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APPROPRIATE TECHNOLOGY HOVERCRAFT

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INTRODUCTION

This paper traces the development of three generations of hovercraft which were designed from the outset to meet the humanitarian needs of people in remote, undeveloped areas of the world. The three designs in question are, chronologically: the "Missionnaire", the "River Rover" variants, and a proposed new design, the "Hover Lorry."

All three types of craft came into being as the result of specific situations where more conventional forms of transport such as wheeled vehicles, boats or light aircraft had proved to be severely limited in their usefulness for one reason or another. It may therefore be useful to briefly examine these situations in order to identify the limitations on the use of conventional vehicles, and then to trace the steps which led to the eventual use of hovercraft in place of these vehicles.

It is also proposed to demonstrate how a great deal of "real-time" experience of operating hovercraft in demanding situations in remote areas has influenced the writer and his associates in designing hovercraft most suited to the needs of people in developing countries.

HISTORICAL BACKGROUND: (1) The "Missionaire" (See Figure 1)

The first design of hovercraft, the five-seat "Missionaire" had is origins over twenty years ago, when the author, a former aircraft design engineer, joined the Mission Aviation Fellowship as maintenance engineer for a newly-established flying programme in the Republic of Chad. A major part of the programme centred on Lake Chad, a shallow inland sea about the size of Wales, bordering on the southern edge of the Sahara desert. There, a Cessna 185 aircraft, equipped with amphibious floats, was used to provide a "flying doctor" service for the quarter-million people living on the shores of the lake and in many of its literally thousands of islands. Prior to the coming of the aircraft, a mission doctor had used a combination of four-wheel drive vehicles and boats to travel around the vast area which constituted his "practice". As a consequence well over half the doctor's time and energy were spent travelling - often in very difficult circumstances.

The aircraft reduced to a matter of minutes journeys which previously took hours or even days. However, even with its amphibious capability, the aircraft was found to have serious limitations:

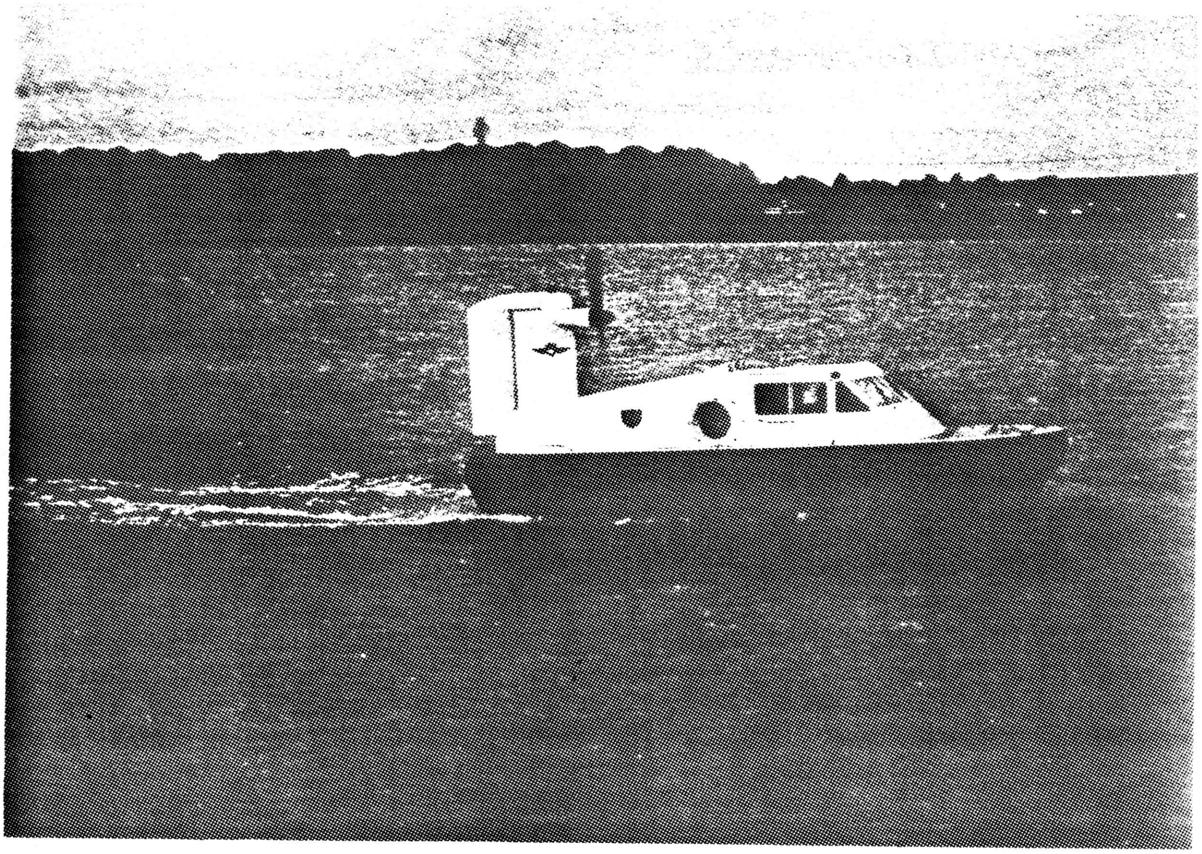
Due to the sandy terrain surrounding the lake, relatively few sites for airstrips could be found, while putting down on water was always something of a calculated risk, as the water was usually so muddy that it was impossible for the pilot to be sure of its depth. It was usual to touch down on the water a long way from the shore, then to taxy as far as possible towards the shore until the floats ran aground. There was then no alternative but to get out and wade through bilharzia-ridden water and sometimes over a distance of several hundred metres, and often carrying heavy supplies, and in temperatures as hot as can be found anywhere in the world.

Under such conditions it did not require much imagination to appreciate the potential value of a hovercraft. On his return to the U.K. in 1969, the author made it his business to investigate the various types of small-to-medium hovercraft then available on the commercial market. Only one design came anywhere near to meeting the requirements of Lake Chad. However, it seemed to be unnecessarily sophisticated, was expensive to buy, and to make matters worse, the manufacturers were about to go into liquidation!

At about this time, the author met Tony Burgess, a professional engineer who had specialised in hovercraft design and development since the time when hovercraft first made their appearance. Together with Tony Burgess, the writer produced a design for a hovercraft with operations in Lake Chad specifically in mind. With a spruce and marine-plywood hull, and powered by two Volkswagen air-cooled car engines, the five-seater craft was designed for ease of construction, and of repair and maintenance. To prove the point, a prototype, subsequently named the "Missionaire", was built at a comprehensive school in north-east London and much of the work being carried out by the pupils.

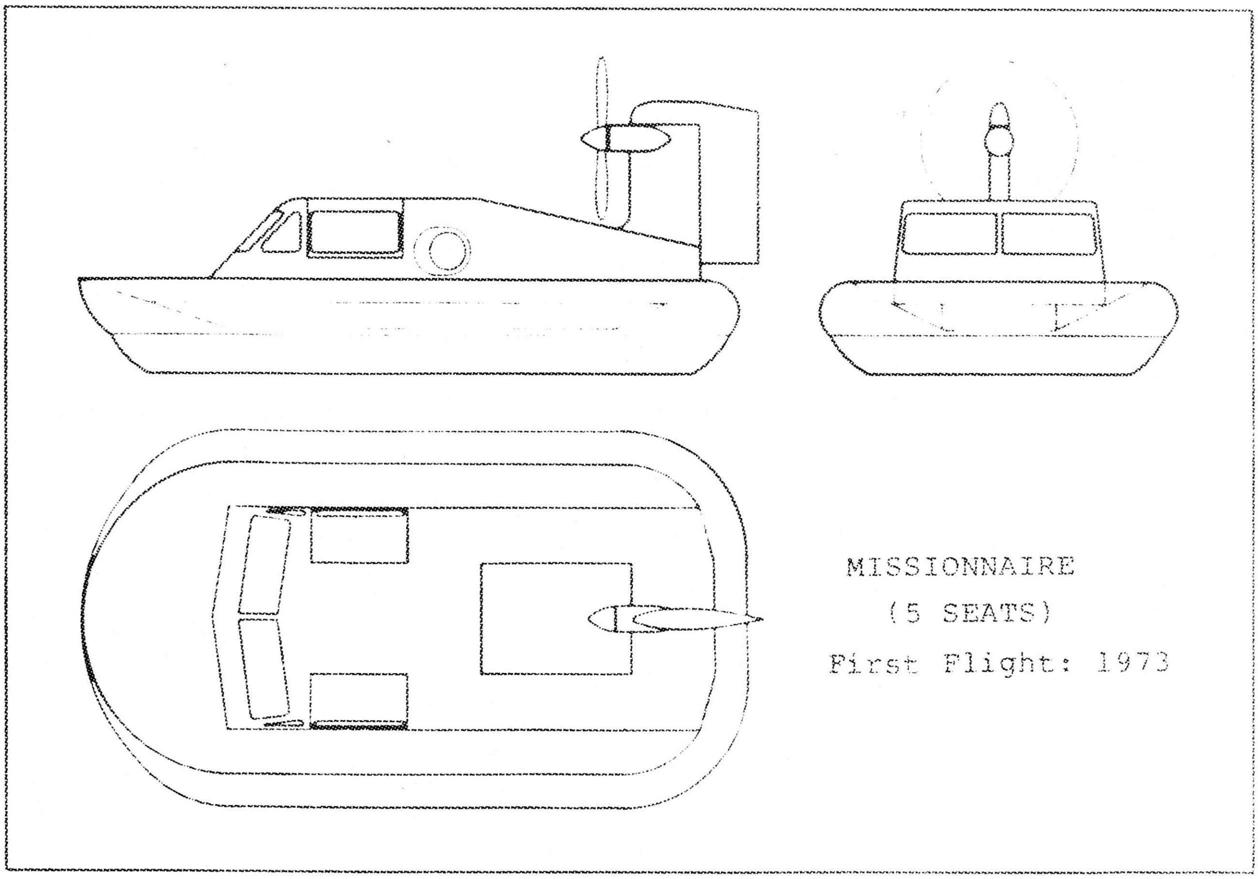
In spite of its unpretentious origins, the Missionaire was in no way an amateurish "Lash-up job". Its performance was impressive, and after a relatively short period of development, its reliability became second to none. In the summer of 1975, the Missionaire established a record for light hovercraft by circumnavigating the Isle of Wight in 2 hours 14 minutes. This circuit has long been regarded as the hovercraft "Blue Riband". In spite of a number of subsequent attempts by other craft to better this time, the Missionaire's record still stands.

Sad to relate, the Missionaire was never sent to Lake Chad, since, by the time the craft was ready to go, a severe drought affecting the whole southern Sahara region had caused a drastic reduction in both the depth and the size of the Lake. Many of the nomadic tribespeople living on its shores moved away in a vain search for greener pastures elsewhere, and the medical aid programme was severely curtailed.



MISSIONNAIRE Technical Data

Engines: (Lift) 1 x 53bhp Petrol.	Propulsion: 1 x 68bhp Petrol	
Unladen Weight	998	Kg
Max. Payload	635	Kg
Cruise Speed	32	Knots
Length (Hard Structure)	6.70	Metres
Beam (Hard Structure)	3.20	Metres



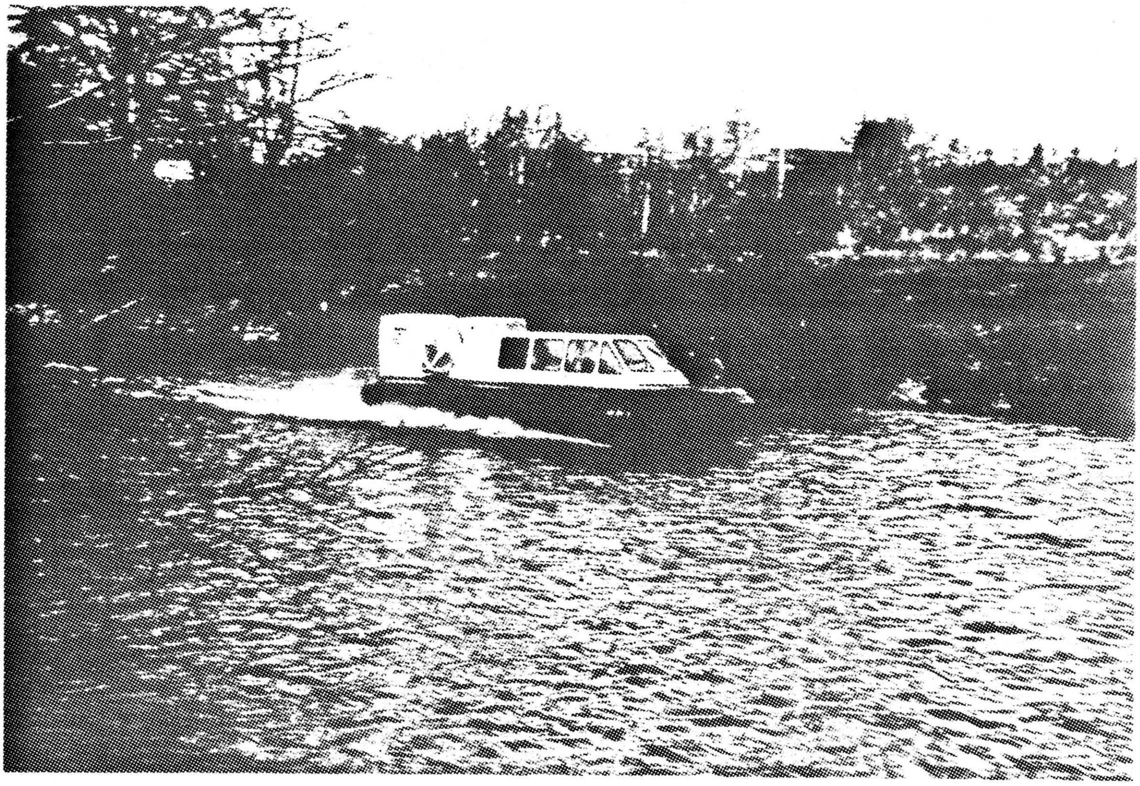
HISTORICAL BACKGROUND (2): The "River Rover" (See Figure 2)

At about the same time that doubt began to be expressed about the practicability of sending the Missionaire out to Lake Chad, a doctor at a mission hospital in Nepal got to hear of the Missionaire and asked whether it might be possible to use the craft on the rapid-strewn River Kali Gandaki, with a view to establishing clinics along a 65 mile length of this otherwise un-navigable river. After giving the matter due consideration, the author, together with others closely involved with the project, rejected the idea as impracticable. Although the control characteristics of the Missionaire were perfectly adequate for the wide-open spaces on Lake Chad they would certainly not be suitable for negotiating sharp bends and for avoiding protruding rocks on fast-flowing mountain rivers.

The need to equip a hovercraft with improved control characteristics led to work on a completely new design, which eventually became known as the River Rover. It was already well known that, if a hovercraft is "banked" into a turn in a way similar to an aircraft, it becomes considerably more controllable, with a significant reduction of undesirable sideways drifting. It was also known that experiments had been carried out on hovercraft equipped with "skirt shift", whereby the craft could be tilted into a turn. Whilst this method was effective, it seemed an unduly complicated solution to the problem. The skirt was in any case the most troublesome part of a hovercraft and, in the author's opinion should be kept as simple as possible.

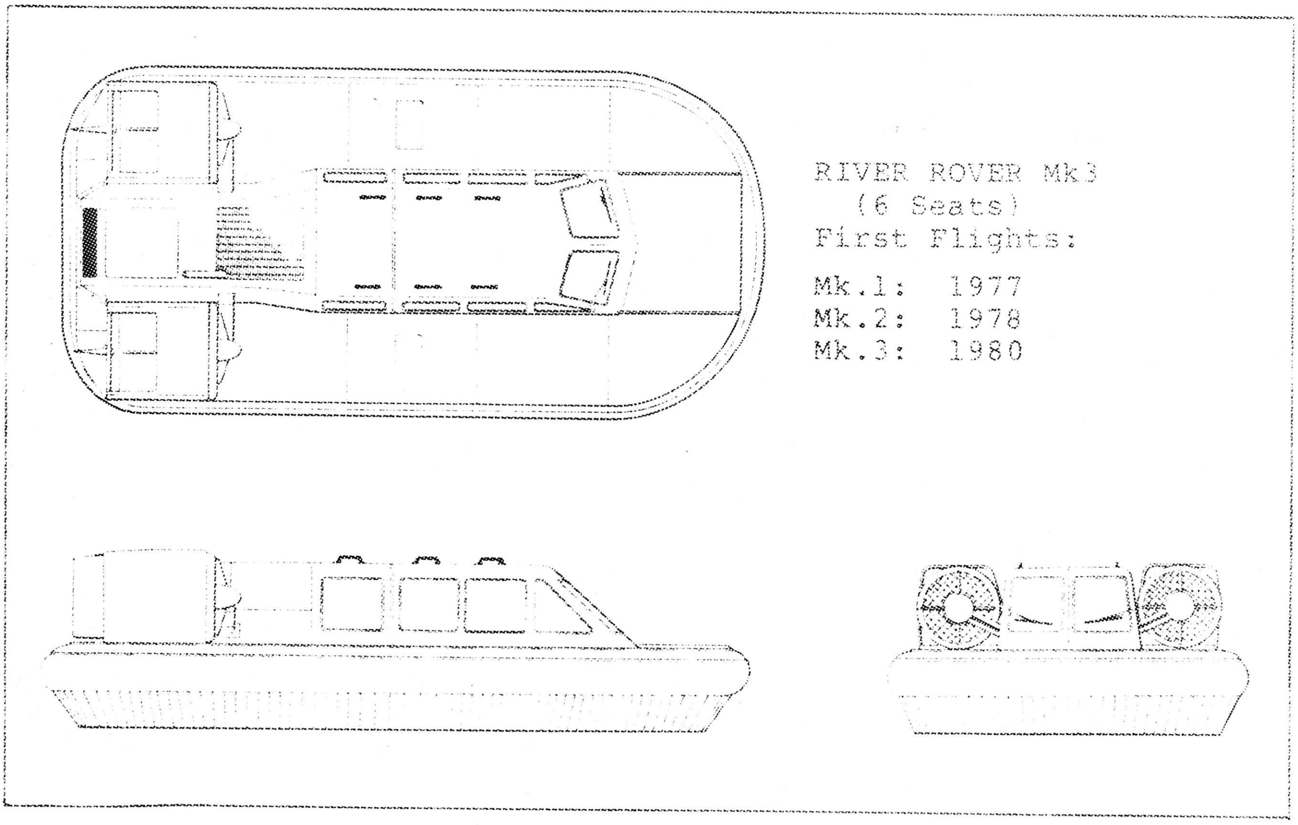
With such considerations in mind, a completely new system of control using differentially-acting "elevons" was devised and patented. The elevons are in effect horizontally-hinged flaps acting in the slipstream of two widely-spaced propulsion fans. Fig.3 shows, in diagrammatic form, how elevons are used to tilt the craft and how they can substantially reduce sideways drift both in a turn and under crosswind conditions. Apart from their differential action, elevons can also be made to act together to produce changes in fore-and-aft trim. A further bonus is that, by moving the elevons through 90°, the rearward-acting slipstream can be blocked, thereby giving the ability to control thrust - either differentially to assist low-speed turning, or together to enable the craft to hover without moving forwards. This in turn means that a single engine driving both lift and propulsion fans can be used without any loss of controllability or the need to disengage the drive to the propulsion fans.

Equipped with its elevon controls, the six-seat Renault-engined River Rover was used with great success on expeditions to Nepal and Peru, where the craft was able to negotiate rivers with sharp bends and dangerous rock-strewn rapids. In such environments several hundred hours of operations were completed with minimal damage to the craft. Two River Rovers were left



RIVER ROVER Mk.3 Technical Data

Engine: (Standard Version)	1 x 108 bhp Renault 2 litre Petrol
(Version for China)	1 x 175 bhp Renault Turbo Petrol
Unladen Weight	800 Kg
Max. Payload	450 Kg
Cruise Speed	22 Knots
Length (Hard Structure)	5.85 Metres
Beam (Hard Structure)	2.62 Metres



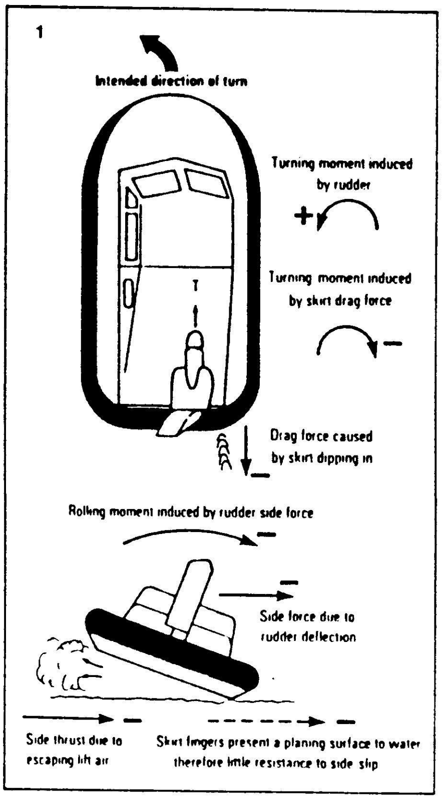
1. When a conventional hovercraft turns, the forces acting on it are all disadvantageous. (Marked by -)

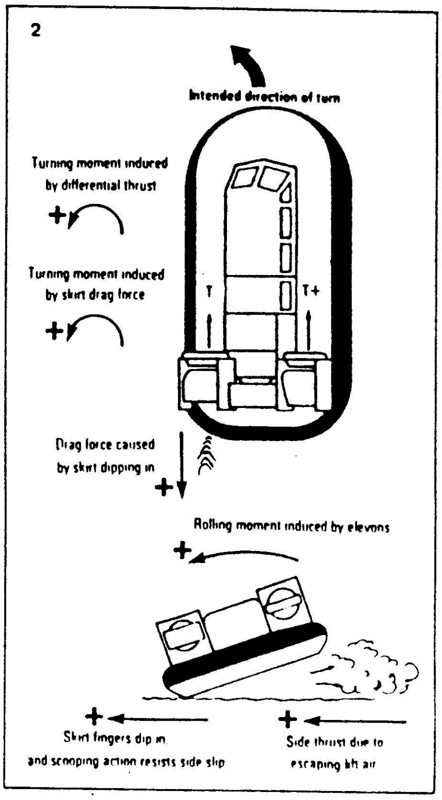
2. River Rover's elevons solve this problem by making the craft bank into the turn.

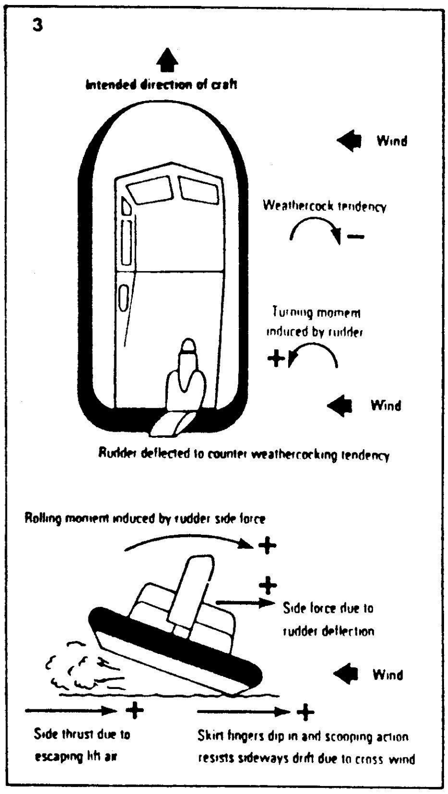
3. Conventional hovercraft naturally resist the weathercocking effect of sidewinds.

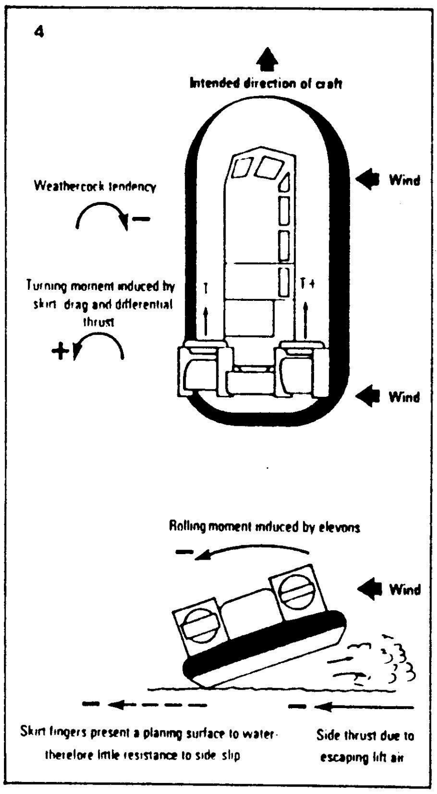
4. When River Rover had elevons alone, these accentuated the effect of sidewinds, giving drift.

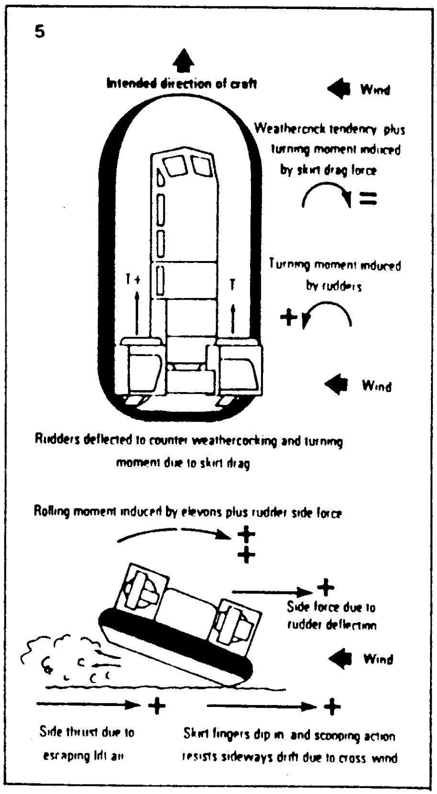
5. When rudders were added to the elevons, side drift was eliminated.











in Peru after the 1982 expedition, and they are still being successfully driven and maintained by indigenous personnel with no formal educational or technical qualifications.

A further novel feature of the River Rover was its simple bolt-together "Meccano"-type of construction. One object of this method of construction was to make for ease of repair in the field and, particularly, for ease of transportation into remote areas. No part or sub-assembly was too large to fit into a light cargo-carrying aircraft of the Cessna 206 type. On one occasion a small 3-seater Hughes 500 helicopter was used to lift large sections of a River Rover into a remote part of Irian Jaya, Indonesia - the sections being slung below the helicopter.

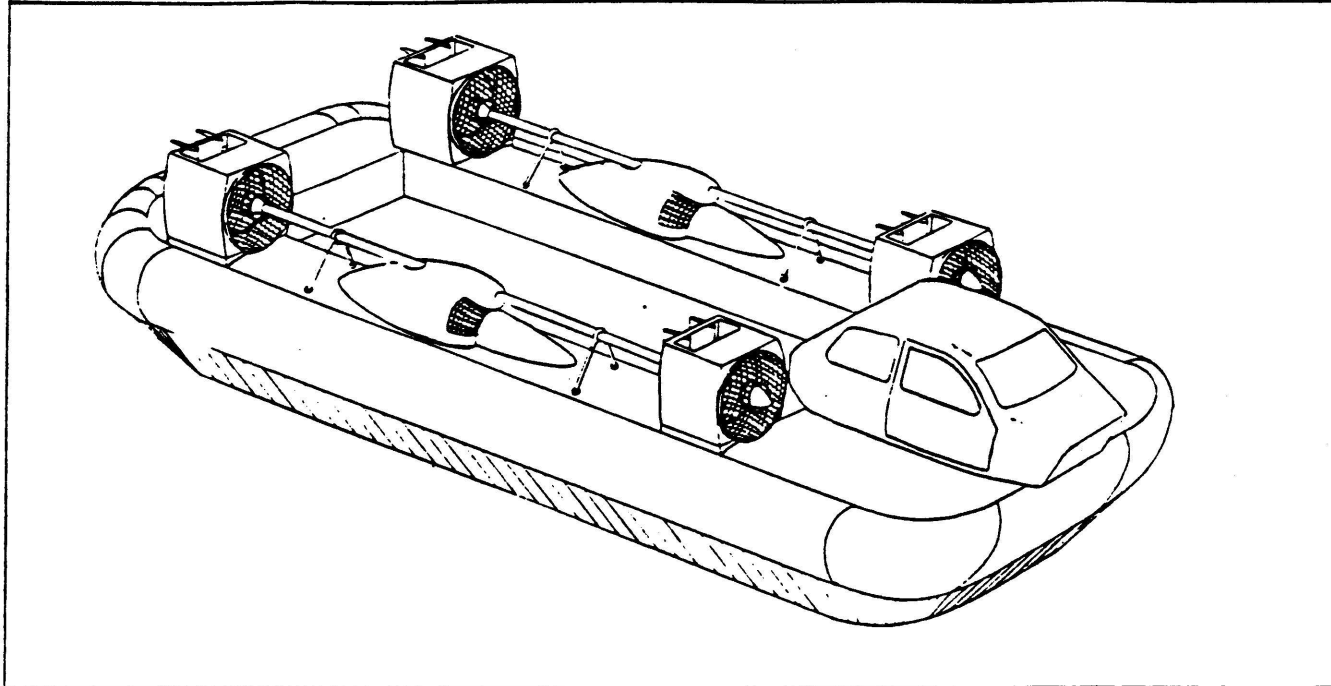
Whilst the "Meccano"-type of construction tends to be labour-intensive, and therefore not entirely appropriate to being assembled in an affluent western country, it becomes a very attractive proposition and is regarded as appropriate technology in poorer countries where labour is cheap, and anything which creates jobs is generally looked on with favour by the governments of such countries. The expedition to Peru generated great interest in the River Rover, and serious consideration was given to the possibility of building these craft in that country. Unfortunately the political situation was very unsettled at that time. This, together with severe import restrictions, caused the plan to be abandoned. Whilst the River Rover can still be made in the U.K. to special order, its production in a developing "user" country could dramatically reduce costs and greatly increase the sales potential of this craft.

3. **HOVER LORRY** (See Figure 4)

The Hover Lorry is designed to be a simple, inexpensive, "no frills" hovercraft with a 3-ton payload capacity. This compares with the half-ton capacity of the River Rover. Like the River Rover, the Hover Lorry employs bolt-together construction and elevon controls. Apart from the larger size there are also several other significant differences: The Hover Lorry is primarily a cargo-carrying machine, with a large 9 metre by 2 metre open hold and a forward-mounted fully-enclosed 4-seat cabin. In addition to a pair of aft-mounted propulsion fans similar to those of the River Rover, there is a further pair of forward-mounted propulsion fans. Each fan has a pair of elevons and a pair of rudders located in its slipstream. It can be demonstrated that the forward-mounted fans and controls give rise to a considerable improvement over the already very satisfactory controls of the River Rover. The Hover Lorry is driven by two engines - preferably diesels of approximately 130 bhp each. The design does however lend itself to changes of engine to suit specific requirements.

FIGURE 4

BRITISH HOVERCRAFT EXPEDITION TO CHINA

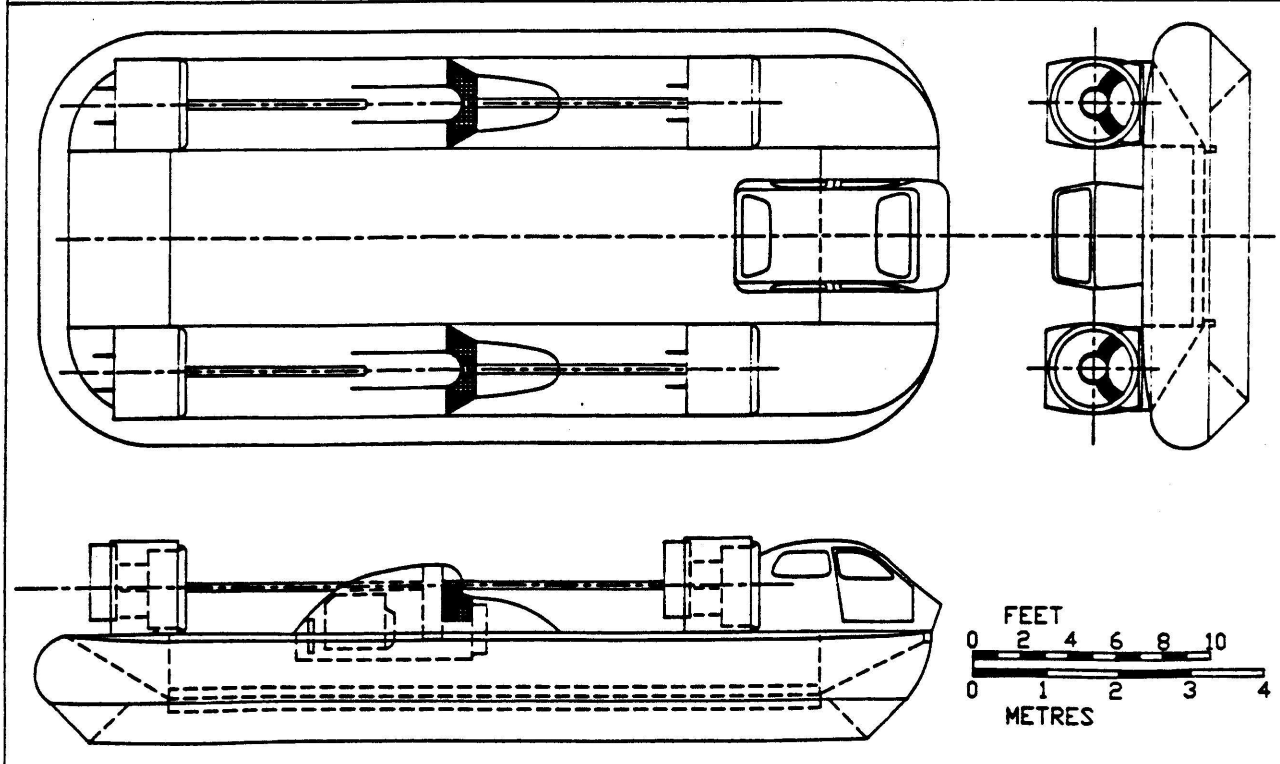


HOVER-LORRY. A 3-TON PAYLOAD UTILITY HOVERCRAFT. PRELIMINARY DESIGN STUDY.

HOVER LORRY Technical Data

Engines: (Standard Version)	2 x 130 bhp Diesel
(Version for China)	2 x 175 bhp Petrol
Unladen Weight	3200 Kg
Max. Payload	3000 Kg
Cruise Speed	25 Knots
Length (Hard Structure)	11.25 Metres
Beam (Hard Structure)	4.75 Metres

BRITISH HOVERCRAFT EXPEDITION TO CHINA



HOVER-LORRY. A 3-TON PAYLOAD UTILITY HOVERCRAFT. PRELIMINARY DESIGN STUDY.

(A) **The Hover Lorry Concept**: Notwithstanding the technical success of the River Rover, its main shortcoming lies in its small size, and, consequently, its relatively short range and limited carrying capacity. In Peru, for example, it was difficult to operate the craft over distances of more than about 80 kilometres from base without an elaborate system of logistic support in the form of large canoes propelled by powerful outboard motors. This in turn meant that the hovercraft was often denied the opportunity to "go it alone" along vast stretches of the upper reaches of the Amazon which were un-navigable by conventional boats. To enable even as few as four people to travel any appreciable distance up such rivers it became apparent that a much larger hovercraft would be needed. In proportion to the size of the passenger cabin, a much larger space and carrying capacity would need to be available for such essential items as extra fuel, camping equipment, food, and medical supplies - not to mention the carriage of any cargo which could well be the primary object of the journey - for example: building supplies, materials for installing clean-water supplies, or even a vehicle up to the size of a long-wheelbase Land Rover.

The potential contribution which hovercraft are able to make in flood-relief operations is another clear case for a large carrying capacity. The floods which recently occurred in the Sudan and Bangladesh underlined the need for a large hovercraft. The most urgent task was obviously to rescue large numbers of people from imminent danger of drowning. In such circumstances even a simply-appointed cabin might be considered an inappropriate luxury. Furthermore, where people are already living at or below poverty level, the ability to rescue their livestock and salvage their few material possessions would go a long way towards relieving their distress. It would certainly greatly alleviate the ensuing problems of rehabilitation, once the displaced people were able to return to what, if anything, was left of their homes.

For tasks such as those just described, even a lorry-sized hovercraft is none too large. It is , however, almost axiomatic that the parts of the world where hovercraft are able to make their most useful contribution are also the parts which are most inaccessible from the outside world. It is important, therefore, that the hovercraft should be easily transportable. For a large hovercraft such as the Hover Lorry, this inevitably means that it must be dismantled into manageable sections. Once again, the Meccano-type construction comes into its own. At all events, the craft should be able to fit into a standard 40 foot freight container with only the side-deck structure folded up. Similarly, it should be possible to carry the craft on a flat-bed lorry. Towing it on a trailer behind another vehicle is not possible on mountain roads such as those experienced in Nepal and Peru, as it would be unable to negotiate hairpin bends. At the other extreme, on flat, low-lying land with unmetalled roads (e.g. the notorious cotton-grass country in the south Sudan) a trailer would very quickly sink in up to its axles if it were not an expensive purpose-built vehicle, with low footprint pressures.

Finally, it should be mentioned that the Hover Lorry is envisaged as being the main element of a flood or famine disaster relief unit. Such a unit would consist of hovercraft held in a state of instant readiness, and manned by crews of already trained volunteers. Normally the craft would be stored in a "developed" country such as the U.K., and transport to the destination country would be by air. (the Hover Lorry can be carried in a C-130 Hercules aircraft). On arrival at its destination the Hover Lorry can be made ready for operation in a matter of only three or four hours.

(B) Hover Lorry - Technical Description

1. **Hull Structure**: The main structural element of the hull is a pair of deep-section box-beams running fore-and-aft each side of the 2 metre wide cargo hold. These beams are sealed to provide buoyancy and integral fuel tankage, and to take all the bending, torsional and landing loads to which the craft is subjected. The box-beams are connected to each other by extended aluminium alloy transverse channels - the joints being bolted together. Over these beams a marine-ply floor is bolted - all joints being sealed. Below the floor, the space between the transverse beams is filled with blocks of lightweight closed-cell foam to provide added buoyancy. There is no bottom skin to the hull, as experience with other designs has shown this to be a very vulnerable area. Damage inevitably occurs to this part of a hovercraft hull, but it would need to be very extensive before the foam blocks would need to be replaced. Structural damage to the transverse beams is readily repairable as these beams can be easily unbolted from the main structure.

   Side decking and the decking forward and aft of the cargo hold is of relatively thin marine ply, and the supporting structure is also relatively simple and light in weight. The side decks will hinge upwards about the line where they attach to the top outboard edge of the box beams. This reduces the overall width of the craft to within acceptable limits for road transport.

2. **Cabin Structure and Fittings**: A major feature of Hover Lorry design philosophy is the use of an all glass-fibre body from a Reliant Robin or Rialto three wheeled car. This may sound like a somewhat bizarre approach, but, on further consideration such a choice can make for a very substantial reduction in the price of a complete hovercraft.

In a limited production situation there should be little difficulty in processing good second-hand body shells, complete with upholstery, seats, doors, winding windows, windscreen wipers and washers, heating and ventilating, and all the other small details which would otherwise need to be incorporated into a purpose-designed cabin. Experience of building other hovercraft has shown that the construction of the cabin and all its fittings can constitute over 30% of the cost of a complete craft. By contrast, a good lightweight G.R.P. body from a three-wheeler can be bought for around £500. Looking at the problem another way, to build small quantities of fully appointed car bodies from "scratch" would incur astronomical costs. It is doubtful whether a unit cost lower than £50,000 could be achieved!

The only changes necessary to the Reliant body would be the replacement of the engine compartment with a simple G.R.P. fairing. Local fairing-in of rear wheel arches and rear light housing, if considered necessary, would be of a purely cosmetic nature. Internally, the only alterations necessary would be replacement of the car controls and instrumentation with those appropriate to the hovercraft application.

It is worth making the point at this juncture that, for a "workhorse" hovercraft, it is not only inappropriate but totally un-necessary to have a cockpit layout and instrumentation resembling the flight deck of Concorde! All that is required by way of instrumentation is that which is normally found in a medium-sized commercial vehicle, with duplication of engine-monitoring instruments to cater for the twin engine installation.

3. <u>Lift and Propulsion System</u>: Each side-deck assembly incorporates an engine driving an axial-flow lift fan and one forward and one aft propulsion fan. The lift fan is driven at engine speed off one end of a primary shaft which also carries a pulley for a belt drive to a propulsion drive shaft mounted immediately above it.

A manually-operated clutch fitted to the engine flywheel enables the drive to the primary shaft to be disengaged for engine starting and shut-down purposes. The belt drive from the primary shaft to the propulsion drive shaft incorporates a speed reduction. From the ends of the propulsion drive shaft, long semi-flexible tubular shafts carry the power to the 1 metre diameter forward and aft fans. The tubular shafts are contained in large-diameter aluminium alloy tubes which incorporate support bearings, in a manner similar to that used to drive the tail rotor of a helicopter.

A test rig capable of testing a complete Hover Lorry transmission and fan system has been built and early results are encouraging.

An automatically-acting non-return flap immediately downstream of each lift fan ensures that in the event of one engine stopping, sufficient lift air can be derived from the other engine to keep the craft hovering. The two propulsion fans on the side of the "live" engine will provide sufficient thrust to enable the craft to continue its journey, albeit at a greatly reduced speed. The controls are sufficiently powerful to resist the effects of asymmetric thrust.

4. **Control System:** With its four propulsion fans, the Hover Lorry promises to be exceptionally controllable. A radio-controlled model has been built to investigate the four-fan configuration and the results are quite spectacular.

The model has confirmed the prediction that, when travelling up an incline, as for instance climbing rapids, the craft can be made to traverse from side to side without moving forwards or backwards. This confers on the driver of the craft the ability to feel his way carefully up a rapid by avoiding obstacles or areas of excessive turbulence. By the same token, inching back on the throttles will allow the craft to make a slow, controlled descent of a rapid in reverse, with good rearward visibility afforded by the positioning of the driver's cabin in relation to the propulsion ducts.

All four propulsion units are identical, each comprising the well-proven horizontally-hinged elevons, and verticallyhinged rudders. Unlike a craft equipped with aft-mounted fans only, the rudders of a four-fan hovercraft always act in a direction which opposes the undesirable sideways drift to which all amphibious hovercraft are subjected.

5. **Skirt System:** The skirt is of well-proven "HDL open loop and segment" design. Being the most vulnerable and wear-prone part of a hovercraft it is the designer's belief that a skirt should be kept as simple as possible, making for ease of repair and minimal cost. The Hover Lorry does not therefore have skirt shift - the necessary banking and pitching controls being provided by elevons, as already described.

CONCLUSION

It is hoped that the writer has demonstrated how the Hover Lorry formula has been devised from actual experience of using other types of hovercraft in remote, undeveloped areas of the world. That experience has demonstrated without much doubt that in all but a few cases a much larger craft would have been more efficient and cost-effective. In a few specialised situations a case exists for small, lightweight, inflatable hovercraft. However it should always be borne in mind that most places accessible to small hovercraft are also accessible to small boats or canoes, even if it means that the boatman has to resort to the laborious but time-honoured practice of getting out and dragging his boat over shallows or mud banks, or even portaging it overland to avoid rapids.

Clearly such options are not possible with larger boats capable of carrying heavy payloads over long distances. However, a low-cost, appropriate technology hovercraft such as the Hover Lorry gives rise to hope that, for the first time ever, the ability to bring relief to areas hitherto considered inaccessible will become a practical reality.