' (ground effect machines).
Type A: Craft capable only of operating in ground effect.
Type B: Craft able to increase flight above ground effect temporarily.
Type C: Craft capable of sustained operation above ground effect (i.e. free flight).

1. INTRODUCTION

The author has been actively involved in promoting the commercialisation of WIG for ten years. During recent years, he has worked closely with Mr Hanno Fischer and Mr Klaus Matjasic of Fischer Flugmechanik/AFD Airfoil Development GmbH to promote their Airfish and HoverWing vehicle technologies. This paper reflects upon some of the lessons learned during this time.

WIG is at the outer limit of the established marine transport industry. Some would rather put WIG outside the marine transport industry altogether, but in aviation instead. Indeed, if one were looking for 'outside the box' marine transport solutions, WIG would be on the list.

This paper is written from the outside-the-box perspective, from which one gains a rather different view of the marine transport industry than that seen by those in the thick of it. It uses WIG to hold a mirror up to the marine transport industry - will we like what we see?

The author is often asked "If WIG is so good, why has it not happened earlier?" This paper argues that there is no technical reason, only apathy. The condition of WIG may be symptomatic of a level of apathy regarding radical innovation endemic in the marine transport industry; most likely affecting the development of other technologies presented at this conference.

2. INNOVATION AND EVOLUTION

Next to prostitution, marine transport may well be the worlds' oldest profession, perhaps pre-dating civilisation itself and going back to the day when man first floated on a log. Yet, given all that time, the author argues that the industry is very slow to evolve.

Some may argue that there is nothing wrong with the industry's pace of innovation; however an indication of the problem is brought into stark relief by the recent legislation on whole body vibration (EU Directive 2002/44/EC [Ref. 1]. This legislation states that for all human environments (including land, sea, and air vehicles) certain levels of motions and vibrations should not be exceeded for health and injury reasons. Few existing medium or fast craft are able to comply with this legislation, which shows that centuries of evolution have failed to deliver. Instead we have come to accept the poor comfort of ships and boats, with their intrinsic risks, as part of the culture of seafaring. Clearly there is a gap between where we are and where we need to be. Is this a problem with the technology or with the way that industry deals with innovation.?

3. WIG TECHNOLOGY MAKING BUSINESS SENSE

"….every time a child says, 'I don't believe in fairies', there is a fairy somewhere that falls down dead."
From Peter Pan, James Matthew Barrie (1860-1937)

Does WIG work? The short answer is "Yes". Both the Soviet led and German led projects since the 1960's have proved conclusively that the WIG principle can be applied to vessels up to 540 tonnes. Since then much technical work has been done to make the concept fit to form the basis of a very profitable marine transport business in the 21st Century. Yet still there is disbelief. J M Barrie's words echo the authors' experience of WIG. Every time someone voices disbelief, part of a WIG project dies, and a major job of work is needed to bring it back to life again. It is not a problem with the technology; it is a problem that people have with radical innovation in the marine sector and an issue we will reflect upon later in the paper.

To an engineer, WIG is about the benefit of the enhanced lift-to-drag ratio (L/D) experienced by an aerodynamic form in certain confined airflow conditions, through which a vehicle skimming in 'ground effect' may achieve a L/D ratio of circa 15-30+. But that is only one aspect of a much broader picture and, in the final analysis, a good L/D may not be as important as it seems.

WIG is really about moving people and cargo over water with much greater comfort, speed and efficiency than is achievable by any other method, and to combine this with other engineering features and attributes which can be reflected in a favourable business case.

Its main attributes are speed and zero water contact skimming:

- <u>Speed</u> – Turning the business machine faster, bringing destinations closer together, opening new routes within acceptable journey times.

- <u>Zero Water Contact Skimming</u> – No sea motion or seasickness, low fatigue for occupants and equipment, no wash, no environmental damage to waterways, immune to sea or river currents, driftwood or other semi-submerged objects or sea life, shallow water operations, no visible wake, stealth.

WIG is the basis of a marine transport system for both civil and military applications, such as:

- <u>Civil:</u> Passenger ferry/water taxi, freight/ workboat, tour boat, resort boat, dive boat medevac.

- <u>Military:</u> Littoral operations, over horizon / ship-to-shore transport, anti piracy, anti smuggling, border patrol, fleet protection, search and rescue, environmental monitoring, covert and special operations.

Earlier papers by the author have outlined a global market opportunity that recognises both the attributes and the limitations of WIG [Ref. 2, 3, 4]. These have identified opportunities for operation in coastal/littoral, inter-island, estuary and major river locations throughout the globe (Figure. 1). The total population of such regions exceeds 600 million and the benefit that such vessels could offer to the local economy is truly revolutionary. For example, the island of Tobago in the Caribbean is only 42 kilometres long, yet it takes more than two hours to drive the tortuous winding roads from one end of the island to the other. The journey could be done in less than fifteen minutes by a 100 knot WIG.

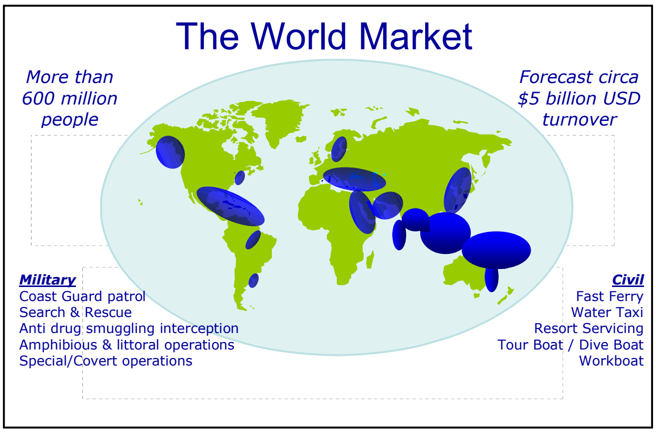

Figure 1: World Market Regions for WIG

In many respects the WIG has similar potential to that of the helicopter, whose market is worth circa US$5billion per year. The authors' guess is that the WIG market is about the same size. Perhaps the full meaning of a figure that large is too difficult to grasp, but written out in full as five-thousand-million dollars or US$5,000,000,000/Year, with all nine noughts, ought to fire the imagination of entrepreneurs, investors and corporates alike. And this excludes operator revenue! Yet still WIG is shunned.

What is clear is that we are not talking about building just the odd one or two vessels. We are talking about mass market potential, with mass production on a scale which has not been seen before in the marine transport industry. The capacity of the market is such that, for example, 200 WIG craft could go into the Malay Archipelago market without causing a ripple, metaphorically or literally. Mass production brings the capability to move according to a different business model, breaking away from the limitations of traditional marine culture: new game, new rules.

Let us look at the business case more closely. There is a popular belief that a WIG is cheaper than an aircraft and more expensive than a boat. This is not proven. The condition can only be arrived at through careful design and manipulation of the business model to make it so. Indeed, it is easy to make WIG more expensive than an aircraft because of the high 'first-of-class' costs (R&D, development, tooling etc.) which have to be recovered through the sale price. From an ideal business model, one is seeking lowest investment, lowest infrastructure, lowest first costs, lowest risk and quickest return; breakeven within three years may be desirable.

Hypercraft Associates has derived illustrative business models which interlink WIG manufacturing and civil WIG operation businesses. These indicate that profitable businesses for both manufacturer and civil operator could be built around a vessel of circa 30 seats. These models require a total investment of circa US$20 million to cover the design, tooling and initial production run of craft, from whose sales the business would be capable of self-financing future expansion, with good margins and a time to breakeven of three years . The vessel price would be around US$3.0 million, which compares favourably to that for a 20-year old 19 seat Twin Otter float plane of well over US$2 million, which is perhaps the nearest comparable vehicle that an operator could buy [Ref. 5]. From an operators perspective, the models show this is also an attractive and profitable proposition because aircraft would require extensive, costly maintenance and refurbishment - particularly in salt water - while WIG costs would be a fraction of this.

Certainly it is the authors belief that within ten years, with the right product, the right management and a seed capital of circa US$20 million, an organisation could be well on the way to controlling around US$1 billion of the industry.

From this we see that the underlying technology works, the market is vast and the money-making potential is huge. Yet WIG fails to attract. Something else must be wrong. So we return to question the marine transport industrys' culture and its attitudes towards innovation.

4. INNOVATION AND APATHY

In management circles they often refer to two types of innovation:

1. Incremental innovation/evolution
2. Fundamental/radical/disruptive innovation

The marine transport industry is very good at accepting incremental evolution; centuries of progress in small steps have resulted in the vessels we have today. Each type of vessel is like a species which can be traced through a Darwinian evolutionary process that mirrors nature.

Yet the industrys' history is littered with cases in which radical innovation has been actively shunned: examples include Turbinia and the Steam Turbine, the hovercraft, and a whole host of innovative hull designs which have taken decades to be appreciated. WIG is another (which ironically could satisfy EU Directive 2002/44/EC).

So barriers to adoption of change and innovation do exist. It has a lot to do with what James O'Toole refers to as: "*the ideology of comfort and the tyranny of custom"* [Ref. 6] - a reluctance to go beyond self-imposed comfort zones which means that whilst evolution is part of our culture, revolution is met with resistance.

Let us explore this in a business context. The problem is that the barriers to entry in boat and ship building are rather low. This means that almost anybody can build a boat. It makes for a very competitive environment in which the customer can ask for almost anything with the prospect that someone, somewhere, can supply. Competition on price is rife. The emergence of low labour cost locations coupled with the globalisation of the industry only exacerbates the situation. At the same time most boats are 'one-offs' which means that the R&D element is limited to that which can be recovered within the price of that one vessel. So we have a supply-and-demand balance issue which accounts for the incrementalism of progress. Is there another way?

If it were possible to raise the barriers to entry, there would be fewer competitors, thus changing the balance of customer/supplier power. Indeed, in a market with limited supply and great demand the customer would get what he is given and be thankful for it *("…any colour, so long as it's black." – Henry Ford)*. If we were also able to lay R&D costs off over a series of identical vessels, we would be able to take bigger, more radical steps. This is the basis of industries like aviation and is also that proposed for the WIG business model.

Perhaps it is unfair to single out the marine transport industry as an example. The problem has been endemic in Western business culture for some time and is now a hot subject of current management rhetoric and at government policy level. A recent UK government Treasury report stated *"Maximising the benefits of innovation is an increasingly urgent priority for both companies and countries."* [Ref. 7]. Across Europe support for innovation, commercialisation of innovation and entrepreneurialism is still lacking and missing the point. Grants which are supposedly to promote innovation are heavily guarded by an army of bureaucrats: in a UK House of Commons review, The

Royal Academy of Engineering criticised the EU 6th Framework Grants system, stating: *"It was repeatedly stressed that the process of assembling, submitting, and justifying a costed proposal could be extremely time consuming, complex, expensive, and bureaucratic, and that the level of effort and persistence required was daunting."* [Ref. 8].

So what are we to do? We have an industry which is radical innovation-averse, within a greater business and societal culture which is similarly innovation-averse.

Yet it is not for the want of innovation that WIG is lacking, because the groundwork for WIG has already been done: it is the incentive to adopt innovation that is the problem. In essence it is the incentive to be entrepreneurial. We should not leave it all to Richard Branson or to support from Chinese venture capital.

In this section we have looked at some disturbing facets of innovation and the adoption thereof. Should we concern ourselves about this condition? Indeed, should we try to see things another way – if not, are we apathetic? Management gurus W Chan Kim and Renée Mauborgne argue *"Most companies focus on matching or beating their rivals, and as a result their strategies tend to converge along the same basic dimensions of competition... [while]... innovative companies break free from the competitive pack by staking out fundamentally new market space – that is, by creating products or services for which there are no direct competitors"* [Ref. 9]. This is the stuff of WIG. It is not just a technology – it is a whole new ball game. So let us look again at WIG, but in a new light.

5. WIG WHERE NOW?

At the current time WIG is poised between success and failure. WIG is not experiencing the high level of activity of the 1960-80's, but there is still a low level of activity underway worldwide which proceeds with mixed success. Those projects of note are:

- Aquaglide, Russia, by ATTK who recently exhibited their 5-seat craft at ILA 2006, Berlin. Amphibious Type A. (Fig. 2)
- Cometel EL 7 'Ivolga', Russia, an amphibious Type C craft (technically an aircraft) (Fig. 3). Part of a larger program which includes Type A vessels.
- HoverWing and Airfish technologies from Fischer Flugmechanik, Germany, both the subject of ongoing work. Type B vessels (Fig. 6, 7)
- Korean Ocean Research and Development Institute (KORDI) multi-million dollar funded development program to create high speed WIG-based transport/logistics sea network in Korea. Prototype is type C/aircraft (Fig. 4).
- Techno Trans, Germany, who have recently completed 'Hydrowing 8' an 8-seat Type A vessel (Fig. 5).

There are also several early stage/concept projects, the most recent being the French Focus21 'Aèroptère' (resembling an enhanced Jörg configuration), and numerous amateur/hobby projects. But the above projects may not be enough to keep WIG alive, as will be discussed in the next section.

Figure 2. Aquaglide 5 seat WIG

Figure 3. Cometel EL 7 'Ivolga',

Figure 4. WIG prototype developed by KORDI

Figure 5. Techno Trans 'Hydrowing 8'

6. REFLECTION - SO WHY HAS IT NOT HAPPENED SOONER?

"Progress lies not in enhancing what is, but in advancing toward what will be".

— Kahlil Gibran

Let us at least advance to what should be: WIG. It was Sir Isaac Newton who first said, *"If I have seen further than others, it is by standing upon the shoulders of giants"*[1].   That is an excellent statement about ones starting position in innovation, but it does not cover the journey from there onwards. Everything on the path from there on is new, never trodden before, except one may be able to take reference from similar situations in other industries. So the task is first to stand on the giants' shoulders and then, the next day, to stand on ones own shoulders from the previous day. In WIG we already have seen several giants: people like Dr Rostislav E Alexeev and colleagues of the former Soviet/Russia's Central Hydrofoil Design Bureau; Dr Dmitry Sinitsyn & Prof. Alexander Isaakovich Maskalik and colleagues of ATT/ATTK/ Alsin, Russia; Mr Hanno Fischer and Mr Klaus Matjasic of Fischer Flugmechanik/AFD, Germany; Mr Günter Jörg of Botec, Germany.

These are the masters. They made the technological innovation, but none have trod the path all the way to successful commercialisation. They gained their experience during the golden years of WIG/Ekranoplan development 1960 – 1990. Some of these people have passed away and those that are with us now are senior in years.

[1] Newton to Hooke, 5 Feb. 1676

Figure 6. 'Flightship 8' 001 by Fischer Flugmechanik/AFD

Let us consider for a moment: for magic, does one go to the sorcerer or the apprentice?   Unfortunately the scale of current, active projects is not sufficient to support a succession of learning to be passed from master to apprentice. Before long it will be too late to benefit from the knowledge that they have gained and the wheel will have to be re-invented.

To open up a new industry sector, should one:

1. Try to start from a small shed in a back yard?
2. Plagiarise the work of others?
3. Try to find some experts for free advice but do the project yourself with non-expert resources?
4. Identify and employ the leading people in the field and back them with a structured investment plan and serious money?

Routes 1 - 3 are typical of the attempts in WIG so far, while it astonishes the author that the real experts in this field are so poorly supported.   Sadly even those projects which have workable funding tend to suffer from amateur management or are heading off in the wrong direction for some other reason. If they succeed it will be through chance rather than skill.   A project along the lines of (4) above has a far greater chance of succeeding. But this means commitment on a far larger scale, by competent, well resourced players.

The greatest issue is the tendency for parties to under-estimate the difficulty of getting the technology off the shelf and into series production.   It requires large amounts of investment (as suggested in section 3), dedication and good, skilled strategic management. This is not something that will start with a few dollars from a small back-yard.   Nor is it simply a matter of building dirt-cheap vessels from a starvation-wage labour base, because as we will see later, there are real boundaries to cost which lead only in certain directions.

Also there is a huge weight of apathy and scepticism in related industries on which WIG must depend (e.g. suppliers, subcontractors, classification societies, marine agencies, government, and military). Moving WIG forward is like trying to push an elephant up a narrow staircase. In the authors' view, for reasons stated earlier in the paper, it should not be like that!

Over the years, Hypercraft Associates have received a great many enthusiastic enquiries from all around the globe for construction and operation of WIG. Some enquiries could lead to large volumes of units. But it has been a problem of "chicken and egg" as most enquirers did not have sufficient financial backing to start up the project from scratch. Also, innovations tend to attract the wrong sort of people. Some of the enquirers were simple opportunists looking to use WIG as a get-rich-quick scam (WIG has already seen several of these). Others had money but were not competent in any other respect (WIG has already seen several of these also). Some wanted to stitch up regional markets exclusively for themselves without putting anything into the project whatsoever. Others had money and technical competence, yet were incompatible for cultural reasons. Some had a thorough understanding of the technology yet lacked commercial insight to pursue it on a commercially viable basis. Others were simply time-wasters and 'empty vessels making a lot of noise'. Very few have come with sufficient money to fund the initial production investment, sensible management and a professional appreciation of the task ahead.

During the same time, Hypercraft Associates have presented this technology to carefully selected potential partners, ones with whom synergies are clear, only to find the idea rebuffed.

What we find is that it is not for the want of the ambitions of technology leaders, or the enthusiasm of amateurs that WIG is suffering. It is the apathy of decent players in embracing this technology. That is what is killing WIG.

Take for example the story of Flightship, one of the most promising attempts at WIG commercialisation in recent years. Flightship Australia aimed to put the Fischer Flugmechanik Airfish8 craft into series production as the 'Flightship 8' (Fig. 6)

In April 2001, Flightship took delivery of the FS8 001 prototype from Fischer Flugmechanik/AFD Airfoil Development GmbH, Germany. Between that time and October 2003 when Flightship went into administration, they were very active yet achieved practically nothing.

What they did do was break off relationships with Fischer Flugmechanik/AFD, then re-design critical parts of the craft themselves which were announced as significant improvements to payload and performance. They also broke off relationships with Germanischer Lloyd who pioneered the classification of WIG and certified the FS8. As a result of this, GL are wary of getting involved with WIG projects in future.

By the time Flightship Australia went into administration, they were reported to have a staggering AU$16 million debt and an equally staggering 100 staff on the payroll [Ref. 10,11], yet they had built only three part-complete craft, which were overweight by more than their payload so were too heavy to lift off. In the process the original FS8 001 (the worlds' only working certified WIG vessel) was cannibalised for transmission parts.

From this story we could conclude that the problem is in the amateurism of the players that are presently in the business. But that is not a fair assessment. The underlying point of this paper is that such amateurs can only be in the game because the professional resource-rich players that should be there are taking no interest. In other words, it is down to apathy.

Another example of apathy comes from gas turbine engine manufacturers. Engines are fundamental to WIG. The engine decision is a mission-critical issue. Unlike a conventional boat which can accommodate a variety of engines of different manufacture, according to the customers taste, a WIG is designed and built around an engine in much the same way as with aircraft design.

From a commercial perspective, once the engine selection is made, it is likely to establish an ongoing, profitable, relationship for engine supply well into the future. Earlier in this paper the WIG market volume was likened to the helicopter market; hundreds of WIG craft will require hundreds of engines. An entry level WIG vessel needs gas turbine engines that are marinised, tough, proven and circa 400hp – 2000 hp. Such engines exist in the naval helicopter sector. Inspection of the conventional high speed marine craft sector also shows a gap in the market for high power/weight solutions in this band, between where petrol engines end and big gas turbines begin. Military 'common-fuel'/no-gasoline policy creates even greater demand in this niche.

Given the above, one would expect engine manufacturers to express some enthusiasm towards the opportunity of extending production of existing products into the marine sector (indeed, simplified products such as WIG/boat do not need aerobatic air-certified power-plants). Instead, the author has experienced a complete lack of interest on the part of engine manufacturers. This has been expressed in many forms from simply not returning phone calls, slipshod enquiry management, promising information which never comes, through to outright denial of interest or support.

This has been common across all the mainstream engine companies. It is as though they have absolutely no mechanism for building new business from anywhere other than through their established relationships. So it is not hard to conclude that engine manufacturers are either doing so well they do not need new business, or that they are complacent.

But maybe this is unfair, because the reluctance could be a reflection of greater strategic issues on the manufacturers' side regarding price. Whereas an aviation engines' price is supported by it living within a closed-loop quality/certification process throughout its life, a marine engine does not need such a system and cannot support such a high price. So is the reluctance of engine manufacturers to support WIG due to a strategy of price-setting, or being satisfied with milking their existing cash cows, or is it simply apathy?

This section concludes that WIG is struggling because it is not getting the level of support that it should from the kind of credible, significant and professional players which should be participating in this sector, either directly as investors or indirectly as suppliers/players in adjacent industries.

7. TOWARDS A POSSIBLE FUTURE

Mans first attempts at flying involved tying feathers to his arms. Some attempts at WIG are still as off-base as that. There is a diverse range of concepts and ideas which would suggest that commercialising WIG is an open field. But is this really the case – if not, how can we tell the bad ideas from the good? This section proposes some dimensions which help define the shape of what is commercially viable and what is not, and also be indicative of ways in which WIG may further evolve as it matures.

- **Configuration and the Cube**
  WIG projects come in all shapes and sizes, each of which has its own interpretation on how best to combine aero and hydrodynamic efficiency. Many, such as the Soviet Ekranoplans, are 'stick-with-wings' 'aeroplane-type' craft, notable for appendages such as high aspect ratio wingtips, large tail volumes and propulsion distributed around the craft. One could call them 'dispersed/distributed designs' whereby the parts of the craft are dispersed around a large volume cube defined by maximum length, max width, max height. Such craft may function well as WIG vessels but may not be ideal from commercial, engineering and operational points of view. This is because 'distributed designs' can mean excessive structure which in turn leads to issues of weight and cost. In addition there can be issues of ruggedness and taking up excessive space in harbour, berthing, or when transported from place to place as deck cargo.

  An ideal vessel would be one which has the minimum cube built around the payload, because this would be an integrated design in which masses and forces are closest together, so minimising structural weight, manufacturing cost and operational constraints. This points to a lifting-body / flying-wing optimum, such as the Lippisch-based HoverWing or similar.

- **Speed and Structure**
  The speed of the craft is related to the structural weight if the craft is to be capable of withstanding sea impact at cruising speed. It has technical and commercial trade-off implications. As speed goes up so does structural weight, since sea impact at 200 knots is in a different league to that at 100 knots. With it the payload fraction comes down. 100 knot operation is within the realm of today's off-the-shelf materials and processes, whereas higher speeds push the boundaries of what is practically and economically possible within acceptable technical and business risk.

- **Being an Aircraft**
  If a WIG craft is capable of free-flight then it must be built and certified as an aircraft. From a commercial viewpoint one cannot expect to achieve advantage over existing aircraft if one uses the same technology and cost base. Therefore commercial advantage comes from being less than an aircraft. This suggests that a viable craft must be a type A or type B craft: i.e. not capable of sustained free-flight.

- **Sea Clearance and Manoeuvrability**
  Generally speaking, the greater the sea clearance, the larger the market potential. Low sea clearance limits operations to calm lakes and rivers, whereas higher clearance gives access to much larger markets in coastal/littoral operation. Manoeuvrability tends to go hand-in-hand with sea clearance, simply because it becomes possible to perform banked turns. The better the manoeuvrability, the greater the ability to operate amongst other traffic; so it can be argued that an optimal craft will have the highest ground effect cruise for the craft size (a good example is the Fischer Flugmechanik HoverWing concept which can perform banked turns of less than 300 m radius at 90 knots). But there is still scope for a trade-off since some market niches may be able to support cheaper products with lower performance.

- **Takeoff/Cruise Engine Power Difference**
  Up until the point at which a WIG lifts above the water, the hull of the craft behaves as that of a conventional speedboat. However, far more power is needed to overcome the hydrodynamic drag at take-off than to operate in the aerodynamic cruise mode. This power difference can be in the region of 5:1. This gives rise to three issues: 1) the capital cost of excess installed power 2) carrying engines instead of payload 3) capability of engines to handle a wide power difference.

Careful selection of the power plant is absolutely critical to a WIG project and one can either try to find a way to live with the wide power difference, or to do something about it. At 5:1, the ideal engine would have a high power-to-weight ratio (kW>kg) yet be capable of operating most of the time at 20% MCR (maximum continuous rating); i.e. during cruise. For small WIG craft (say max 8 pax) it may be possible to find suitable aviation diesel or gasoline piston engines. However, once above circa 500 hp there is no option but to use gas turbines (simply because alternative high power/weight ratio engines do not exist where kW>kg). Gas turbines do not like to be run below 70% MCR. At this point the power bandwidth needs closer examination in order to minimise the number of engines which contribute to take-off but not to cruise. This is a very critical issue from the commercial point of view because the high cost of gas turbines could easily exceed 50-70% of the total manufacturing cost of the craft.

The capital cost of engines drives up the craft sales price dramatically and also limits the impact of any savings achievable through low cost manufacturing practices. Also, having such a great a proportion of the project being dictated by a single factor or sub-supplier is a risky commercial scenario.

At the core of the problem is the hydrodynamic drag. Several clever 'take-off aids' have been developed to try to minimise this, including the use of hydrofoils, hovercraft cushions and 'power-assisted-ram'. One of the most notable is the HoverWing system by Hanno Fischer which uses a retractable air cushion to reduce the power difference from 5:1 to below 3:1. This means that for two installed engines, one can be shut down in cruise and the other run at circa 70% MCR. The ideal solution is one that brings the take-off and cruise power within 1.43:1 (i.e. 70% engine rating at cruise). Then no redundant engines need be carried.

- **Scale and the Business Model**
  The price of a craft must not only recover the cost of building the individual unit but also the investment which has been made in getting to that point, i.e. any first-of-class R&D costs. Just how such costs are apportioned over a production run is a Directors decision, with reference to the length of the production run and the time period it takes.

  What is clear is that, although engineers can make a technical case for large one-off WIG vessels, the costs of the vessels with their associated R&D and build-time may not sit well within a viable business model because of the high price that is dictated. On the other hand a very small vessel of, say, six seats may not be able to command sufficient operator revenue to make it worth while. Put simply, the ideal craft will be big enough to earn money but small enough not to cost too much.

  Another facet is the time it takes to build the craft and, by association, the construction method. Choice of construction method is essentially between composite and aluminium for small/medium craft, above which there comes a point where composites may not be suitable. However, composite construction is capable of very rapid production and this enables more craft to be made in a given time, so allowing each craft to carry a lower first-of-class cost burden, which keeps price down. The upshot of this is that it is easier to build a viable business case for composite small WIG craft than large aluminium ones.

- **Unique End User Experience**
  All the technical finesse in the world will come to nothing unless the craft means something in terms of a unique end user/customer experience. This is what will draw users to justify any premium on the fare price (in civil operation) or capital cost (in military operation) above that of alternative methods of transport.

  For example, a good view through the passenger windows may be a key element where WIG craft are to be used in sightseeing locations (since visibility from passenger windows of fast vessels is often poor), but this may need to be a traded off against the cabin configuration of, say a flying wing, in which it is difficult to give all passengers a window. On the other hand, at 100 + knots it may not be safe to allow passengers to move around as freely as on a boat of 40 knots; this will impact the user experience in some way. WIG already has unique attributes: a good design will work with them to create and maximise the unique end user experience.

We have seen that within the general dimensions above there are some step change decision points which need particular strategic attention (i.e. piston/gas turbine, composite/aluminium, aircraft/not aircraft). It is the business model, not the technology, which will dictate commercial success. A winning product is one in which the commercial model takes maximum advantage of, yet at the same time defines, the optimum technical specification.

Based on the above, a 'photofit' picture of a good WIG project includes an integrated lifting body form with few appendages, a lift-off aid, high sea clearance, no free flight capability, off-the-shelf composite construction, speed of circa 100 knots, small/medium size. It may look a lot like the HoverWing 20/30 (Fig. 7).

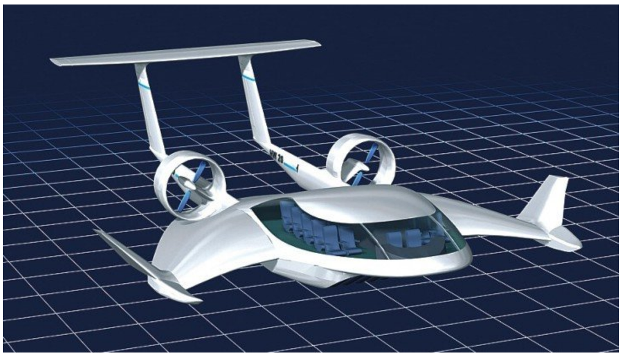

Figure 7. HoverWing 20/30 by Fischer Flugmechanik

8. CONCLUSIONS - INNOVATION DYING OF APATHY

Some years ago, the author took a senior naval architect from one of UK's leading companies to a hangar in Germany to see the final assembly of the Fischer Flugmechanik Flightship 8 001. At the sight of the craft his jaw hit the floor in astonishment. Sight of the mythical secrets of Hangar 18, Area 51, Roswell Air Force Base could not have provoked a greater response. But this is not alien technology. It is real, proven technology which is not receiving the support that it deserves. WIG is begging for adoption, not just because it is a neat technological proposition, but because it is a neat strategic business proposition also.

This paper has used WIG as a case study to juxtapose and explore attitudes towards innovation and also to explore the potential of WIG to move from concept to reality. Through experience, the author concludes that amongst the problems faced by WIG is the lack of commitment towards the adoption of innovation from western industry in general and the marine transport industry in particular. This is a cultural thing which borders on apathy. WIG is suffering from the absence of commitment from major companies.

This paper is dedicated to the memory of Klaus Matjasic; a good friend to the author, a great guy, and the designer of the beautiful FS8 001 vessel which never received the level of acclaim it deserved (Fig. 8). He dared to dream the future of such craft but died of cancer in April 2005, age 51.

One day, if WIG is successful, its story will be written up alongside that of the telephone, the TV and other great innovations in history. But history, as they say, is a tale told by the victors.

As for Apathy, well, it doesn't give a damn.

Figure 8. Klaus Matjasic and the FS8 001

9. ACKNOWLEDGEMENTS

The author would like to acknowledge the help and encouragement given by Mr Hanno Fischer of Fischer Flugmechanik (Germany) over the years which contributed to this paper.

10. REFERENCES AND NOTES

1. Directive 2002/44/Ec of The European Parliament and of The Council on the Minimum Health And Safety Requirements Regarding The Exposure Of Workers To The Risks Arising From Physical Agents (Vibration) 25 June 2002.
2. Taylor G. K. 'Market Focused Design Strategy - Wing in Ground Effect Craft, Viable Transport System or Flight of Fancy?' *Proceedings of International Conference on Wing-In-Ground-Effect Craft, Royal Institution of Naval Architects, London, (1997) and China International Boat Show* April 1998.
3. Taylor G, Matjasic K. 'Turning Seaways into Freeways: The 90 Knot Zero-Wash Ferry'. *Pacific 2004 International Maritime Conference. Sydney, Australia* (February 2004)
4. Taylor G 'WIG - What Are You Waiting For?' *International Conference on Fast Sea transportation, Fast 2005, St Petersburg Russia.* June 2005
5. 'Viking aims to save Twin Otter from extinction' *Flight Daily News* 17 July 2006.
6. O'Toole, James 1995 "Leading Change: Overcoming the Ideology of Comfort and the Tyranny of Custom"**.** Jossey Bass Wiley press
7. UK Government report: "Science and innovation: working towards a ten-year investment framework". *HM Treasury/ Department of Trade and Industry, HMSO.* March 2004
8. 'Response to The House Of Commons Science And Technology Committee, UK Science And Europe: Value For Money?' *Memorandum*

submitted by The Royal Academy of Engineering. January 2003

9. W Chan Kim & Renée Mauborgne "Creating New Market Space" *Harvard Business Review on Innovation. Harvard Business School Press 2001*
10. Emma Kelly Flightship assets go up for auction. *FlightGlobal http://www.flightglobal.com* 03/02/04
11. Flightship Employees Hit Government Safety Net**.** *Alternative news network http://us.altnews.com.au* 01/12/03.

11. AUTHORS' BIOGRAPHY

Graham Taylor is Managing Director of Hypercraft Associates Ltd, UK, a consultancy dedicated to the promotion and commercialisation of WIG vehicles and emerging marine technologies. He has been involved in WIG for over ten years and has presented numerous papers on WIG at international conferences. He has a wide range of business experience, an MBA from Thames Valley University and was formerly a Technical Director of the Royal Institution of Naval Architects.

12. CONTACT

Mr Graham K Taylor. Director. Hypercraft Associates Ltd. 23 Wyndham Avenue. High Wycombe. Bucks. HP13 5ER. England

Tel: +44(0)1494 461689
Email: mail@hypercraft-associates.com
Web: www.hypercraft-associates.com