SKIMMING THE SURFACE

The Aquaglide-5, developed by Russian company ATTK-Invest, carries 5 passengers
New ferry designs with optimized characteristics and built with the most modern materials, systems, and equipment can offer a level of service and quality far above what the old designs could provide. These designs are once again attracting riders away from land transportation.

There are many high-speed ferries around the world. Most are catamarans. There are some trimarans, a few surface-effect ships and air cushion craft, and some hydrofoils. But none are wing-in-ground-effect (WIG) vessels. Yet the benefits of WIGs as ferries, in some places, would be huge. Travel time can be reduced significantly by the higher speed of some of these new designs, and the WIG—with comfort and convenience to match any other—is capable of speeds several times greater than the rest.

When land transportation was scarce and tedious, even a slow boat could provide a relatively fast and comfortable ride. As land travel improved, water travel fell behind, because boats remained wedded to displacement hulls with low-power engines. But once more powerful engines were developed, and hullforms evolved to make better use of them, boats were able to regain their competitiveness in some places.

The most basic type of ship or boat is the displacement type, with buoyancy providing all of its support. The boat floats in the water and is pushed forward by a propeller or waterjet. This works well until the boat approaches its “hull speed,” where further speed increase becomes unreasonably costly in power and fuel. Transitioning to a semi-displacement hullform can then enable greater speed to be attained without as great an increase in power and fuel.

The next jump in speed requires a fully planing hullform, with features that don’t stop the escalation of power and fuel consumption but at least reduce their rate of increase. When planing, the boat is partly raised up in the water by hydrodynamic forces, so less of it is immersed and having to be pushed forward by the propulsors. Energy is expended raising it up, but less is then required to push it ahead, and less is required in total. Water is about 800 times as dense as air, and proportionately more difficult to push through, so getting more of the boat out of the water and into the air is a good thing.

**Opposing gravity**

Whereas operating in displacement mode accepts gravity and its limitations, a planing hull generates additional forces that oppose gravity and raise it up. Once fighting gravity is on the table, however, other ways of doing it start to make sense. Those often have included hydrofoils and air cushions, both of which raise the boat partly out of the water to reduce its resistance to forward movement. Ferries using one or the other have been in use since the 1960s.

**Bringing the wing-in-ground-effect concept to fast ferry design**

_by William Hockberger and Stephan Hooker_
These ways of fighting gravity to reduce the power of forward movement all have their appropriate regimes of application and their adherents. WIG technology provides another way of fighting gravity that has been largely unexploited, but in many cases would be better. A WIG operates very close to the water but entirely above, more like an aircraft, so it entirely avoids the drag generated by water except during takeoff and landing.

An obvious question: If we’re going to operate above the water, why not operate well above it as a seaplane, rather than risk impacts with floating objects and other marine craft? In fact, there are types of WIGs that are designed to fly at high altitude as well as near the surface, but they sacrifice a degree of efficiency compared with those designed to operate close to the water. (In addition, the risks of those impacts are extremely low for a properly operated WIG.)

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If WIG technology is so promising, where are the WIGs? As we’ll see, it isn’t for lack of research and development or even for lack of building and operating full-scale WIGs. WIG technology today is a solidly proven, operationally feasible mode of seafaring that has been ready for commercial use for many years. There actually are many small WIGs in use today in many places, produced by numerous small companies, mainly outside the United States. Companies that have tried to build and operate larger WIGs commercially apparently have lacked the resources to sustain early teething problems and costs before revenues could grow and make them profitable.

Surface effect
During the formative years of aviation, some airplanes while landing would either suddenly lose lift and drop onto the field or, just as astonishingly, refuse to alight and float across the field, sometimes coming to an abrupt stop against a tree. This became known as ground effect, and aerodynamicists and airplane designers of the day tried to understand and explain this annoyance to pilots. A few of them were inspired to wonder how that floating tendency might be used to advantage, and thus was born the idea of what we today call WIGs (or wingships), and in Russia, ekranoplans. (The phenomenon occurs over any surface and could more generally be called surface effect, but it was first recognized over land, and that association stuck.)

A WIG experiences the same aerodynamics as conventional airplanes. However, close to the surface, the pressures surrounding its wings are redistributed and changed in such a way that an increase in lift and a reduction in resistance can occur that do not happen when flying well above the surface. This obviously is a favorable feature, except for those tricky effects on a craft’s dynamics. When conventional airplanes take off and land, they are configured (mainly using wing flaps) to generate as much lift as possible, as takeoff and landing are performed at speeds much lower than normal cruise speeds and at higher angles of attack. But this configuration is not usually conducive to favorable ground effect. By contrast, an airplane set for cruising at altitude (flaps retracted and not angled) can experience a favorable surface effect if it is then flown close to the ground or water in that configuration.

A suitable height above water for a WIG is as low as a foot or two, or it can be many feet. A rough rule of thumb for good performance is ten percent of the chord length (front to back of the wing section) above the wave tops. However, for practical reasons, such as keeping above waves or being high enough to bank slightly for a turn, somewhat greater height is generally better. WIG wings tend to be short with long chords, in order to have the required lifting area with a chord long enough to generate good ground effect at the necessary height.

The stability and control of an aircraft are also affected significantly, and in a highly nonlinear way, as it moves into or out of ground effect. Aircraft have an aerodynamic center or neutral point (analogous to a ship’s metacenter) determined by the pressures on their lifting surfaces. They have one such point while flying in free air, but on entering ground effect more than one such point can occur. Their placement relative to the vehicle’s center of gravity is important to designing a properly stable WIG.

Evolution and configurations
The earliest known attempt to employ air wings on a boat to enhance its propulsion and speed was made in the late 1890s. Clement Ader, a French aviation pioneer, developed a tandem wing boat, which could lift itself clear of the water while using a water propeller for propulsion. Its wings were folded back initially and deployed when needed.

During the first half of the twentieth century, fundamental knowledge was gained mostly through analytical and experimental work in Germany, Russia, Japan, and England, leading to a basic grasp of the influence of ground effect on both lift and lift-dependent drag. Between the two World Wars, NACA, the predecessor of NASA, carried out extensive experimental work on airfoils and investigated the behavior of wings in surface effect, but mainly to understand the takeoff and landing of airplanes.

Fast forwarding to the 1960s, three fundamental configurations emerged from what can accurately be called the first decade of concerted scientific and engineering development of wing-in-ground-effect craft. The lion’s share of that belongs to the
Russians and the vision and leadership of Rostislav Alexeyev (1916–1980). His equal (but a man who was not as well funded) was the German Alexander Lippisch (1894–1976), who was one of Willy Messerschmitt’s outstanding designers. He developed his X-112 WIG concept while working in the U.S. for a short time after World War Two.

Three basic configurations evolved from their work: tandem wing (two similar wings near the surface in fore and aft positions); single wing and tail (aircraft configuration); and all wing. Both monohull and multihull variants of each have been developed.

Both Lippisch and Alexeyev in the end favored the single wing and tail arrangement over the other two configurations, and most WIGs developed since their era have gone that way. However, their wing planforms differ, Alexeyev choosing a rectangular form and Lippisch a reverse delta shape. Both configurations require vertical and horizontal tails for stability and directional control.

Another set of distinctions is based on whether the wing has a high or low aspect ratio (length to width), referred to respectively as “span-dominated” or “chord-dominated.” Span-dominated wings generally can be folded to reduce overall width for maneuvering a narrow channel and docking.

This sketch of history might sound like a typical development process, with various researchers working in different places over an extended time contributing their parts to the total. But what was accomplished in the Soviet Union under Rostislav Alexeyev from the 1960s through the 1980s was truly phenomenal in scale, and it resulted in many large models and manned test vehicles and even military WIGs. In fact, one of the first overt signs that this program was underway was the sudden appearance in late 1966 of what came to be known as the Caspian Sea Monster—a 302-ft., 550-ton test vehicle that cruised just above the waves at over 300 knots. It could take off and land in 15-ft. seas and could cruise at that height. The later military craft were the Orlyonok, a transport able to move unaided from water to beach and back to discharge vehicles and cargo through its swing-away bow; and the Lun, which could carry and launch large surface-to-surface missiles at cruise speed. Browsing the Internet for these names and related terms will uncover a vast trove of fascinating material.

Through the work of Alexeyev and Lippisch and a handful of exceptional designers who followed them, supplemented by many other researchers before and after, wing-in-ground-effect is now a well developed and understood body of scientific knowledge and engineering application.

The International Maritime Organization (IMO), with the participation of the United States Coast Guard and many other national regulatory bodies, has defined three types of WIG in accordance with the degree of flight capability. A type A WIG is functionally tied to the water it operates over. Type B is designed so that, in a controlled and stable manner, it can exchange its kinetic energy for potential energy and momentarily climb out of surface effect into free air to avoid a hazard. Type C is one capable of aircraft-type flight over land, including at altitudes sufficient to clear low mountains, although not as efficiently as a true aircraft.

Type A is the simplest and least costly WIG for early introduction into fast ferry services. Under the tutelage of Hanno Fischer, a talented protégé of Lippisch, a Korean group has developed a 50-passenger type B WIG.

A surprising and significant aspect of WIGs is their transport efficiency (defined as ton-knots per kW of propulsive power), which tends to increase with size. This is true for conventional displacement ships, but not for the other high-speed marine vehicles. Those generate dynamic lift as a function of surface area, which decreases relatively as vessel size increases. Higher speed can partly compensate for that, but only to the point of cavitation inception, which of course is not a problem in air.

Where a WIG ferry might excel

A WIG ferry will probably be somewhat more expensive to ride in than most fast ferries, so it needs passengers who place a high value on their time. It should also be attractive for carrying specialty
cargo with high time value, such as pharmaceuticals, fresh seafood and produce, financial instruments, and so forth. People speculate whether these markets even exist, but the answer is absolutely yes. All around us, we can see the parallel market for air travel; this would be very similar, but substantially less costly.

The possibilities are broad, and here are just a few examples. At the smallest size, imagine a WIG water taxi operating on protected water with waves of negligible height. The existing Aquaglide-5 carries 5 passengers, and the design could be enlarged to carry more, say 10-12. An excellent service area would be upper New York Harbor and around Manhattan, connecting with points in Brooklyn, Queens, and Staten Island, and across the Hudson River in New Jersey.

A somewhat larger design, such as the Aquaglide-30, could carry 30 passengers over water a bit rougher but still protected and smooth to ride, as between Manhattan’s Lower East Side (for example, the Wall Street area) and points along the Connecticut shore of Long Island Sound. There are other significant commuter sources along the north shore of Long Island, New Jersey to the south of New York Harbor, and both sides of the Hudson River to the north. Land transportation is highly developed in these areas but often is congested, uncomfortable, and slow.

New York City is such a major center that there are even more distant points along Long Island Sound that already provide a market for fast comfortable transportation. In summer, there’s an existing fast ferry weekend service between Manhattan and Martha’s Vineyard, which goes out Friday afternoon and returns on Sunday afternoon. It takes five hours and costs $240 round trip. Imagine such a service costing about the same but taking just an hour and a half, from and to the exact same docks. It would attract more riders and also be able to make more trips per ferry than with a fast catamaran.

It has been pointed out that, when starting a ferry service, it helps to start with an island to serve! Then, of course, to serve places where water must be crossed. However, usually it’s stressed that a boat shouldn’t try to compete with land transportation parallel to the water—especially mass transit, as it tends to be well developed and efficient, much faster than a boat, and less expensive.

But that rule may not apply to a WIG. A WIG’s speed and overall level of service might attract riders away from the highways and railways, and New York provides another example. Several years ago, a New York attorney with frequent business in Albany was considering starting a fast ferry service on the Hudson between

The Aquaglide-5 could be enlarged to carry 10 to 12 passengers, and the authors believe it could service areas such as upper New York Harbor and around Manhattan.
those cities for high-priced people such as himself. But he wanted a 70-knot boat, which he soon found didn’t exist (and probably wouldn’t have been permitted to operate because of wake wash). A WIG ferry could do all he wanted, and far better, with no wake wash issue at all.

**WIG Ferry vs. conventional fast ferry**
Except for its speed, a WIG ferry service will have most of the same attributes as that of a conventional fast ferry. But there are other factors to consider.

**Passenger comfort.** Cruising above the water, a WIG won’t experience roughness due to waves or even the updrafts and downdrafts of an aircraft, because of the absence of vertical air currents near the surface. But being more aircraft-like, smaller WIGs will have less open space for walking around.

**Suitable routes.** Conventional ferries often stop at intervals to pick up passengers along the route. A large WIG ferry may take two minutes to get off the water into ground effect, so it won’t make sense to come back down for frequent pickups. It’s best suited to a route with relatively long stretches above water in ground effect. However, a WIG can take shortcuts across shallows or low-lying land, rather than having to remain in deep water and take the long way around.

**Environmental impacts.** A WIG will create practically no wake while cruising in ground effect, but it will produce a wake while getting off the water. It also will use its full power then and generate greater noise, although ducting the propellers can reduce that while shortening the run into ground effect. By completing its trips in much shorter time, a WIG’s fuel consumption and emissions per passenger mile will be considerably less than for a conventional fast ferry.

**Channels.** Because of its high speed, regulatory authorities will probably require a WIG ferry to operate along a special course established for its exclusive use. But a WIG channel can be a very shallow one, which no other vessel could use anyway.

**Maneuvering.** A WIG underway is much faster than any other vessel on the water and can maneuver to avoid them. Modern radar and navigation equipment can enable it to see far enough ahead and anticipate the need to maneuver. In the case of an object that’s very low in the water, even a type A WIG can pass over it.

**Terminal facilities.** A WIG should be able to use the same docks and other facilities as a conventional ferry, and the usual means for tying up.

**Operators.** The WIGs considered here are marine vessels and can be operated and maintained by people with marine skills, training, and certification, although they would probably require additional training for maneuvering at high speed.

**Routine upkeep and maintenance.** This probably would be a more systematic program than for conventional marine vessels, as the WIG will rack up many more miles in a time period, and its high speed makes prevention of equipment failures more important.

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**Ruggedness.** A WIG will be boat-like rather than aircraft-like in its construction and can be treated the same as a conventional high-speed vessel.

**Operational safety.** At high speed, a WIG has less time to maneuver to avoid an impending encounter on the water. However, it has greater flexibility for accomplishing it, because the other vessel can be treated as essentially static.

**Operational flexibility.** Taking much less time from origin to destination than a conventional ferry, a WIG ferry has more opportunities to shift routes during the day and reach more potential passengers in different locations. During non-commuting hours, it can be used in a wider variety of ways and to greater distances (for example, tourist excursions). What would be dead time for the conventional ferry can be productive time for the WIG, and fewer units can handle a given level of demand.

**Costs and profitability.** Acquisition cost, and operation and support costs, will be higher for a WIG than for a conventional fast ferry (yet far below those of aircraft). But its speed and consequent high productivity can make its cost per passenger mile comparatively low and improve its potential to be profitable.

WIG technology may be new for a ferry service, but it has been around for many decades and has been solidly proven. Many WIGs have actually been built and operated, including very large high-performance units. It’s a technology ready for commercial use.

WIG ferries will be fast, comfortable, and safe. Substantial attention has already been given to how they will be certified and regulated for commercial operation, and the IMO and United States Coast Guard and many other agencies internationally have developed draft rules that are ready to be finalized when needed.

WIG ferries can be operated and supported in essentially the same way as conventional high-speed ferries. Their high productivity can make them affordable for their passengers and profitable for the company that operates them.

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