HOVERCRAFT DESIGN JOURNAL

By
Carlos Camoesas

(r/c model Hovercraft designer, research and development since 1991)

INTRODUCTION

Hovercraft is one of a kind machine, in designing a hovercraft, one have to consider various scientific fields such as, aerodynamics, mechanics and hydrodynamics.
There is no other machine that involves so much scientific areas to research and develop, so, we can say that hovercraft is expected to improve performance as well as science and technology are applied to it.

As well as other transportation means, hovercraft technology can benefit from military, transportation, racing, or just "backyard" homemade construction this last including r/c model research and develop. It is not intended here by, to observe all those fields, but just concentrate in racing, homemade and r/c model.

Hovercraft as we know it, was invented and demonstrated in 1959 by Sir Christopher Cockerel, a British engineer. We can also refer to hovercraft as an A.C.V. (Air Cushion Vehicle), and since its first appearance it was mostly applied in transportation, but also in military and later on some decades, in competition. This last hovercraft issue, as a light, single seat machine, was developed and "revealed" mostly due to "backyard" homemade efforts, and soon meetings and racing started.

Since its appearance this "weird" as all transportation machines, hovercraft touched the heart of some, and soon, static scaled models of the prototypes, transportation and military versions where done and also radio controlled electric powered versions. With the implementation and spreading worldwide competition, scaled racing "nitro" racing r/c models, had also born.

Here is the time were our venture begins, back in 1991, in Portugal.

The author had a dream and started to make it real, scale racing, "nitro" powered, light hovercraft that real it must include a pilot figure also at scale with real driving moving feature.
First "free flying" model was demonstrated that year, powered by a .49 "black widow" cox engine, it was named as "Footcraft" because of is unique steering control…
One year after, in 1992, first complete model including all those dream features appeared, it was "Morais", named out of a bold with glasses friend, as the model figure was.

A dream came through!

Carlos J.O. Camoesas, Portugal - Ovar -Válega, 2004/04/16

(To be followed)

Carlos Camoesas

R/C Model Hovercraft Design

An Essay

HOVERCRAFT DESIGN JOURNAL
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FROM THE AUTHOR

I thought about making a book, I have some 13 years of real work, development, given proofs and history making, so, I think I have enough to "download", instead of it, I hope to be able to share it for FREE:

Here, I will post in a regular basis, a kind of (Hovercraft Design Essay), where you can find some information as well as my point of view about hovercraft design and development.

It is the objective, to be a Living Book, as well as I can maintain it ongoing trough the times. As being a Living Book, you can expect it not to be as well organized as a standard book, also English is not my Mother Language, so expect also some English errors.

I hope everyone can do a good use of it, and also expect you to download, print and collect it , as an humble gift from This Hover Lover.

It will be a "compendium" of my research, know how, facts and theory about Hovercraft design, performance and future of such unique machine, Thanks Sir Christopher Cockerel by inventing it!

Sincerely,

Carlos José de Oliveira Camoesas

Válega, Ovar, Portugal, 2004/04/19

(to be followed)

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Thinking a hovercraft

Before you start designing your hovercraft, make some questions to yourself;
What kind of hovercraft I want? Real or model Scale, what for I want it, just for joy? For racing? To achieve speed and top performances? Where will I use it? Just in the backyard? In the beach? In the river, snow, grass, land ...?

Just after all this questions are answered, begin thinking in what you need to build it. You have enough budget for the purpose? Are you able to work required materials; are all the things you need available? Can you homemade those that aren't ?
If you have negative answers, get back to the starting point and choose not the ideal one but a similar one that could obtain all affirmative answers of the second step.

Once you reach this point, get all data from the materials and accessories you need, or if you already have them just take data, figures, graphs, sketches, dimensions...
You have it all ,now, it is time, to start designing your hovercraft.

First statement: ***Never think hovercraft as separate parts. Hovercraft must be thinking as a whole thing!***

You don't think the hull, the deck, the skirt, lift, power, thrust etc, as independent things. Hovercraft is all one, every little thing you design or change in an existing craft, will interfere in another one, or lots of them.
If you take an existing one and replace just the engine, by another one with double the power, for instance, you are not improving and just altering power.
Probably will need also a new prop or fan, maybe the rudders have to be altered, maybe gravity centre must be adjusted, maybe the skirt or lift system are anymore enough for the improved speed, maybe...

Get the point?

Just think it all as one piece, as a "team", nobody plays alone in a team. You have to chose (design) the team, after that "teach" the players to reach your desired purpose, and just at this point, you take one by one.
After you have designed it at first, you have your "team", just stop and think, figure out, how they play each other, are they a team? See how thrust can interfere with steering, and lift. See how power interferes with lift, how it acts on the skirt, in " flying" attitude, in balance, stability...
See how centre of gravity interferes with stability, manoeuvrability, how it is affected by the driver, passengers or just load.

So, do you have a good "team" or you just have the best and expensive players in the world, and the "coach" (you), is unable to get them all to win?

2004/04/19
(to be followed)

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Brief Resume and some history

Now, that you know the way I think, some historic facts are needed to understand it, and also to demonstrate that those comments and statements are not just simple talking and theoretical issues. This part won't be long, as short as possible in order not to be boring.

Carlos José de Oliveira Camoesas, born in Elvas – Portugal 1963,

Having been since the High School a "Library Rat" searching all documents and papers relating Aerodynamics, found at the Air Force, the best resource on that field.

Not only by studying all available documents but also learning from those that make also Aircraft a living way.

As well as theory, nothing better than observing and sharing ideas and learning from Pilots, Flight Engineers etc.

So, those were the basis.

Later on, we are now jumping to the year of 1991, when all started, after seeing a photo and an article on a magazine, about… **hovercraft racing???**

Till that time I thought hovercraft were only those big transportation machines, but also light and racing ones and single engine? I started to design an experimental model just to figure out the principles, after all, I leaved nearby the beach, also one river and also an Air Base, that r/c model planes were allowed to practicese at the weekends regarding in regarding no traffic flies.

I had it all, some Aerodynamic mechanics and r/c knowledge, asphalt, concrete, land, sand and water, and during that year also a working model, free flight, powered by a small .049 cox engine.

"Footcraft" was born in 1991, named out from its unique steering device (some friends in a circle kicking it). It performed very well on sand, asphalt and also on the water, since no flameout, because just for theory testing purposes, it was not featured with floating capabilities.

First, complete dreamed featuring machine was **"Morais" in 1992**, A Real master piece at its time; 1/4 scaled , "nitro" powered racing Hovercraft featuring a real moving pilot also at scale, with floating capabilities and two channel radio controlled.

It was so amazing that I even took it when I gone to Ofir – Portugal to see a race for the first time, it was part of the European Championships 1992. I had no chances to perform it there, it was so much wind that the races where cancelled at the afternoon.

Lots of models followed those ones, they also are historic Marks, but for now lets end this presentation, will have a section just for my models later on, another proper section.

2004/04/19
(to be followed)

Physics

We will use some aerodynamics knowledge, as well some other physics concepts, and facts. It is not intended hereby to go much deep in this then we will need, so, **don't expect to find complicated formulas or exhaustive explanations**.

We just need to know some physics facts, and understand its meanings by observing happening all around us. By observing those phenomena, we can understand why they happen in order to apply that knowledge in our venture.

This is not intended to be a scientific source, only a simple resume of facts!

Air is a Fluid; Water is also a Fluid but with higher density.

Air can be compressed:
So you can have a bottle filled with air just by opening it and the normal atmosphere pressure (1 Bar) will fill it, or fill it with the double or triple or… so much air as you want, before it becomes liquid air by compression, and spending Energy on doing it.

That is the reason why an air compressor for pistol painting, from time to time need you to release water from the container by unscrewing a special purpose bolt.

Air heats when compressing it:
That's why if you use a hand tool to fill your bicycle tyre, it becomes a little hot (and also by friction).

Air augments is volume if heated and also rarefies:
That's why actual turbocharged automobile engines use intercooler, in order to fill cylinders with more quantity of air than if it was heat.

Fluids tend to follow a curve surface:
It depends on how much speed it goes following a curve and also curve radius, a long curve radius is easy to follow.

After raining you can see tear drops of water falling down your cars body, they are being attracted by gravity and follow the curves till a point where an angle or just too small radius curve is for the drop's falling speed.

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Hull
I

Hovercraft is an amphibious machine, this means it can travel over solid as well liquid surfaces. Besides this ability it can also perform over mud, ice, grass, almost any imaginable one.

In most Countries, or even all, Hovercraft is classified as being a "boat", it makes sense. Hovercraft is not an airplane, Airplane definition refers to fly out of ground effect and to have lift caused by aerodynamic devices trough the air.

One cannot imagine a hovercraft in the streets, stopping in the red lights, giving way when others have priority, suddenly stopping when traffic becomes congested…

Hovercraft still not having necessary maneuverability for that purpose, but, in between boats, is like a "King" in what refers to performance!

In conclusion, yes, it is more a boat than other "Thing", it is just itself, a unique transportation machine.

As being like a boat, it is logic that we use terms to define it, alike boat terms. So, Hovercraft has a Hull. Hull is the lowest surface that supports it when not moving, when it is grounded. This lowest surface is the one that during a ride, sometimes touches the "ground" it goes trough. Hull shall be designed in order to glide over solid surfaces as well as cause less drag as possible when going over water.

Not only because surface irregularities or drivers attitude, sudden loss of lift caused by engine malfunction, or skirt damage, one have to prevent Hull to cause minimum friction as possible.

Third statement: ***Hovercraft lower Hull shall be designed as being a boat***

Flat bottom hulls are not performant and are dangerous. Flat bottom causes drag when hitting water or touching solid ground, unless you just have a low speed one just for joy, or a Physics demo concept, otherwise do not design a flat bottom Hull.

Do not think Hovercraft as being always supported by the air cushion and the skirt, do not think that the lower Hull just touches the "ground" when you stop it. Lower Hull also touches the waves and flat water or just hard ground in transitions, or irregular terrain, or just by using aggressive steering driving style.

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Thrust and Lift
V

Thrust, is the Force that will fight and win Drag, inducing movement to your Hovercraft. Hovercraft Thrust, once it moves over different surfaces, can only be achieved using the only thing it has on "flying" in different environment, Air.

Thrust can be obtaining by means of Propellers or Fans, also Ducted Fans or jet engines could be used, any source of thrust using air or through the air is possible in theory. Solid fuel or Rockets…

By now, lets remain focused just on the two usual types; Propellers and Fans (turbines). For same given thrust, a propeller has a greater diameter than a turbine. We can consider prop light than a turbine not only by it self but because in order to be efficient Fans require a duct around them. Fans also have a lateral big area exposed to cross winds that affects Hovercraft. So, regarding only Thrust, we can say that a prop is the best method to move a Hovercraft.

Of course this is only valid in a craft that uses independent "devices" to generate Thrust and Lift!

If we are talking about a single "device" providing both Thrust and Lift (Integrated Hovercraft) things tend to be lot more complicated…

Lift, as we know, is the Air Cushion beneath the hull, surrounded by the skirt. Lets take a look at that Air Cushion; imagine a hovercraft standing on the cushion, with no movement (Not a Integrated one!). It has no movement because has no thrust!

Skirt is touching surface ground, hull is suspended not touching it , we can see some air escaping in between skirt/surface, but it stands there!

Air Cushion is doing it all, skirt helps maintaining it, but some escapes, lift engine keeps giving power, delivering air, weight is compressing the Air Cushion and at a point this one has more pressure (Force) than craft weight, overpressure escapes from the skirt.

So, we need amount (volume, mass) of air as well as pressurized in order to win weight. Velocity of the air supplied to cushion is not an important factor!

Seventh statement: ***Air cushion needs air mass and pressure to be efficient, not air speed!***

2004/04/21
(To be followed)

Physics II

Pressure decreases when airspeed increases:
Take a bill in between two fingers, put your fingers closed to, and under your mouth in order to the bill be parallel with the ground (but the end will fall a little because of gravity). Blow fast over the bill and will see it rising, the bill gets "sucked" by the sudden decrease of pressure over it.

Gravity opposes to Lift

Drag opposes to Thrust

Static drag is stronger than Dynamic drag:
Riding a bicycle it is easy once you are already moving, Energy spending is greatest when starting from zero velocity.

Static Thrust required to oppose to Static Drag is greater than

Dynamic Thrust required to oppose to Dynamic Drag

Airplane Lift is granted by the wings

Hovercraft Lift is granted by the Air Cushion and skirt

Airplane Drag is caused by the Air against exposed surface

Hovercraft Drag is caused also by Air against exposed surface and Friction caused by the surface where it "flies"

HOVERCRAFT DOES NOT FLY
Hovercraft lift is not caused by aerodynamic surfaces going trough the air, out of ground effect.

Aerodynamics

Wings are aerodynamic devices that provide lift.

At first we must make use of some imagination and "see" **Air**, as **being a kind of laminated fluid**, composed of various Layers like sheets of a book.

Every time that air goes over any surface, **first Layer** skippering over it is called as **Limit Layer,** followed by another skippering over it, and another and…
This limit Layer tends and follows curved surfaces as much as the radius is not too big, or the speed is not enough.

At this point we need to talk about **Stall.** Stall happens when the limit layer detaches from the surface, does not follow it anymore. Stall can be caused by various factors, not enough speed, and too small radius curve, or just because of inertia. There will be always in a circle, a point where the limit layer detaches from surface, no matter how much speed it goes or how big the radius is. Cannot make the fluid surround it and come back 180 degrees.

Relative Wind, is what we call to the air trough an object or the air that object is going trough, it is relative, it is the same, A wing going at a given speed trough the air, or air being blown against a steady wing with this same given speed. Always imagine relative wind as moving horizontally.

Angle of Attack is the angle wings **attack** or goes trough Relative Wind.

Leading Edge is the front of the wing that attacks the Relative Wind.

Trailing Edge is the opposite, the end or rear of the Wing.

Chord is the imaginary line that goes from the leading edge till the trailing edge, as if separating the Wing in two parts.

Upper Surface is the superior surface between leading and trailing edges

Lower Surface is the inferior surface between leading and trailing edges

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Skirt
III

Skirt is the device that grants Air Cushion to be maintained. Skirt is fixed in the crafts perimeter, holds and keep enough air mass and pressure beneath the Hull granting it to be away from surface, it must be flexible and contour surface irregularities and waves and be water and air proof. Airproof means the skirt ability to not allow air to escape trough it. Waterproof means skirt ability to not absorb water, if absorbs water, it will increase weight and also maintain dust as mud and sand attached to it. At last, skirt material shall resist to friction not being easily damaged by rough surfaces and as light as possible.

Various types of skirt have been used, and mostly, types are:

Bag (closed) - like a tube around the Hull

Bag (open) – suspended from craft periphery inwards and "connected" to hull lateral panels near the bottom by rubber bands or adjusting strips.

Finger/segment (straight) – several independent pieces all around craft periphery like "spoons" connected to Hull lateral panels near the bottom by rubber bands or adjusting strips. From the top periphery they point inwards the craft.

Finger/segment (extended) – same as previous, but, till mid height of the finger they point outwards the craft periphery and from that point till the surface they point inwards.

Bag and Finger – Bag type skirt with extensions (fingers) on the touchdown point.

Sixth statement: ***Think Hovercraft Skirt as being a competition cars tire!***|

Why all those (and probably others) different types of skirt?
Hovercraft skirt, almost alike automobile tires, provide different performance and comfort. Skirt must be thought related to the craft purposes. Later, will compare performance and comfort related to each skirt type.

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R/C MODEL HOVERCRAFT DESIGN, NA ESSAY
(THE LIVING BOOK)

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As being a Living Book, chapter's evolution will be depending on readers, requests and interest.

If not enough input from readers on the topic, issues will be done casually, not following standard chapter's evolution.

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Rudders
IV

Aircraft use rudders in order to move around vertical axis, turning right or left. Hovercraft also use rudders to change direction of "flight".

Aircarft usually has rudders in the tail, at a vertical position. As well, Hovercraft uses rudder in the tail but they are a bit different, not in design but in the way they perform. On an Airplane you shall not display rudders into the airflow generated by Thrust, otherwise "steering" would be affected by power. Even at "low" speed, Relative Wind is enough to act on them.

In a Hovercraft, cruising speed is not enough to Relative Wind cause effect on rudders, and as it operates at Ground Level, you need to steer. So, you must place rudders in the way of the airflow generated by thrust in order to be effective also at low Relative Wind speed as whenever you want, by just applying power (Thrust).

So, you cannot steer (around vertical axis) a hovercraft at low speed, unless you have it (Thrust).

Second statement: ***Hovercraft rudders need to be affected by Thrust***

Hovercraft suffers from crosswind effect!

Aircraft uses aileron (aerodynamic devices near tip of the Wing) in order to not glide and make a more precise and, in a small radius turn. This way, aircraft moves not only around Vertical Axis, but also, caused by ailerons, in longitudinal axis. Rolling in this axis, changes Lift vector direction opposing not only do Weight but also to Centrifugal Force.

Hovercraft also rolls around Longitudinal Axis (but unwanted), due to centrifugal Force when making turns at high speed. Roll causes Air Cushion losses and stall, falling with the Hull on the ground, suffering from suddenly friction and because of this, accidents would be to expect due to inertia!

These facts origin the place of rudders in between the flow generated by thrust. This way, driver is able to perform small radius turns by applying thrust combined with rudder movements, changing gravity centre to the inside of the turn, moving his body. Aerodynamic devices can be added in order to counter-act inertia.

Also counter-acting on steering is to be used if unexpected or deliberated sudden deviation from course is needed.

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Deck and Cabin
II

Deck, as in a boat refers to the upper surface of the Hovercraft. Here is the place where driver, cargo or passengers fit in, also it is intended to be supporting engine(s) thrust device(s), lift devices etc.

It is intended that deck can be designed with the less low profile as possible; Hovercraft is highly affected by crosswinds, so, less lateral area exposed to wind, less the derived Force caused by undesired crosswinds. When designing Deck, not only exposed area is to be considered, but also its ability to let crosswinds skippering over it.

Nineth statement: ***If you cannot design a low profile deck, make it angled or curved!***

If by any strong reason (passengers compartment for instance) you cannot design a low profile Deck, at lest do it angled or curved, never as being flat and vertical. **Vertical** surfaces will act as the best area to the wind apply is force, acting at 90 degrees on a plane, once by definition Wind is a **horizontal** movement of the air.

So, if we design an angled surface with the lowest side at periphery of the craft, and the highest one at the middle, wind will not act at 90 degree on it. At same wind speed, in this angled surface wind applied Force will be inferior to if it was vertical with same area profile view.

If By other hand, instead of an angled surface we design a curved one?

In theory this is the best solution for a high profile craft and can even counter act to wind force!

Fourth statement: ***A curved profiled deck and cabin tend to react against wind force!***

As we already know, fluids (wind) tend to follow curves. Let's imagine a bubble type deck and cabin; Crosswind is blowing against it, wind starts to follow the curve, wind airspeed increases, this provides a force (lift) because pressure decreases.

Lets just for now consider the segment between periphery and the top of the bubble. Resulting force (lift) will be at 90 degrees from a tangent to the curve, what we get?

A little counter acting force against crossed wind!

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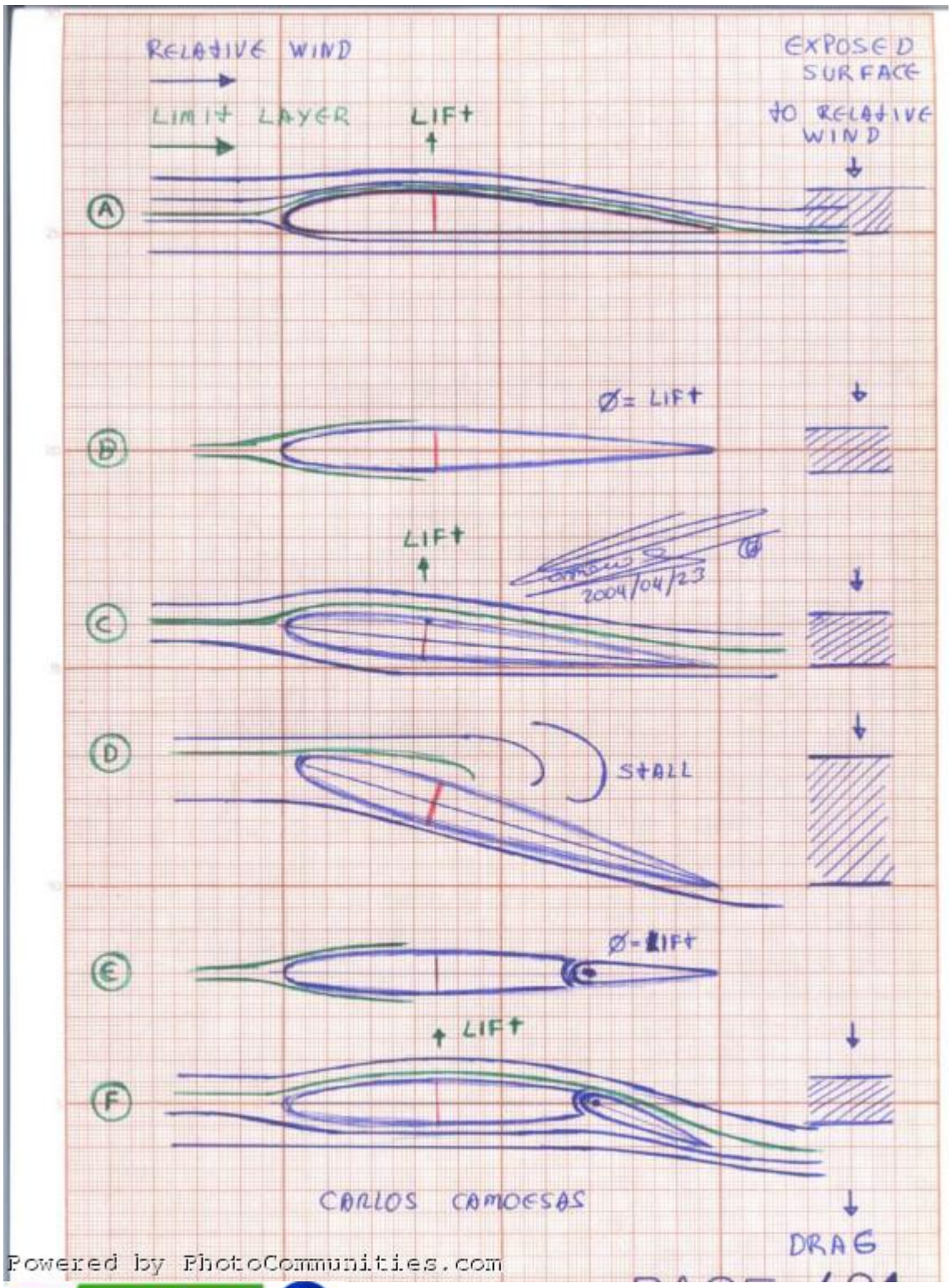

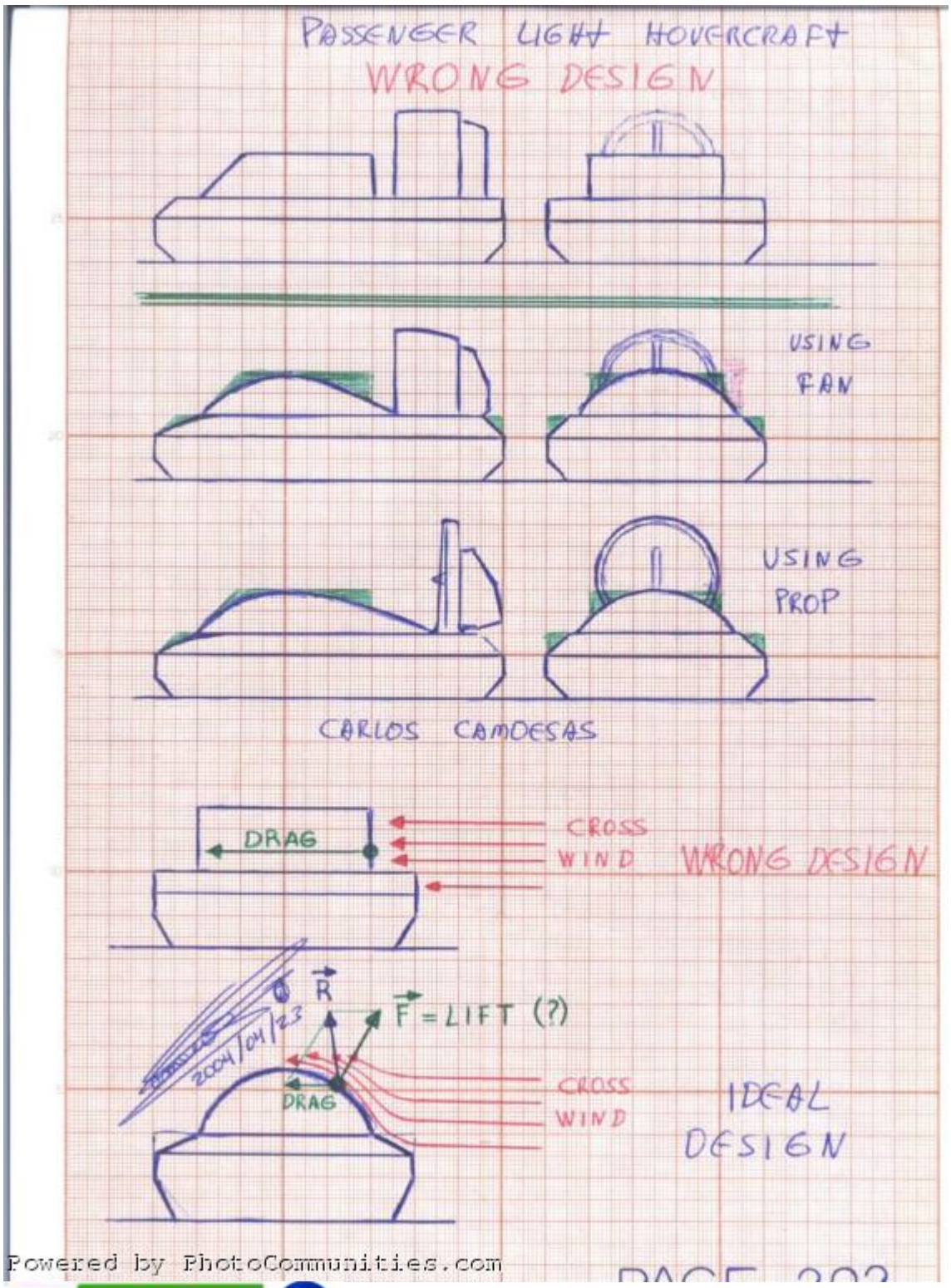

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Deck and Cabin
II

You ask now; and the other halve?

No problem! After reaching top of the bubble sooner or later Limit Layer will distich from it, or just simply insert at the top a simple device to force distich "Vortex Generator" will talk about it at another chapter, ***Aerodynamic Devices***.

As well we must think Deck from the front view, same design features must be considered, but, we have some other.

Just the driver or a cabin, are frontal areas exposed, now, we are talking also about Wind, but this one is **Relative Wind,** this is the one that cause drag, so, we must also have a least as possible frontal area exposed. It is to consider a windshield on a single person hovercraft (if it is intended to achieve high speeds, not needed for leisure) alike those used in motorcycles.

In case of a light passenger craft (3 or 4), the cabin shall be aerodynamically designed, but, always paying attention in not regarding only Drag factor, there's a bigger problem!

Airflow feed into thrust device:
Cabin shall not be an obstacle in between Relative Wind and thrust device (being a propeller or a fan or what else).

Regarding Static Thrust is not to fear so much as regarding Dynamic Thrust. Dynamic Thrust suggest Relative Wind airflow to be direct feeding thrust device, if this flow is suddenly interrupted or disturbed (can occur due to high speed and/or sudden manoeuvre causing a deviation from direct going through Relative Wind).

Sounds complicated? By other words; Feeding dynamically a fan (not so problematic on props), needs air to be supplied in same axis, if air is feeding the fan deviated from is axis (or suddenly interrupted), will be an angle that causes **Fan Stall**.

If fan Stall happens fan speed suddenly increases causing loss of Thrust, Fan over speed with possible disintegration of blades and also over R.P.M. in the engine!

Fifth statement***: Cabin shall be designed as an air feeding device!***

A simple design is a kind of half tear drop (cutted in longitudinal axis).

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Skirt
III

General considerations on Skirts

On designing a skirt, one have to think it not only full and retaining air mass, but also when it's "unloaded". Lets see a skirt before Lift:

Your hovercraft is grounded, no lift, no Air Cushion. Hover Hull is resting on surface, look at the skirt, what you see?

a) Is any portion of skirt at the lower end (if open bag or finger type) out of craft's perimeter?

b) Is the Hull or any part of it, pressing skirt material against the surface?

c) Pull one side of the craft till you get about some 30 degrees inclination from ground plan, does any of the previous occur?

d) Do same procedure at the front and rear, but now, about 45 degrees, does a) or b) occurs?

If just one answer is yes, you don't have a skirt, you have a problem!

Tenth statement: ***skirt cannot be pressed by Hull, when in rest, out of lift!***

30 degrees just because of inertia and counter-act (body balance) by driver on making curves.

45 degrees because of transitions.

Do not try to make a transition to a level higher than "clearance" (height from the surface to the bottom hull when on lift) height! It will probably overtake it, but will press and damage skirt.

Transitions from a higher level plan to inferior one, bigger than clearance will not affect skirt if you have enough thrust and lift, so, it is not to fear as much as climbing.

If skirt is pressed between hull and surface at any time, in rest or "flying" will be damaged. If you use a closed bag it is enough to loose skirt and Air Cushion Air mass and Pressure, as well if running on water, weight and drag will be added, you will loose thrust, so, steering also…

You will have to change it, It is better before an accident!

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(To be followed)

General considerations on Skirts

If a) occurs, then you have Air losses when getting lift and also on running.

If b) , c) or d) happens, you will have damaged skirt every time you hover, that's expensive and also to be fear of.

Resuming;
When designing an OPEN or FINGER type skirt, make sure that the inferior perimeter is shorter than craft's perimeter, expecting some formula?

Just as simple as designing it in a way that the projected perimeter of skirt touchdown is inside projected craft's perimeter.
Now that you have equal designs, one inside the other, make the distance from each side of the inner, till same outer side, to be equal at the designed "clearance"!

But, if you want a closed BAG skirt?

Unless you just use your hovercraft on flat water or ice, or just for physics demo concept, don't use it!

It will soon be damaged if used in transitions or hard soil, or it will have to be made of hard material to resist longer. Anyway, prepare for a hard drive.

Closed bag is easy to do as well as to "tune", just don't need! It works easily also, besides some tell, it is simple to do as well as the hull! You can just make one feeding hole to the bag and another direct to the floor; it works for sure and is simple to do and to fit. Also, you can make a simple flat hull (don't do it), as if it was "a solid block". It has the smallest low profile achievement!

Just before starting, before choosing skirt type, think well and compare to what was said before, and choose, remember, what for I want it ?!

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Aerodynamic devices
VI

Wing, is for sure most known aerodynamic device. A wing is intended to cause lift, in fact, if you abstract and look at a wind without any reference to aircraft, if you name it just as an aerodynamic device and not wing, what do you have?

A device using Relative Wind able to generate Force (not talking about wings nor aircraft) and you can use this Force in several different applications.
This one is the simplest design one, the Upper Surface is curved and the Lower Surface is plain. If you take that device upside down (Upper Surface is now at the bottom and Lower Surface at top) and move it into Relative Wind, will not have "Lift" but additional "Weight ", don't mind the definition, what really matters is that you can obtain **Force**.

Based on this point of view, this principle and basic design can be used in order to achieve different purposes.
If you want it to generate lift and Fly, yes, it is a Wing.

If by other hand you take another Wing design which has equal Upper and Lower Surface, moving it trough Relative Wind at Zero Angle of attack, you will only get some Drag, it is the only Force you get, and most of times you don't need drag!
But, if you give to it some positive Angle of attack, you have also Lift. And giving to it a negative Angle of Attack you will get Down Force (weight).

Take a look at a propeller from a side view…It is a weird…Wing!? And it provides Thrust!

Variable pitch propellers can also generate …Drag!

Take a look at a rudder… it is also…a Wing!? And it provides steering!

So, ***Wing basic design*** can be used to generate most kinds of …Force! Don't matter the name of the device, don't matter the name of that Force, it matters Force itself, applied in and pointed to whatever you need.

Wing, Aileron, rudder, propeller, stabilizer, flap…
Lift, Down Force, Thrust, Drag…

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(To be followed)

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Performance
VII

Hovercraft performance:

Pure Speed / Manoeuvrability / Comfort / just Fun / Physics demo concept.

Actual Official Speed Record in a Hovercraft is 137,40 Km/h.
American Bob Windt and his "Triflyer" are the holders; it was achieved in Portugal 1995 at Peso da Régua "flying" in Douro River, during the World Speed Race Championship.

World Speed Races are supposed to be held every 4 years. It is a singular competition method that pursuits mostly Speed, performed along a straight pattern over water, one craft at a time.

Every year World/European/Local …championship are also held, during the year, at different locations. These races are different from the Speed Races, here; the quest is not only speed. Races take place at special purpose circuits with different surfaces; land, water, grass etc. also curves, transitions climbs and descents.

Besides just fun and pleasure, light Hovercraft also races, and we can see that are at least two different quest:
Pure speed, and a combined speed/acceleration/manoeuvrability.

It is proved that one type of design is unable to beat the other. A speed designed hovercraft is unable to win championship circuit races as well as circuit designed crafts are unable to achieve such high speed as previous one!
Actual F1 Racing Hovercraft engines deliver around 200 H.P. and they still cannot beat "Triflyer" 120 H.P powered, 1995 Speed record, they are not designed for that!
As well, do not expect to find "Triflyer" (or similar design and length) at a circuit race.

Eighth statement: ***Do not search for Speed just on Power, design will do it better!***

As stated before, one has to design Hovercraft, in regarding what is expected the hovercraft to achieve, such as speed, manoeuvrability, comfort…

2004/04/22
(To be followed)

HOVERCRAFT DESIGN JOURNAL
By
Carlos Camoesas

Skirt
III

General considerations on Skirts

Bag skirt (closed)

This type of skirt is easy to build; it is just a kind of tube. It has to be inflated with some higher pressure than the Air Cushion itself, remember that is the skirt that holds the Air Cushion.

Air Cushion needs also to be feed with air mass, so, you have to feed both. There are two ways of doing it:

a) You have separate feeding holes, one or a group to feed the "tube", and the other one or group to feed Air cushion, remember must have different pressures between them.

b) The other way is supplying air to the tube, and this one has holes letting air to escape to the inside of craft's perimeter, forming and feeding Air Cushion, total area of those holes determine flow and pressure feed to Air Cushion, so you can start "tuning" skirt performance by starting with some less area (holes) than you have calculated. After testing, you can vary that area and reach best compromise in between them, skirt (tube) pressure and Air Cushion pressure.

As said before, expect hard drive with closed bag skirt, also high drag if running on other than flat surfaces, and be careful with skirt damage. Will soon loose pressure inside the tube, loosing pressure in the cushion, and …

Closed Bag skirt also does not "absorbs" terrain irregularities as other skirt designs, so, it is to expect Air Cushion pressure losses on these irregular surfaces. Besides that fact it is heavier than open bag, and a little heavier than finger type.

Resuming good aspects; it is easier to build. It easier to design and build a hull for it. It is good for flat surfaces. It improves performance if little fingers are added.

But this is another skirt type.

2004/04/24
(To be followed)

HOVERCRAFT DESIGN JOURNAL
By
Carlos Camoesas

Skirt
III

General considerations on Skirts

Bag skirt (open)

This type of skirt, besides name has lots more in common with Finger Type than with closed bag.

An Open Bag skirt cross section looks alike a semicircle, it is just half of a closed bag one, and it has not the inner portion of the circumference. Just has that part from craft's Hull periphery, down to the touchdown perimeter. At the bottom, open bag skirt is fixed to hull walls, near but above, touchdown point. It is fixed by rubber bands or adjusting strips as well Finger Type is.

a) You can feed open bag direct from hull to Air cushion, skirt is just the "wall"that contains and helps to "compress" Air Cushion.
b) Also and better is to feed skirt direct from Hull sides, and that air will form Air Cushion, it is faster to inflate the bag also as prevents air mass leak during "take off".
Open Bag skirt can also be feed separate from Air Cushion, by just using a mix of two previous methods.

Open Bag performances are quite different from Closed Bag; it provides a soft ride, reasonable irregularities adaptation but…
It always needs a "drag flap" a flat skirt material fixed to all hull width, near touchdown point, extending to the craft's periphery. Mostly at the rear is needed, but others are to consider to achieve best performance if most used over water.

This type is far less affected by friction than Closed Bag, and when it happens is not that dangerous. It is simple do build and it weights about half than open bag, it is a bit more difficult to tune, and expect to verify and change frequently rubber bands or strips. This last fact is very important in achieving good performance with Open Bag Skirt.
Open Bag is rare to find at 1/1 scale Hovercraft, maybe even just not used indeed, I have used it mostly since my first designs back in 1991!

2004/04/24
(To be followed)

HOVERCRAFT DESIGN JOURNAL
By
Carlos Camoesas

Skirt
III

General considerations on Skirts

Finger /Segment type skirt

This type is a must! It is the best adapting skirt to irregular surfaces as well as waves. It is the one that preserves better Air Cushion mass. It is the one that achieves best performance. It is the one that friction or even a hole, less affects. Finger type skirt is just… The Skirt!

It is hard to build, it is heavier than the others, it needs to be direct feed (but also direct feed to Air Cushion is possible, using both).It needs high pressure on the outlet holes from Hull sides, because this initial pressure at "take off" is the Force that keeps all the segments closed to each other. If not enough pressure from direct feed, inflating each segment, they won't remain "attached" and Air Cushion mass gets lost in between them, mostly when lifting off.

Segments are supposed also to be fixed at the Hull walls, near touchdown point, using referred rubber bands or strips. Till a point (regarding weight and complexity), the more the segments the more perfect it will be.
If the Hovercraft looses one segment or a hole is on it, looses pressure and lateral (both "neighbors") segments will press it and solve big part of the problem, it is almost a fail safe designed skirt!

A drag flap is needed at the rear, or rear fingers (segments) must be almost closed or even closed ones in order to prevent water drag.

Two types of fingers can be seen at the Races and some use combined versions.
a) Inwards perimeter inclined.
b) Outwards perimeter till mid height than inwards till touchdown point.

Inwards has less Air Cushion Area, so, less air mass needed, easier to feed as well easier to maintain pressure.
Outwards bigger area needs more mass of air and pressure is hardest to achieve.

2004/04/24
(To be followed)

HOVERCRAFT DESIGN JOURNAL
By
Carlos Camoesas

Performance
VII

Integrated/Non integrated craft

Integrated Hovercraft, is a craft that uses same device to achieve Thrust and Lift. Usually uses a Fan to provide both, it can vary something in between 20/30 % the amount of the airflow used just for lift, and the rest of it for Thrust.

Just behind the Fan you have the "splitter", a device that splits the airflow needed to feed Air Cushion and skirt. So, we just have one engine, and one Fan, if you have thrust also have lift, if no thrust no Lift.

Of course we are talking conventional integrated Racing Hovercraft, you can also have just one Engine and Thrust/Lift are achieved by two devices ("Triflyer").

Integrated (All in one), so lets back to where we where.

Integrated craft has less response to acceleration and winning Static Drag. At a Race, an Integrated Hovercraft is at the grid but remains with the Hull on the ground, you cannot give power before start signal, or Hovercraft would get lift/thrust and would cause a False start.

Non-Integrated craft is at the grid with no thrust, but lift engine is delivering some, enough to rest in the Air cushion. So, when start signal is given, it has only to give thrust to win static Drag. Just one vector, just one Force, horizontal.

Integrated craft will have to win same static drag but also friction lifting the hull from the ground. So there are two Forces, two vectors, same horizontal one and another one, vertical.

So, it is to expect Integrated Craft, to have less acceleration capabilities!

But, that isn't enough to win the race, it just made a better start than the Integrated one

Performance
VII

Integrated/Non Integrated Craft

You can learn by observation, if you go to the races, at first you just enjoy and then, just think and ask to yourself, why? Why this and why that?

After starting signal is given we have non integrated craft leading the race, but the integrated one maintains the distance or even is gaining some, after a while when hovering on water, suddenly Non integrated craft loses is lift engine, it stops.

Hovercraft falls from clearance height and pilot is almost projected from the craft in a forward motion caused by inertia due to Hull sudden impact on water. He starts lift engine but the other hovercraft has overtaken him.

Both are closed to each other now, and in a small radius curve, while Integrated one goes in the outside controlling thrust in order to prevent lift losses, Non Integrated goes trough the inside making almost a 180 turn in same place, maintaining lift and suddenly cutting and applying thrust while turning rudders, he is again in first place!

What to learn from here?

If nothing goes wrong, if engines don't fail, if both are tuned, Non Integrated Hovercraft is supposed to win, we saw that it has more acceleration capabilities; also it can turn at speed in a small radius while Integrated cannot loose its speed due to lack of acceleration and also sudden loose of power when curving (losing lift) could cause it to touch the ground and due to inertia, to roll over.

Non Integrated is much more manoeuvrable and fast to recover from loss of speed, the only advantage is that you still having "two engines, two troubles".

It is all just a question of liability, not only performance makes you win, you also need Regularity, talking about models you need it also, that's boring being in the "boxes" repairing your model and others having fun. If you trust on both your engines, go for a Non Integrated.

In a real 1/1 scale, there is another benefit from using separate engine for lift, when going over water essentially, even without thrust, just by balancing your body, you can get out of there, slowly but you can!

2004/04/25
(To be followed)

Performance
VII

Circuit race design/Speed race design

Speed race design, is completely opposed to Circuit racing design. Wind Drag is a big problem when you want to achieve speed, does not matter in what kind of vehicle, just a bicycle, an automobile, a boat or just a Hovercraft! You have to design an aerodynamic vehicle able to "penetrate" trough the air, also using the less surface exposed to it. This is the meaning of S.CX, surface and ability to "penetrate" air.

In a Hovercraft this is also most important because wind will also tend to act on skirt pressure, and you cannot loose it. Bumping on waves or hard soil at high speed is dangerous, if a nose down attitude happens; remember water is a high-density fluid, water will crash your craft like an egg!
If a nose high attitude occurs, it will flip backwards and also be crashed, and remember in this attitude you may be with you head down…

So, you don't have to think only in frontal area.

Eleventh statement: *Think Hull as if it moves also in a vertical position!*

Why is that?
In a nose high attitude at high speed, Relative Wind will act on exposed hull, if no stabilizer devices are used, or even with them, starting on a little angle, if not Auto-Stabilizing, increases so fast that pilot cannot react. So, before thinking on stabilizing devices, as wings, or gyros actuating those, think Automatic-Stabilization design.

Lets see what happens at a relative low, nose up angle on a conventional Race designed hovercraft (based on a rectangle);

Rear hull of the craft touches water, centre of gravity is moving back, Relative Wind attacks that exposed surface (bottom of the hull), will tend to move it. Like a "lever" , craft has already a balancing axis, that line at the rear that touches water, wind will force this lever, and angle will increase, increasing, exposed hull surface is greater, still having a rotating point, centre of gravity moves back and its easier for the wind crush it backwards!

2004/04/25
(To be followed)

Performance
VII

Circuit race design/Speed race design

Lets now see a triangle design, pointing to the front end;

A wave lifts the hovercraft, the rear also touches the water, centre of gravity also moves a bit to the rear and Relative Wind attacks hull bottom.

Wind has also a "lever" with a balancing axis, but lets watch Wind acting into two different areas just as if we divided in the middle, front (a) and rear (b) part. Area (b) is about the double of Area (a), so, wind force is much greater on (b) than on (a).

Wind will tend to balance the hull not in the rear axis (line touching water) but over an imaginary line (axis) in the middle of the craft, result?

Wind will force the rear of the craft to rise and the front to fall, rotating over that middle line axis; gravity centre resumes its original position moving to the front. Rear hull does not touches water anymore and water drag disappears, speed is increased in a flash, wind force at (b) grows and…

It is back into horizontal position, "flying" at speed!

Remember, all this happened in a fraction of a second, but it was Auto-Stabilizing itself, with no wings or gyro or pilot action (pilot did not knew what happened, just a sudden lost of recovered speed)

Other things have to be considered, to have a positive centre of gravity, is also a stabilization design feature. This is much alike Airplane design, there; you have positive stabilization when centre of gravity is ahead of centre of lift. If aircraft sudden looses lift (stall) it will tend to a nose down attitude.

Hovercraft lift has also a centre of lift. Think that all Air cushion is equal pressure, just one piece, centre of lift will be at the Area centre point, it is easy to calculate.

Centre of lift of a rectangular hull, is in the mid line at half of hovercraft length.

Centre of lift of a triangle hovercraft hull, is a little back of the mid hovercraft length.

So, you have a positive design stabilization in a rectangular hull if gravity centre is ahead of mid length, In a triangle hull, could be at the mid length or even a little back, and still positive.

2004/04/25
(To be followed)

Thrust and Lift
V

Talking about the Future in Thrust:

Besides propellers and Fans, when talking about a non Integrated craft (two separate devices for Thrust and Lift), Performances could be improved by using a jet engine. Of course we are talking about a craft just for special purposes, not to be drove at every place or at any time. Hovercraft designed just for Speed enhancement.

It looks contradictory, using a Jet Engine to achieve Speed!

It is not! The use of such an engine that's not just by seeking Power, no, there are Industrial jets, also small jet for small aircraft and Unmanned Aerial Vehicles. Whe are not talking about Power, but just these engines architecture and operating principle. Lets say you have such engine but delivering just the same Thrust of a conventional Racing Hovercraft, lets say equivalent to the thrust of a 90 cm diameter Fan of an 120/130 H.P. Rotax engine.

It would be just a bit heavier than the whole Fan/Engine/stator/shroud/rudders; yes we will not use them! Instead, we will use the Jet engine, it must have vectorized nozzle, not commercially available? Technology already exists!

What will we gain?

Since the beginning we are gaining Exposed Area, much less area exposed to crosswinds.

No rudders, less crosswind effect again.

Less frontal Area also, so less static and dynamic Drag; best static thrust as well dynamic Thrust response.

Lower centre of gravity, so, best stability of the craft.

Vectorized nozzles would serve also to control attitude and longitudinal stability; so, we could avoid also stabilizers, less drag and weight.

Once stabilization is made at the rear (where) engine is, it is behind centre of gravity, and a Gyro could do it.

Well, lets back to present!

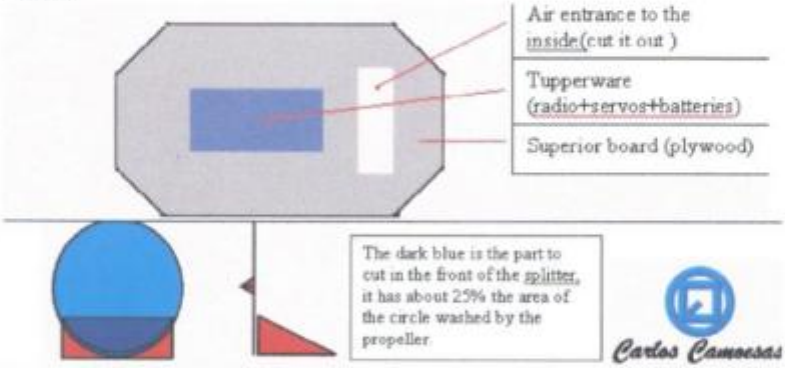
2004/04/23
(To be followed)

Carlos Camoesas

Instructions to build an entry level r/c hovercraft
PART I

Materials- Balsa or plywood
Radio required-2 channel/2 servos
Engine-.15/.25
Skirt-open bag/nylon from rain coat or umbrella
Length – 40 till 60 cm

Cut the superior board of plywood, after you chose the right "tupperware"(sealed box) to fit the equipment. After you fit the box into the hole in the board, cut the blue foam and adjust to the box(surround it), with the dimensions of the flat bottom.
Cut the plywood flat bottom and glue it against the blue foam/bottom of the box.
Now we have a "sandwich" formed by two boards of plywood with a box surrounded by blue foam in between.

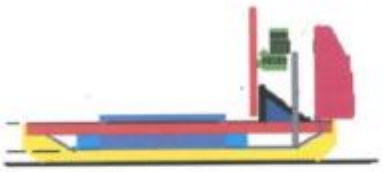


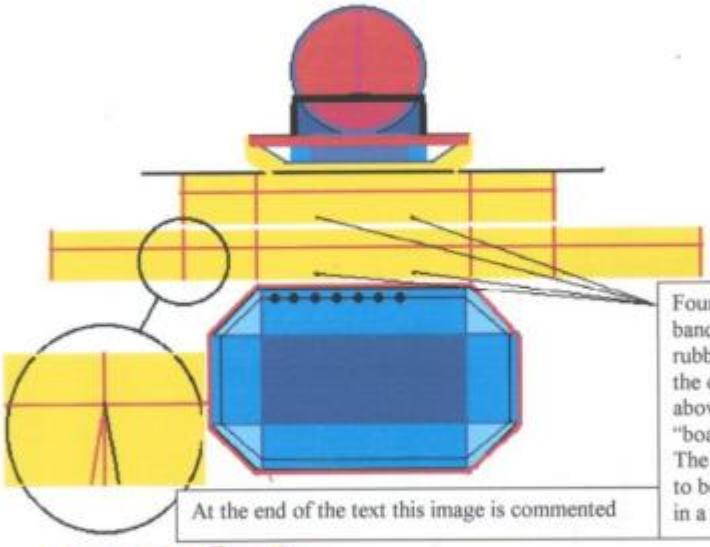
Mesure the distance between the edges of the two pywood boards and cut and glue four rectangles to them. Now you have four triangle holes, with a paper design the triangles and transfer to plywood, cut and glue them in place to close the "boat".
The splitter is made of two triangles glued in the upper board, one each side of the rectangular hole to the inside , then cut and glue two rectangles, one in the top and the other vertical in the front (this is the one to be cutted in the next step).
THE SPLITTER OPENING it is cut only after you fit the engine and the propeller, to ensure that the propeller diameter is a little larger than the opening.

http://www.geocities.com/camoesas
http://www.freewebs.com/camoesas
http://www.rc-hovercrafts.com

Carlos Camoesas

Instructions to build an entry level r/c hovercraft
PART II





Four holes to fix four rubber bands). One end of the rubber is fixed in the skirt, the other is fixed 5 mm above the flat floor of the "boat".
The skirt and the rubbers are to be changed like the tyres in a car.

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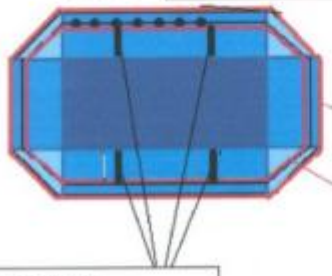


Hovercraft périmeter

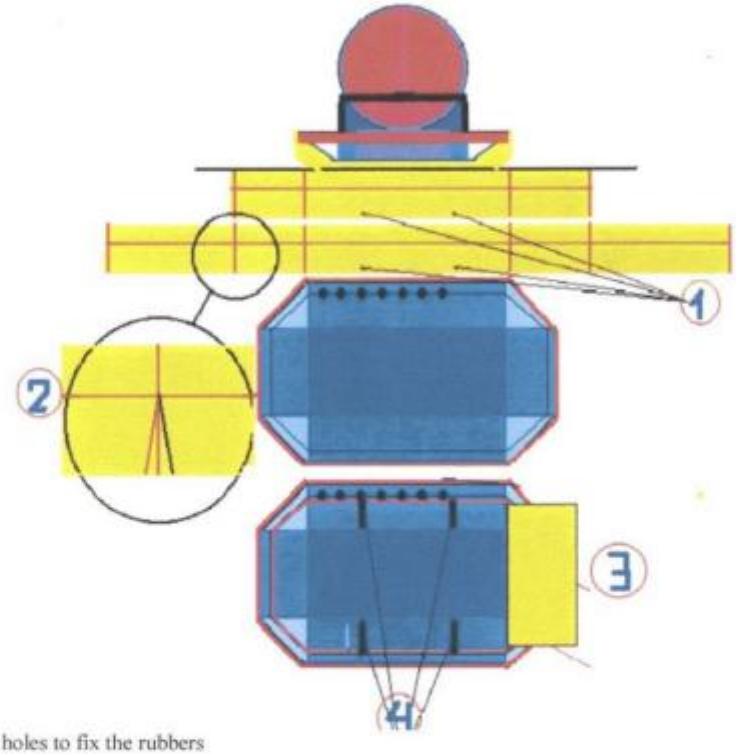
Ground contact perimeter of the skirt with the ground.design the projected craft perimeter on a sheet of paper. After that, inside of it design another perimeter with all the sides parallel to the previous (pink colour).In the paper sheet, the distance from each side to the paralel one, should be around 2 cm.

Rubber bands

Image comented:the two yellow strips are the total skirt length. Each segment at the top shall have the same length of the correspondent segment of the craft. At the bottom, each segment shall have the same length as correspondent segment f the inner (pink) perimeter, to achieve this, you must cut the black line as the circular image shows, then you glue it (the triangle)opposing to the red line. The up (longest) perimeter of the skirt shall be sandwiched to the craft using plywood strips or just gluing it (in this case with bi-adhesive tape is needed). Also you can use small screws to attach it.

Carlos Camoesas

Instructions to build an entry level r/c hovercraft
PART III



1 – holes to fix the rubbers
2 – cut and glue
3 – without this "drag flap" will not run on water !!! must be fixed to the bottom of the craft, near the touchdown contact plan.
4 – rubber bands that fix the skirt to the craft near the bottom.

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http://www.freewebs.com/camoesas
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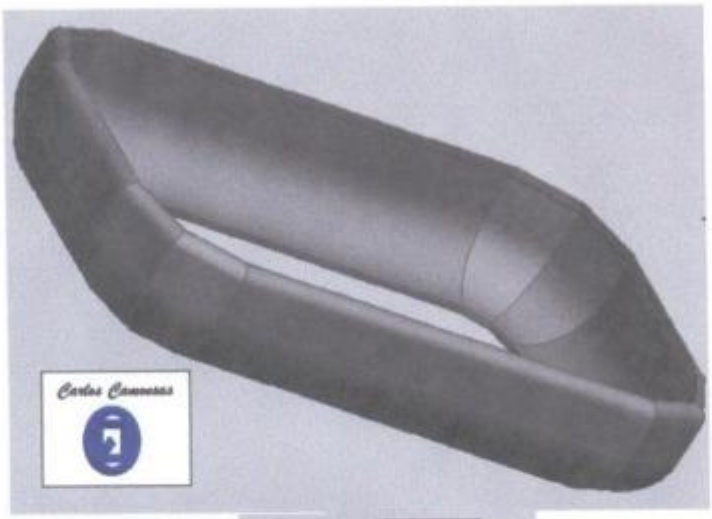
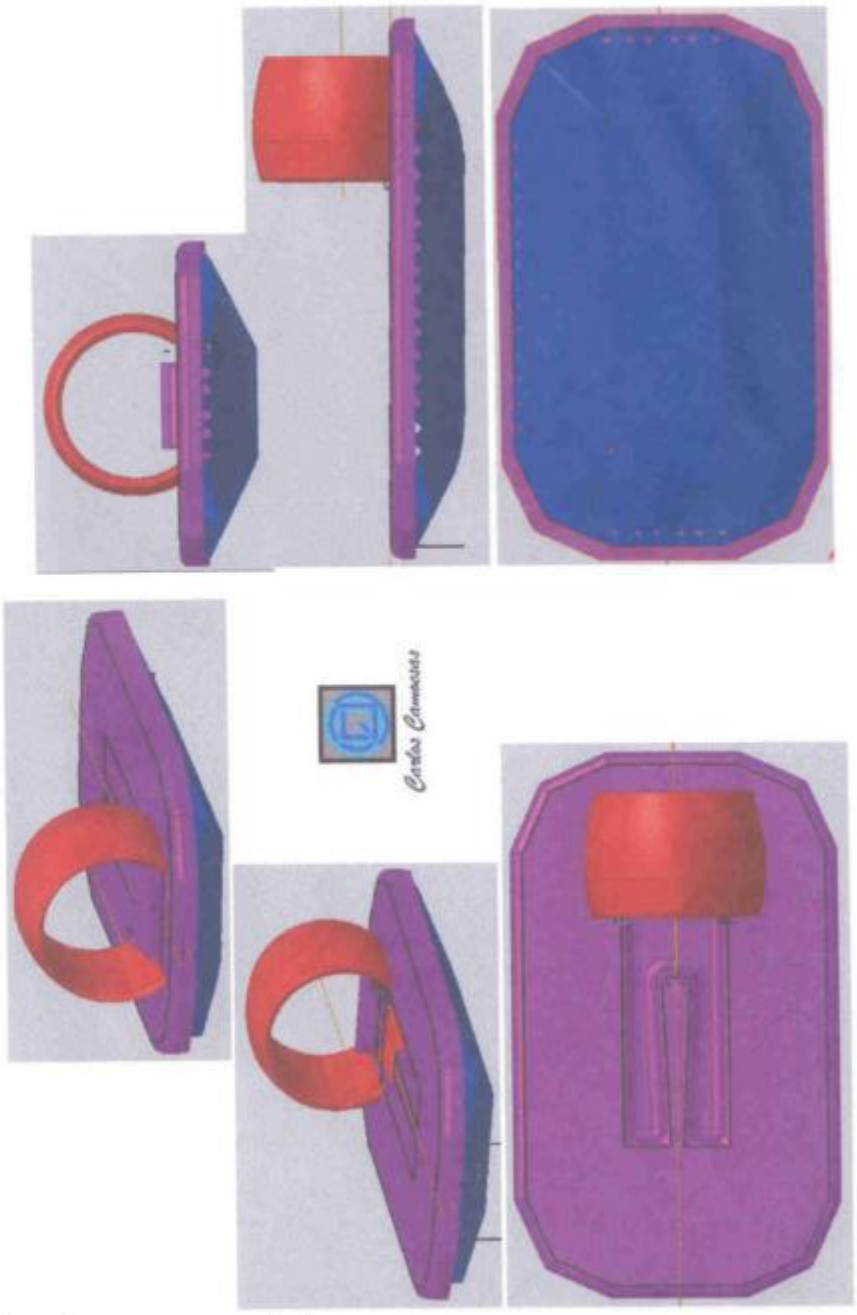


Rubber bands to fix in this points, the other end of the rubber to fix in the bottom side walls.

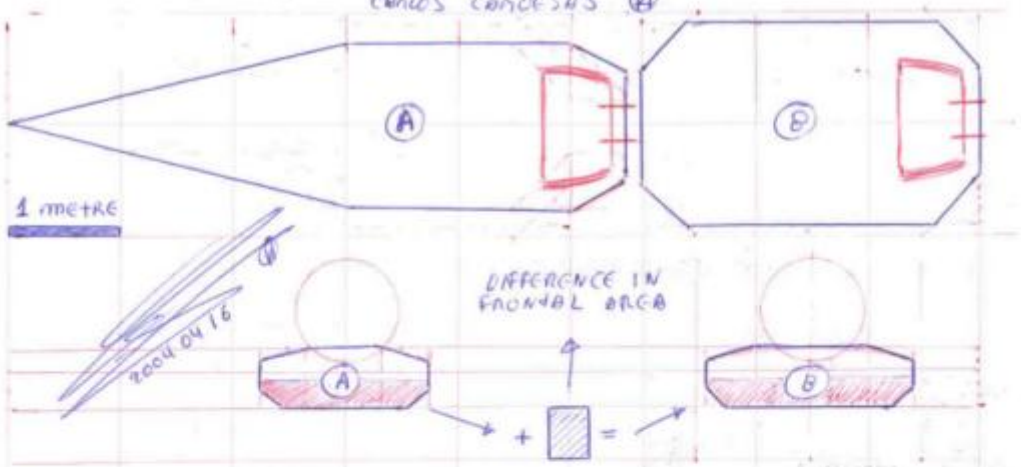
This is an open bag type skirt

The upper perimeter of the skirt must be fixed to the top perimeter of the "boat". Like a sandwich; pressed against the craft with an aluminium strip fixed with bolts or quick release .



HULL DESIGN
(WITHOUT COMPLICATED FORMULAS)

CARLOS CAMOESAS ©



(A) SPEED CHALLENGE DESIGNED HOVERCRAFT HULL
(B) RACE DESIGNED HOVERCRAFT HULL

CUSHION AREA A = B ⇒ 4,850 m^2 → SAME LIFT POWER REQUIRED FOR BOTH CRAFTS.

	LENGHT	WIDTH
A	5,50 m	1,50 m
B	3,00 m	1,80 m

FRONTAL AREA < A – LESS 0,15 m^2
B – NOT IMPORTANT TO KNOW, JUST THE DIFFERENCE.

YOU CAN EXPECT (A) TO BE FASTER IN A STRAIGHT LINE, IT HAS LESS AREA (FRONTAL) SO LESS DRAG. ALSO THE SHARP DESIGN IS MORE PENETRATING THROUGH THE AIR (AERODYNAMIC) CX IMPROVED. SO, IT IS FASTER SINCE THE DESIGN BOARD!
YOU CAN ALSO EXPECT LESS RELATIVE WIND AFFECTING THE SKIRT EFFICIENCY.
IF FOR SOME REASON (SPEED, WAVES...) THE CRAFT RAISES, WILL BE QUICKLY AUTOMATIC LEVELLED AS SOON AS THE REAR BE ALSO (IF) EXPOSED TO RELATIVE WIND, AS THE REAR HAS A GREATER AREA.
YOU CAN SEE THAT AT HIGH SPEEDS IN A (B) TYPE HULL, PILOT MOVES TO THE FRONT OF THE CRAFT TO AVOID WHAT FREQUENTLY HAPPENS, TO FLIP OVER ITSELF, BACKWARDS.
WHEN MAKING A TURN, (B) WILL BE MORE STABLE SLIDING SIDEWAYS, BECAUSE IT IS LONGER. ALSO DUE TO SHORT DIMENSION (LENGTH) IT IS EXPECTED TO BE BETTER MANOUVERABLE AND TO HAVE A MINOR TURN RADIUS. IT HAS LESS LONGITUDINAL STABILITY BECAUSE OF SHORT LENGTH AND IT IS EXPECTED TO FLIP OVER AT HIGH SPEED, IF NOSE RAISES, SINCE FIRST UPWARD RAISE WILL HAVE GREATER AREA EXPOSED. RAISES
(B) IS DESIGNED FOR RACES, LOTS OF TURNS AND ACCELERATING, NOT DEPSEED.

2004 04 16 SORRY MY ENGLISH ERRORS

II

HULL DESIGN

(without complicated formulas)

Carlos Camoesas (A)

IN A RACE, YOU WILL HAVE (THE) CIRCUIT TURNS AND ALSO THOSE TO MAKE FOR OVERTAKING AND AVOYDING OTHER COMPETITORS.. SO, YOU NEED THE CRAFT TO BE MANOUVERABLE AND ALSO SHORT, AS ABLE TO PERFORM LOW RADIUS TURNS MAINTAINING LATERAL STABILITY.

RACING CIRCUITS MAY HAVE TERRAIN IRREGULARITIES, SUCH AS WATER, GRASS, LAND AND TRANSITIONS IN BETWEEN THEM. ALSO ARE EXPECTED TO HAVE DESCENDS, CLIMBS AND NOT LEVELLED TRANSITIONS FROM LAND TO WATER, SO A SHORT CRAFT (B) WILL HANDLE BETTER THOSE FACTS.

IN A SPEED CRAFT (A) YOU DONT NEED IN FACT ALL THAT LATERAL STABILITY, SPEED RACE USES TO BE IN A STRAIGHT LINE AND NOT HAVE TRANSITIONS, AND YOU DONT NEED TO AVOYD OR OVERTAKE OTHER COMPETITORS, USES TO BE ONE AT A TIME.

YOU CAN EXPECT (A) TYPE TO BE SMOOTH AND CONFORTABLE FOR JOY, WEECKEND AND TRAVEL LONG DISTANCES.

A TYPE (B) CRAFT IS AFFECTED BY PILOT WEIGHT. THATS GOOD! AS THE PILOT HSELF IS NEAR ALL AND EACH POINT OF THE CRAFT PERIMETER, PILOT CAN CHANGE THE DUAL MAN/MACHINE CENTRE OF GRAVITY BY BALANCING HIM SELF, MAKING IT MOST MANOUVERABLE.

SO, IF YOU WANT TO DESIGN A R/C HOVER HULL, THINK BEFORE THE PLACES YOU HAVE TO "PLAY" WITH IT.

IF YOU HAVE BIG SPACES AND NOT MUCH TRANSITIONS, MY ADVICE IS THAT YOU CHOOSE (A) TYPE, AND ENJOY THE SPEED!

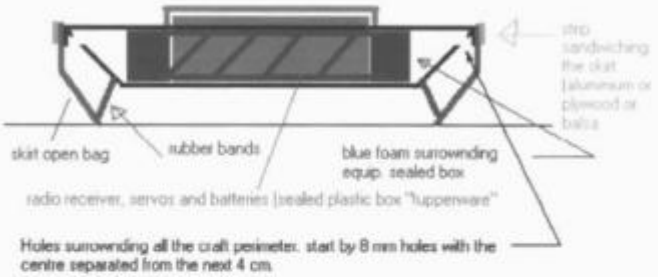
IF YOU WILL USE IT AT SMALL PLACES AND/OR LOTS OF TRANSITIONS, YOU SHALL CHOOSE A (B) TYPE HULL AND FEEL IT SLIDING AND TURNING LIKE A SOAP BAR.

"RES, NON VERBA"

Carlos 2004 04 14

Instructions to build an entry level r/c hovercraft
PART V

Carlos Camoesas



Holes surrownding all the craft perimeter. start by 8 mm holes with the centre separated from the next 4 cm.

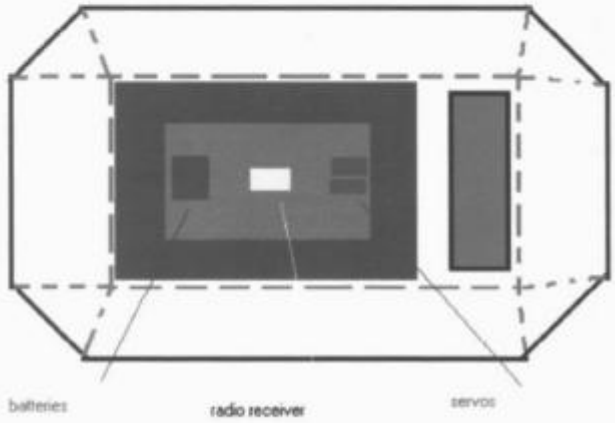
after the first running tests, if you get not enough lift, make them all 9 mm and test it again.

After you get lift, if you notice that equilibrium is not perfect (not running parallel to surface) :

a) check if the rubber bands are all equal distance and none is broken.

b) change the display of the batteries pack and move it to the corner or side of the box that gets more lift to counter balance.

Note: servos position shall be fixed at the rear of the box.
Receiver shall be in the centre of the box.
Batteries shall be fixet to the box floor with "velcro" tape, at first test they must be set in the front of the box!



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