Flight and the Dream of Daedalus

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Δαιδαλοσ

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Executive Summary

The tale of Daedalus, the “clever artificer” of Greek mythology is the most compelling of all ancient lore.

This paper explores the Daedalus myth in the light of the modern technology of flight. It consists in a series of *gedankenexperiment* undertaking to show that Daedalus’ flight was possible with materials and knowledge available to the most ancient of the ancients.

The basic premise is that you can power an aircraft with a kite in the same way that you can power a boat with a sail: That the wind can serve as the only power source for aviation just as it can for navigation.

All of the analyses of force and torque needed to do this are presented qualitatively here. To quantify these analyses, this paper proposes the formation of a formal organization. The organization would carry out a series of projects, of which the exploration of the Daedalean dream would be only one.

Come let us reason together.

Flight and the Dream of Daedalus

The tale of Daedalus, the “clever artificer” of Greek mythology is the most compelling of all ancient lore.

Daedalus built a labyrinth for Minos of Crete. The labyrinth was a prison for the Minotaur, offspring of Pasiphae and Appollo, half man, half bull, and a genuine embarassment to Minos, who was, after all, Pasiphae’s husband.

This being the case, Minos stranded Daedalus and his son Icarus on the island to keep them from getting Minos’ name into the popular literature and ribald ballads.

Daedalus labored for some time on a means of escape, which turned out to be an aircraft. He is said to have built a framework of wood to which he attached birds’ feathers with wax. He cautioned his son, for whom he had built a similar craft, not to get too close to the sun, because that would melt the wax and cause the craft to fail.

Of course, Icarus did precisely what his father told him not to do. That is the nature of young men. He fell into the ocean and died.

Daedalus, though, made it to the Greek mainland, where he went on to make many other wonderful things, all of which were lost to an eon that considered them impossible and therefore impious. Although many people flew in gliders, the first historically recorded flight that wasn’t just a more–or–less controlled fall didn’t take place until 1903.

There can be no question that Daedalus existed, at least as a manifestation of the Greek collective unconscious. The question is whether he actually flew. What seems certain is that if he did, he didn’t use birds’ feathers and wax, and he didn’t propel his craft by flapping his arms. Beyond that, is there any compelling reason to believe he didn’t fly?

I’ve never seen one. Daedalus is credited with inventing the sail, which is a kind of airfoil with which we’ve been familiar for millenia. We’ve also been familiar with kites. When the Wright Brothers flew at Kitty Hawk, they rose in an aircraft that had evolved from a long line of kites, notably the Hargrave box kites that the Wright Flyer so closely resembled.

Somewhere in the ancient technology of kites and sails is locked the secret that Daedalus knew. Somewhere in the modern technology of flight since 1903 is the key to that secret.

Come let us reason together.

Vectors, Force, and Torque

To understand how an airfoil works, it helps to have a graphic means of analyzing physical phenomena, in our case, force and torque.

Vectors

“Vectors” provide the handiest means of doing this, because they describe physical entities that have both *magnitude* and *direction.* Force and torque are such entities.

You can think of a vector, as nothing but an arrow. The direction of the arrow indicates the direction of the thing you’re representing. The magnitude of the quantity you’re measuring is proportional to the size of the arrow.

Nevertheless, it’s useful to know how vectors work quantitatively as well.

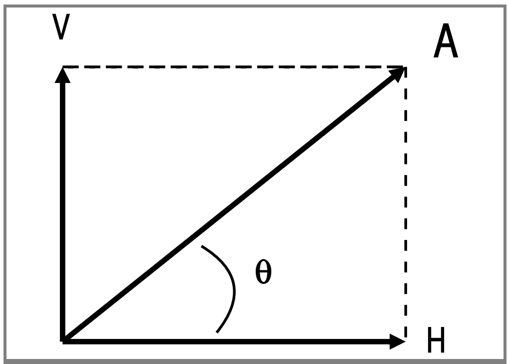


Figure 1: A Vector

Consider the vector of Figure 1. We call Rene Descartes to witness that it begins at a point called the “origin,” which is taken to be at the intersection of two perpendicular lines, called “axes.” By immemorial convention, a horizontal axis is referred to as the “x axis,” and a vertical axis as the “y axis.” When you did graphs in school, you used a graph paper built on this scheme.

The axes themselves don’t appear in Figure 1, which shows only the vector itself and its two *components* along the x and y axes. The vector begins at the origin at an angle θ to the x axis.

Now look at the dashed lines. These show that you can draw a rectangle with the origin and the tip of the vector as corners. The vector, then, divides this rectangle into two right triangles. The long side of the two triangles is the vector itself, and is called the *hypotenuse* of the triangles.

This is a very nice property of vectors, because right triangles have some special rules that make them easy to work with. One of these is that if you want to know the angle the vector makes with the y axis you only have to subtract from 90° the angle it makes with the x axis. That’s because the three angles of any triangle have to add up to 180°, which means that the two angles that aren’t right (90°) angles have to add up to 90°.

Another nice property of right triangles is that the ratio of the two shorter sides to the hypotenuse is the same for any angle θ and for all right triangles. These ratios are called the *sine* and the *cosine* of the angle θ. Let h be the hypotenuse, then, and let the side opposite and adjacent to θ be o and h respectively. You can find the length of o and a by the formulas

$$\mathbf{o = h\ sin}\theta$$

and

$$\mathbf{a = h \cos\theta.}$$

Because these sides are sides of a rectangle, the vertical and horizontal components of the vector are equal in length to the short sides of the two triangles. This makes it easy to analyze vectors, because you can add them by adding up all the horizontal and vertical components. When you do that, you can find the magnitude of the resultant vector by means of the familiar formula

$$\mathbf{h^2 = o^2 + a^2}$$

This is all you need to know to analyze force and torque. If a physical entity is moving at a constant speed, or is at rest (which is to say, if it isn't accelerating) then the sum of all the forces acting on it is zero. So is the sum of the torques that act on it, about which more anon.

The vectors we need to talk about exist in three dimensions, like the single vector of Figure 2. To describe this vector fully, you have to know all three of its components, one of which lies along the z axis as shown. It makes an angle ϕ with the z axis, and otherwise follows the same rules in the *plane* of the z–y axis as it does in the x–y axis.

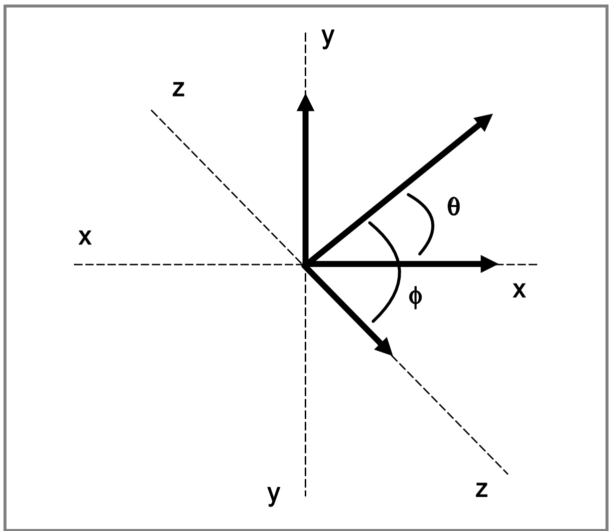


Figure 2: A 3-Dimensional Vector

You can therefore simplify the way you deal with vectors by considering them in two dimensions at a time. The price you pay for this is that some vectors face perpendicularly into or out of the page, but this doesn't hurt anything as long as one understands what's happening.

Forces

Everyone has an intuitive concept of what force is. Formally, it's what causes something at rest to move, or something that moves to move faster or more slowly. If you push a table across a room, for example, you apply a force to it with the palms of your hands. The table accelerates in response to that force.

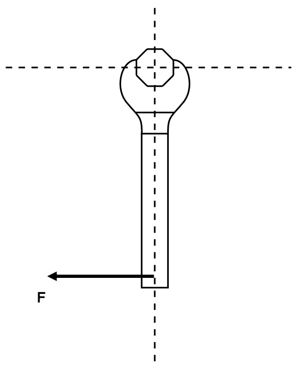
The table doesn't go on accelerating indefinitely because your hands aren't the only force it experiences. Its legs drag along your dining room carpet, which generates friction. Friction is itself a force. That frictional force pushes back against your hands. If the table is moving at a uniform rate (not accelerating), the force it pushes against your hands with exactly equals the force your hands exert on it. This is what Isaac Newton meant when he said that for every action, there is an equal and opposite reaction.

Vectors are great for analyzing forces, because forces have magnitude and direction. The harder you push, the more the table accelerates. If you push the table toward the east wall of your dining room, it moves east. That's really all there is to it.

Torque

Torque is a little more complicated, but not much. The most familiar example, which turns out to provide the best way to explain torque, is that of a wrench turning a bolt, as illustrated in Figure 3.

Torque is the moment of force. What that means is if a force gets applied at a distance from the point it acts on, like the force at the end of the wrench at the center of the bolt's head, then it causes the thing it acts on to rotate.



Torque is a vector pointing into the page at the point where the dotted lines cross.

Figure 3: Torque

Reconsider the example of shoving a table across a room. If your carpet is particularly thick and luxuriant, then it exerts rather more force at the ends of the legs than, say, a linoleum floor might. You're pushing the table at its top with your hands. That means that the force you exert on the table is acting at a distance from the bottoms of the legs. Your force, then, can cause the table to rotate around the ends of the legs. That is, the table tips over.

Quantitatively, you can compute the magnitude of the torque vector (and it can very nicely be represented as a vector) as the product of the force and the perpendicular distance to the point it acts on. Because you're multiplying *force* — pounds, for example — and *distance,* for instance, feet, you're going to get a vector whose magnitude has to be measured in units like "foot–pounds." If you've ever used a torque wrench, which has a gague built onto it to measure torque as you turn the wrench, you won't have any trouble with this concept.

Look again at Figure 3. The direction of the torque vector in that example is into the page, through the bolt head. If the force were acting in the opposite direction, then the torque vector would point out of the page. That's just a convention to help people agree on what's negative and what's positive. They view force in the same way, taking as positive forces that point upward or to the right, and negative as down or to the left. If a vector points down *and* to the right, then it has a positive component along the x axis and a negative component along the y axis. As a rule, in real life, you're going to be more interested in vector components than in the vectors themselves.

What Daedalus (At Least Instinctively) Knew

Whether you're sailing a boat, flying a kite, or aviating in a plane, the forces that most interest you are the ones that act on your craft when it moves at a constant speed. In the case of the kite, you're most interested in the forces that act on it when it's standing still. It's really moving, of course, with respect to the air that streams past it, and it's doing so at a constant speed.

To make something fly, Daedalus had to know that when something moves at a constant speed, the sum of all the forces acting on it is zero. So is the sum of the torques. We'll explore the fascinating consequences of this immutable physical law momentarily.

What Daedalus also knew is that there is no difference between a sail, a wing, and a kite. They're all airfoils. To understand one is to understand all, as we shall see.

How Airfoils — Kites, Sails, Wings — Work

Daniel Bernoulli once observed that if you stuck something in a wind, and if the wind had to go farther to get around one side of it than it did to get to the other, then the pressure would be lower on the windward side. Where the velocity is greatest, the pressure is the least.

Well, pressure is force per unit area, which means that if you can make the velocity of an airflow greater around the top of something than it is on the bottom, then you'll have a force pushing upward on it. If you can make air flow faster on one side of an object than it does on another, then you can make it move to the side, the way a sail does. That's how an airfoil works.

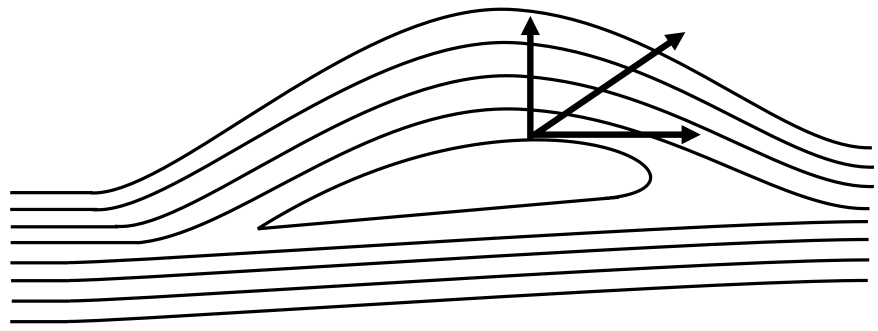


Figure 4: Airflow over a Wing

Figure 4 shows a cross section of a wing as it responds to the air flowing over it. You can represent the Bernoulli force acting on the wing as a single vector pointing up and forward.

The force has a horizontal component, called "thrust" and a vertical component, called "lift." If the wing isn't accelerating (and we agree it isn't), then thrust is exactly countered by a horizontal force pointing to the trailing (thin) edge of the wing, and the lift is exactly countered by the force of gravity acting on the wing. The wing moves through the air at a constant speed.

You can think of an airplane in level flight as having the x, y, and z axes we discussed earlier passing through it. In a well–designed aircraft, the axes all meet at a common origin, which serves as the center of all forces and all torques acting on it. Imaging viewing the airplane from the side. The x axis is the horizontal axis, the y axis is the vertical axis, and the z axis passes laterally across the airplane from wingtip to wingtip.

How Airplanes Work

Figure 5 shows an aircraft and the axes passing through it.

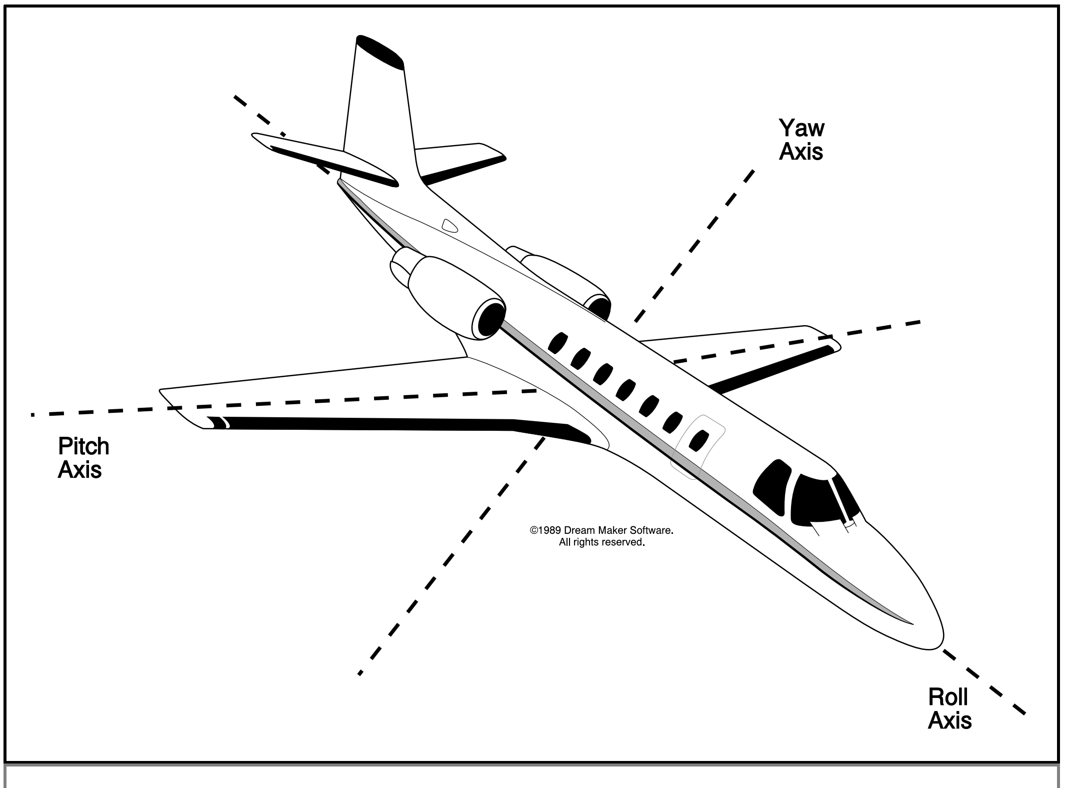


Figure 5: An Airplane

These axes have special names. The x axis is called the *roll* axis, the y axis is called the *yaw* axis, and the z axis is called the *pitch* axis. You control the aircraft by rotating it around one or more of these axes. Figure 6 represents the control surfaces that make this possible. You can see that moving one of the control surfaces in one direction or another increases the airfoil's lift on one side or the other.

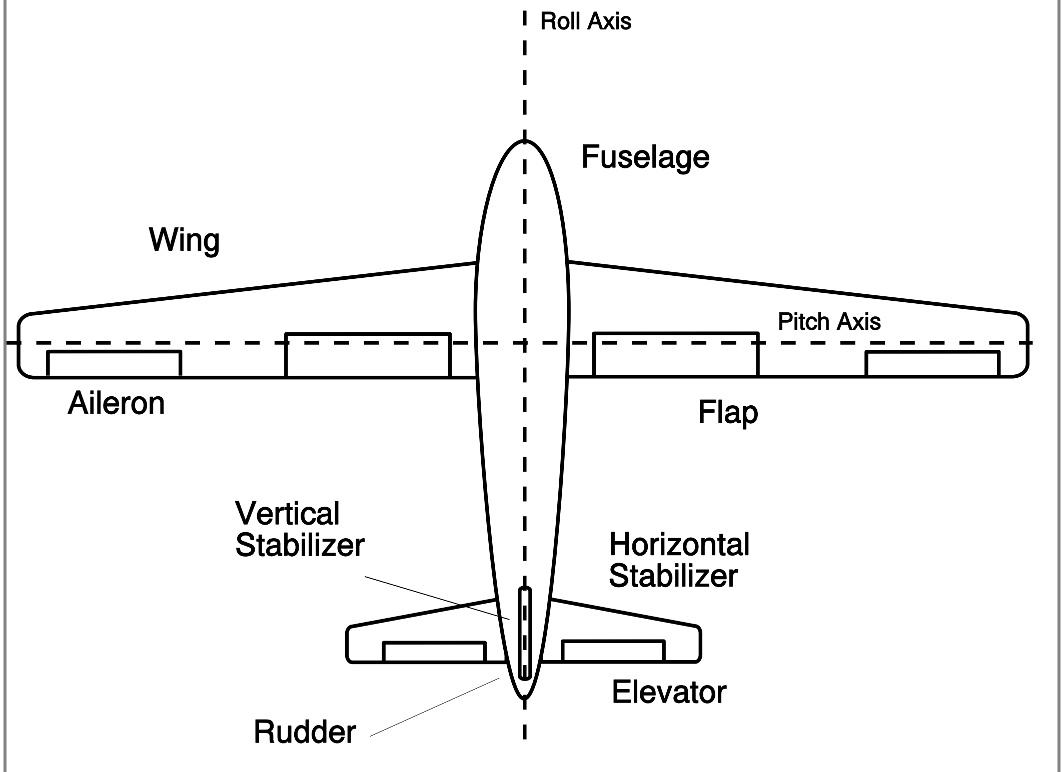


Figure 6: Control Surfaces of an Airplane

You can alter the lift and drag an airfoil generates by putting control surfaces on it. Figure 6 shows an airplane with the control surfaces it needs to change the way it flies. Remember that we're only going to look at two dimensions at a time, which means that one axis and at least one of the vector components we'll be discussing will point straight into or out of the page.

If you want to rotate the craft about its roll axis, then, you turn one aileron up and the other one down. This causes both wings to generate a torque that acts along the roll axis of the aircraft.

The rudder makes the aircraft rotate about the yaw axis by generating a torque that acts along the yaw axis of the plane. In the same fashion, the elevator generates a torque along the pitch axis, making the plane climb or dive.

Figure 7 shows all three of these rotations for our platonic airplane.

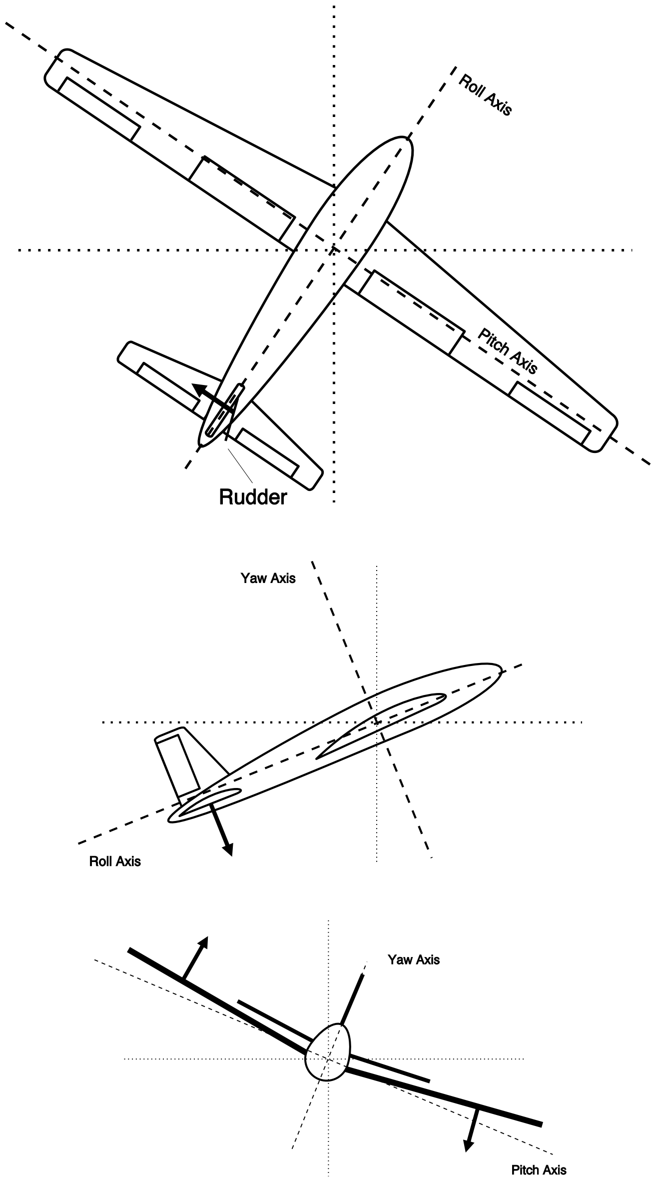


Figure 7: Yaw, Pitch, and Roll

How Kites Work

Kites work the way wings do. Figure 8 shows a kite as it interacts with the air passing over it.

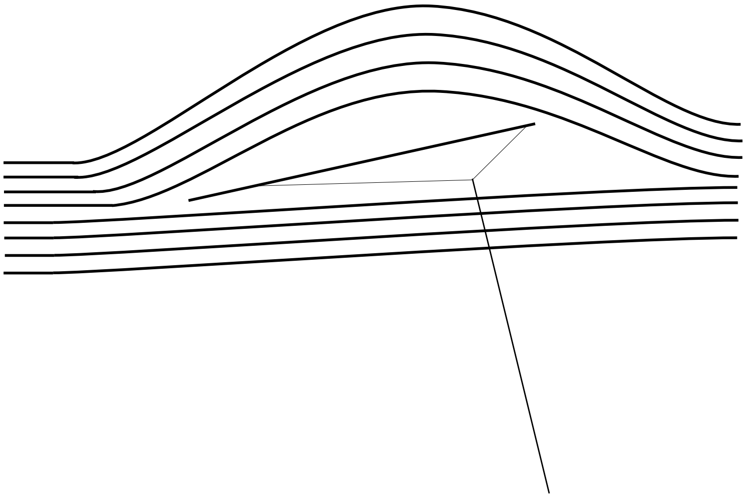


Figure 8: Airflow over a Kite

A typical kite has a *bridle* to control the angle it makes with the wind. The bridle attaches to a string. When you fly a kite downwind in the customary fashion, you exert a force acting along the string that counteracts the drag and the lift the wind generates as it passes over the kite. The kite string force components, then, correspond to the forces of thrust and gravity that operate on the airplane. The forces, and the torques, that act on a kite are all in balance when it hangs motionless in the sky.

As a rule, kites don't have control surfaces. This is a rule that's been rather creatively broken, as we shall see.

Kites also, as a rule, have some dihedral. This stabilizes them the same way that dihedral in an aircraft wing stabilizes the aircraft. You give a kite dihedral by tying a "bowstring" across its back. This curves the horizontal spar of the kite, making it a three–dimensional object. If you've ever flown kites, you've seen this done.

You control the kite by altering the bridling angle, the dihedral, and the angle at which you apply the string force. Kites with no dihedral, for example, are highly maneuverable because of their instability. They crash a lot, but then they cover a lot of sky in a little time. Fighting kites are usually flat for this reason.

Altering the bridling angle affects the angle the kite string makes with the ground. The higher you bridle, the more stable the kite is and the lower it flies. The lower you bridle, the less stable it becomes, but the higher it soars. If you bridle too low, the kite loops, eventually crashing on its vertical spar. There is a fascinating area between the stable kite and the looping kite in which the kite neither loops nor climbs. In fact, it turns over on its side and comes about into the wind, like a sail.

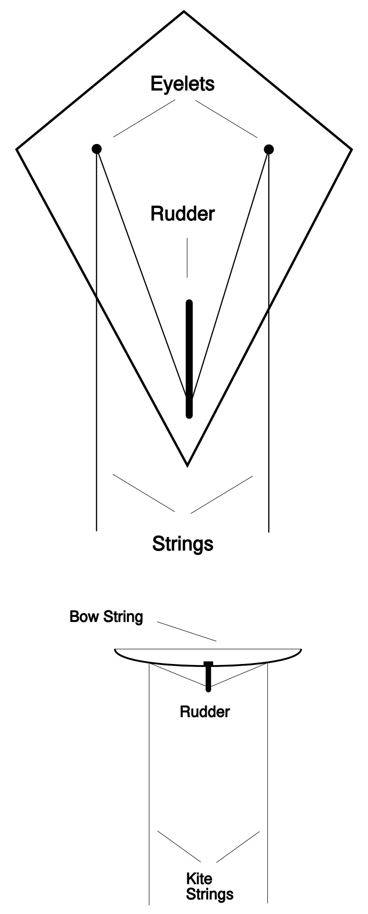


Figure 9: The Garber Kite – It Has a Rudder

Figure 9 shows a kite Paul Garber made for the Navy during World War II. This kite has a control surface, a rudder, which imparts some interesting motions to it when you tow the kite behind a ship. Garber built the kite, which ususally had the outline of a Mitsubishi Zero fighter painted on it, to provide target practice to Navy gunners.

For years, these kites were available in war surplus stores, and the plans for making them are still available. The interesting thing about this kite is that, at least to my knowledge, no one has ever tried to see what happens when you fly the kite without towing it. My belief is that if one does fly the Garber kite in this way, and if one carefully manipulates the rudder, the kite should fall off on the windward side and come about into the wind in the same way a high–bridled kite does.

The Garber kite, then, should act as a sail. You should be able to tow a boat or a vehicle with it, although Garber’s arrangement is by no means the only configuration that works this way.

This ability of a kite to fly into the wind explains the number of uses of the kite as sail that history records. It explains George Pocock’s *Char–volante*, for example. The *Char–volante* was a light carriage to which Pockock attached a large kite. The kite powered the carriage over a number of miles of English countryside, returning to the point from which it departed.

The fact that it came back implies that Pocock was able to fly the kite into the wind as well as with it. Pocock used a kite with joints in the wings and a four–line bridling arrangement that controlled their angle to the wind, bringing the kite up into it. He used a string of several kites in tandem, rather than a single, very large kite.

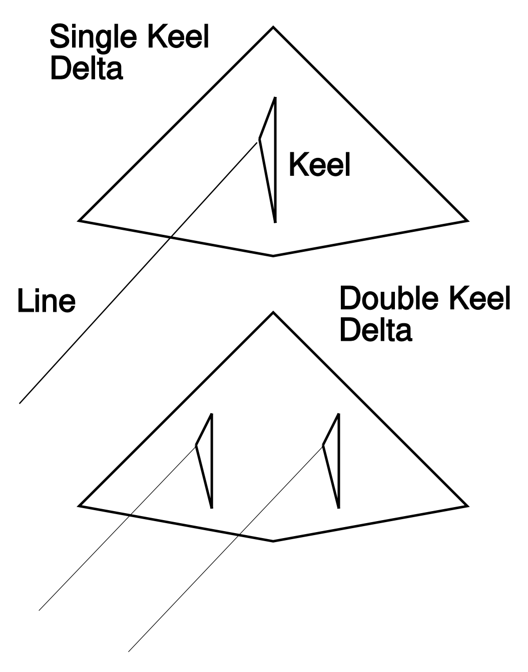


Figure 10: Typical Delta Stunt Kites

The technique of tacking the kite by using two bridle lines appears in a number of modern stunt kites, a typical arrangement of which appears in Figure 10. The kite comes up into the wind by banking (turning on the roll axis), rather than yawing, but the effect is the same in either case.

Pocock’s great nemesis, and the nemesis of all ground–based sailing schemes, was that on the ground, there are too many objects you can snag your kite line on.

Pocock couldn’t keep his lines out of the trees. Today, you’d have to contend with power lines, tall buildings, billboards, railroad trestles, and heaven knows what other obstructions, none of which plagued Pocock when he flew the Char–volant.

Clearly, if you want to use a kite to tow something, it should be a boat, simply because there aren’t so many obstructions over water as there are on land. But why should anyone want to tow a boat with a kite? Especially when the technology of sailing is so highly developed and familiar.

There is a reason, and it derives from the fact that even the best sailboat has to fly on a single wing. This one fact is the prime determinant in all sailboat design, and it sets a number of limits on what you’re allowed to do with a sailboat. Let’s take a look.

How Sails Work

A sailboat, like an airplane, exists in three dimensions, which we can easily examine by looking at two dimensions at a time. Figure 11 shows the boat as it appears from the top.

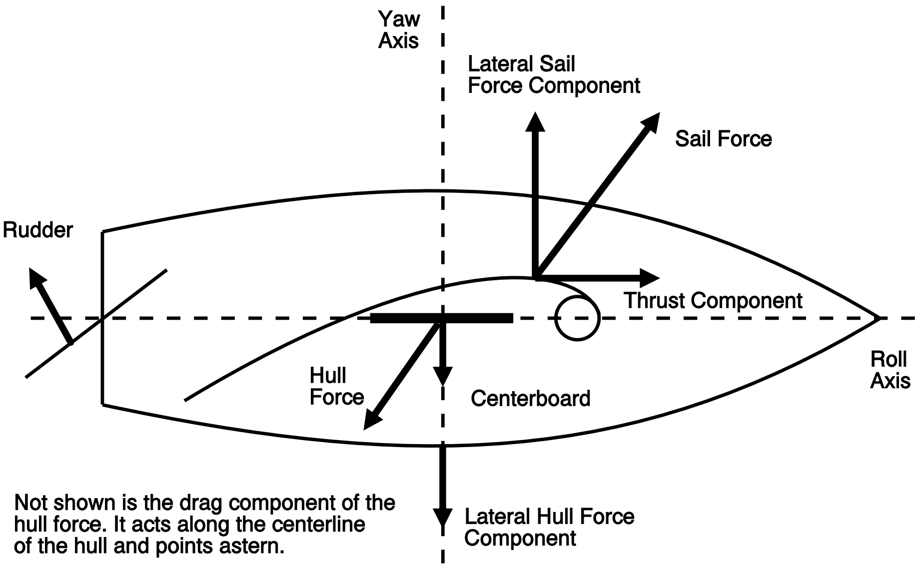


Figure 11: A Sailboat Viewed from the Top

Notice that from the top a sail looks exactly like a wing which, of course, it is. It assumes that shape when you turn it into the wind.

The same forces — lift, gravity, thrust, and drag — that operate on an airplane or a kite act on the sailboat. Thrust comes from the wind itself: It's one component of the sail force that results from passing the wind over the sail as depicted in Figure 4 above. Friction between the water and the hull of the boat produces drag. If the boat isn't accelerating, but moves at a constant speed, then drag exactly balances the thrust component of the sail force.

But thrust isn't the only component of the sail force. There's also an important lateral component that operates perpendicularly to the hull.

This rather large force makes the boat drift. If you could make it act at the center of force of the hull, then the boat would sail sideways as well as forward. That is, it would crab. If the force doesn't act at the center of force, as it usually doesn't, then it makes the boat yaw as well because it produces a torque along the yaw axis.

To counter the tendency of the boat to yaw, you use a rudder, which produces a torque opposite to that produced by the sail. To counter the drift, you use a keel or a centerboard. Since most small boats use a centerboard, and since our primary interest is in small boats, it's the technique we assume here.

You can also balance the lateral sail force component by increasing the area the hull presents to the water. Clearly, the greater that is, the harder it is to drag the boat sideways through the water: The hull exerts a force on the water that tends to keep it where it is. Unfortunately, the more area your hull presents to the water, the more drag it generates. This makes it less fun to sail, which causes drag to be a malign force indeed.

The tendency of a boat to drift and yaw, however, isn't the worst effect of the lateral component of the sail force. Look at Figure 12 overleaf.

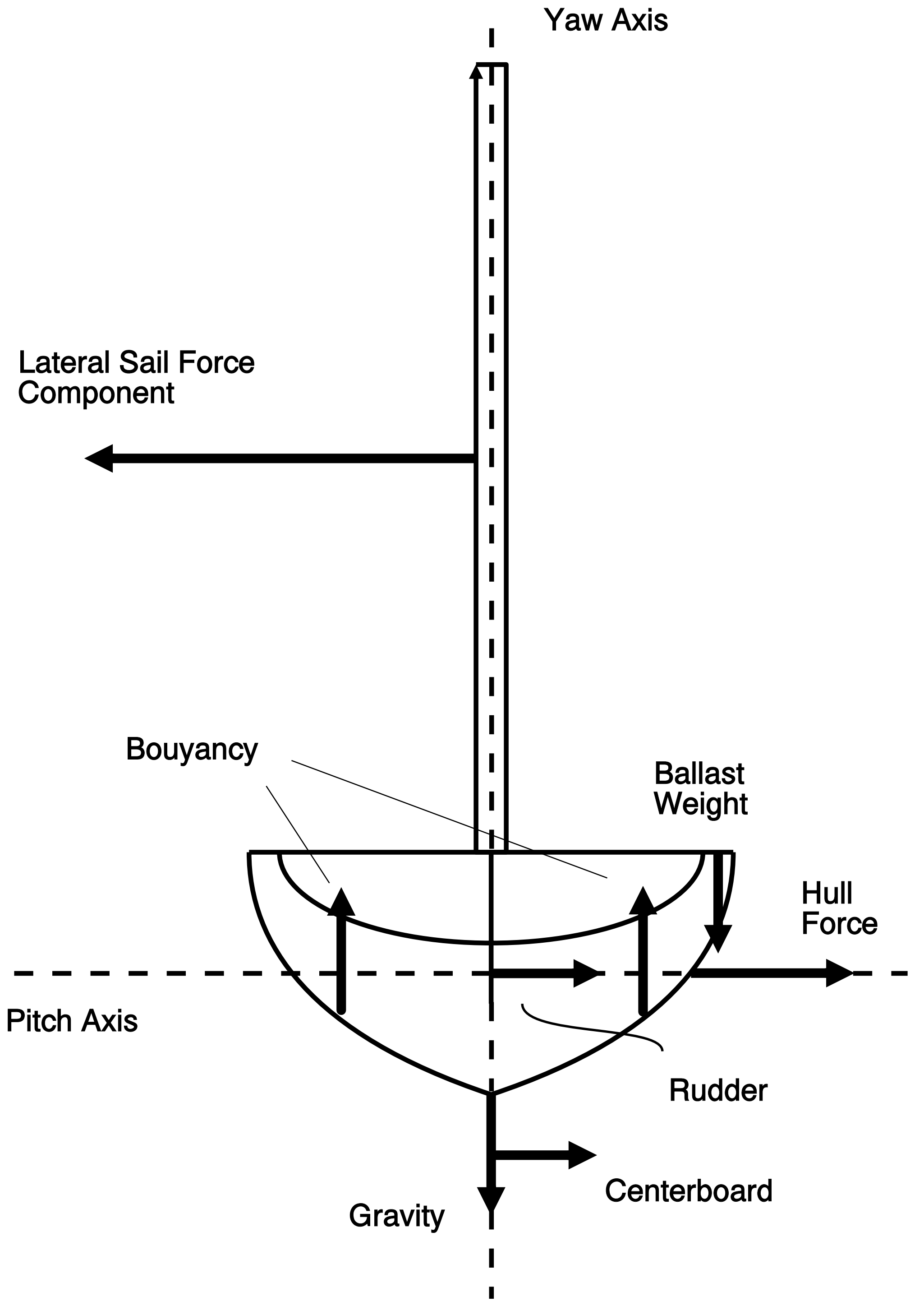


Figure 12: A Slowly–Moving Sailboat from Behind

In that figure, it’s clear that the lateral sail force component produces a hefty torque along the roll axis of the boat. That is, it tries to tip the boat over. This single torque is responsible for more decisions on sailboat design than any other. It sets almost all of the current limits on the way a sailboat performs.

Sails are tapered, for example, because of this lateral force. Tapering the sail makes the effective origin of the force occur lower on the mast, which reduces the torque.

The torque also limits the minimum width, or “beam” of the boat at its widest point. If the boat is too narrow, then it rotates around the roll axis in response to the torque. Mariners call this “capsizing.” Capsizing takes the joy right out of sailing. If the beam is too broad, then the hull generates a lot of drag, making the boat slow and sluggish.

The ideal design, then, given these constraints, includes the narrowest beam that won’t capsize when the boat is under sail. One thing you can do to allow a narrower beam is to add *ballast* to the high side of the boat. Ballast is any weight that isn’t the weight of the boat or its cargo. You ballast a boat under sail by sitting on the high side of the boat. This produces a torque along the roll axis opposite that produced by the lateral sail force component.

You also counter the torque along the roll axis with *bouyancy* which keeps the boat afloat. You can think of bouyancy as a single force acting at the center of the boat, but it’s more descriptive to show it as two forces on either side of the center as in the figure. When the boat isn’t moving very fast, these forces are nearly equal. As speed picks up, and the sail force increases, the boat tips over as in Figure 12 on page 18. At this point, the side of the boat that sinks into the water produces most of the bouyancy of the boat, which tends to right it.

Notice that the centerboard, which is there to help the hull force conteract the tendency toward drift, generates a torque that tries to rotate the boat in the

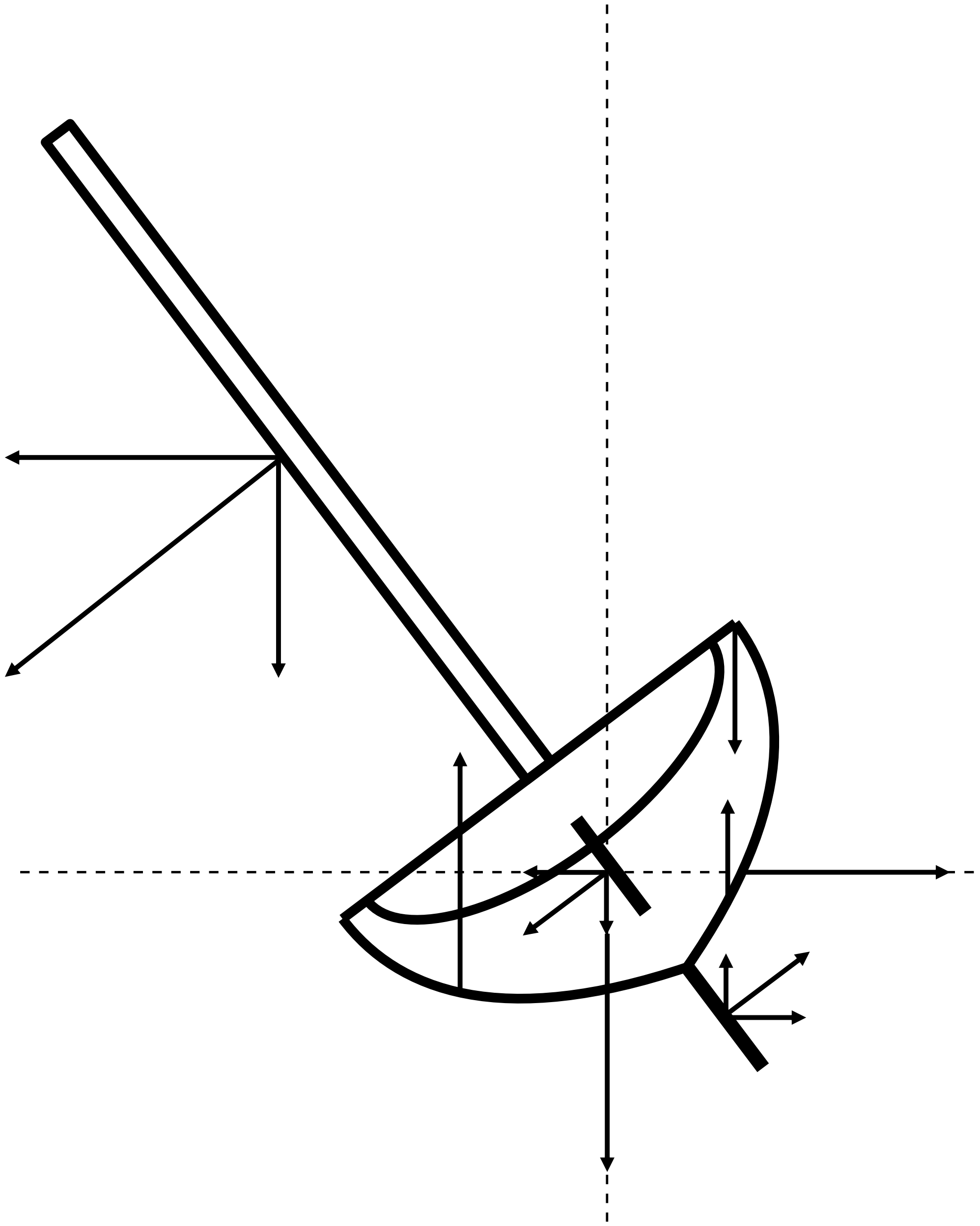


Figure 13: A More Swiftly–Moving Sailboat

same direction that the sail torque does. This is doubtless the general kind of thing Enrico Fermi had in mind when he referred to “the sheer cussedness of nature.”

The lateral component of the rudder force can always be arranged so that it operates at the intersection of the x and y axes. It doesn’t generate any torque unless it’s badly placed.

Figure 13 shows all of the forces except for thrust and drag on the boat in constant motion. Except for a small torque along the yaw axis that might be associated with thrust, that figure shows all of the distances at which the forces act, hence everything you need to infer the torques. The sum of all the force components is zero because the boat is assumed not to be accelerating. The sum, likewise, of all the torques is zero. All of the forces and torques are in perfect balance.

But the boat is tipped over, and you can’t make the sail any bigger because that would make the boat capsize. You can’t make the beam any narrower because that would do the same thing. You have to perch on the high rail, or hang out perilously therefrom to get more performance out of a given wind, and that wind can only blow so hard before you can’t sail into it at all. All this is why you might well consider the kite as an alternative to the sail if you knew you could make it work.

Concerning the Kite as Sail

History has established that you can fly a kite into the wind. If you want to use a kite as a sail, then, you need only take down your mast and tie the kite to your boat.

It makes some difference where you attach the kite line. If you tie it to the bow of the boat, then you’ll generate considerable torque along the yaw axis. On the other hand, your rudder should compensate for that without becoming too draggy.

If you locate the attachment point at the center of force, then your kite won’t generate any torques at all, but then your kite line might be constantly in the way. This takes a big load off the rudder, which then can be used only to control the direction your boat sails in. Figure 14 shows a top view of the boat without the sail and with the kite line attached between the bow and the center of force as a sort of compromise.

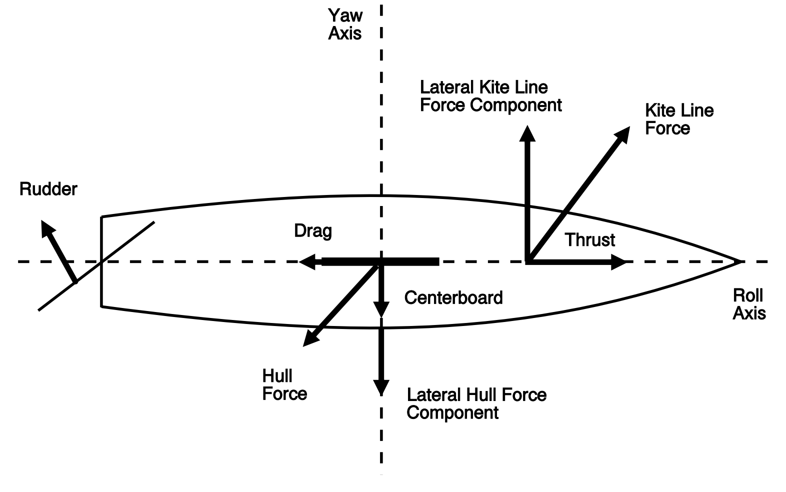


Figure 14: A Kite–Drawn Boat from the Top

In either case, what you eliminate is the torque along the roll axis attributable to the lateral sail force component, which is the one that causes the lion's share of the trouble. Figure 15 on the facing page shows the end view of the boat with the kite sail.

Note that there is still a component of the force that causes drift. That means you still need a centerboard as well as a rudder, and that you'll still experience some torque along the roll axis as a result. Still, you've eliminated most of your boat's tendency to capsize, and there are alternatives to the centerboard that minimize or eliminate the roll torque as well.

With the lateral sail force component gone, you can add kites or make your kites bigger or both without upsetting your nautical applecart. You can make your boat much narrower in the beam. A canoe might not be too narrow, especially if

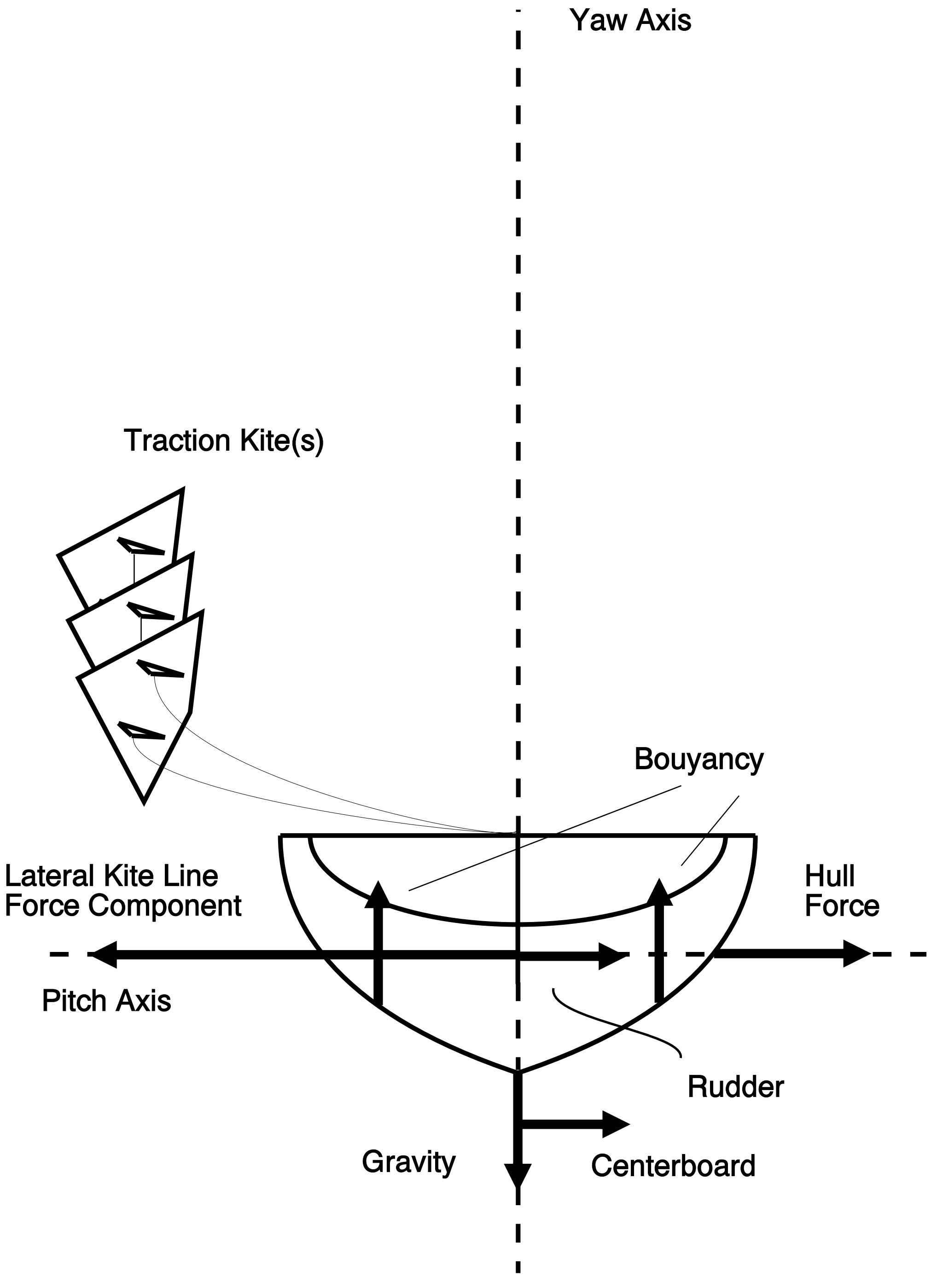


Figure 15: End View of the Kite–Drawn Boat

you locate your centerboard in an outrigger as south sea islanders are wont to do. The possibilities are numerous.

Probably the kiteboat won't replace the sailboat: It can be glorious fun to keep a sailboat from drowning you as you glide swiftly across the water. Still, the kiteboat seems to be a practical alternative with limits of its own worth challenging.

The Kite Plane

Now to Daedalus. Assuming that you can successfully draw a sailboat into the wind with a kite — and there is plentiful evidence that you can — what is to keep you from adding yet one more airfoil to your kiteboat?

This airfoil would lie across the hull of the boat. It could take any number of forms: That is, it could be a rogallo wing of the kind used in hang gliders as shown in Figure 16. It could be a glider wing attached to the hull, making your kiteboat resemble an airplane with the hull for a fuselage. It could be an unpowered, rotating wing, like the kind that supported the autogiro of the thirties and forties. It could be an English arch–top kite like the one Sir George Cayley used as the basis for the earliest gliders. It could be any airfoil shape or type that flies, and these comprise a seemingly infinite variety.

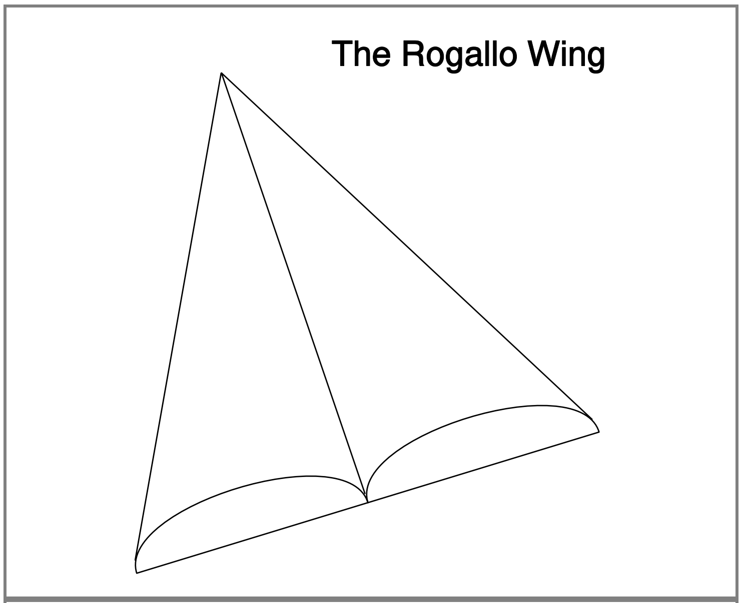


Figure 16: The Rogallo Wing

Now as you drag your boat across the water, you can adjust the angle of the transverse airfoil so as to make it rise. At this point, especially if you use a design like the rogallo wing or the autorotating airfoil, you may be able to control the drift as well as the torque along the yaw axis by banking your transverse wing. If you use a narrow wing, then you may have to add an empennage with a rudder and an elevator of the kind found on conventional aircraft.

You’re also likely to experience some torque along the pitch axis as the traction kite, which flies at some angle above the kite plane, tries to make the nose of your fuselage rise. If you don’t have an elevator to counteract this torque, you may be able to add a small canard wing near the nose for that purpose. Note that when you use a kite for towing, you fly it at a fairly low angle to the thing towed, because you want most of its lifting force to go into the useful work and only the minimum necessary to keep the kite off the ground. You should be able to keep your nose level without too much difficulty. My conception of how, more or less, this device woud appear in flight appears in Figure 17 on page 24.

This, then, is the secret of Daedalus, who knew that you can fly with the wind as your engine using only the materials available to a clever artificer of three millenia past. Try not to get too near the sun.

A Modest Proposal

To build such a craft is within the capability and budget of anyone with enough imagination to take the project on. I propose, therefore, that

- An organization, Daedalus, be formed for the purpose of exploring kites, wings, and sails and the more interesting applications thereof
- That Daedalus adopt as one project the building and testing of a kite plane.

I envision a formal network of local clubs with a national or international organizational structure. These clubs would meet formally once a month and would serve primarily to bring people together to experiment, test, and document in these areas.

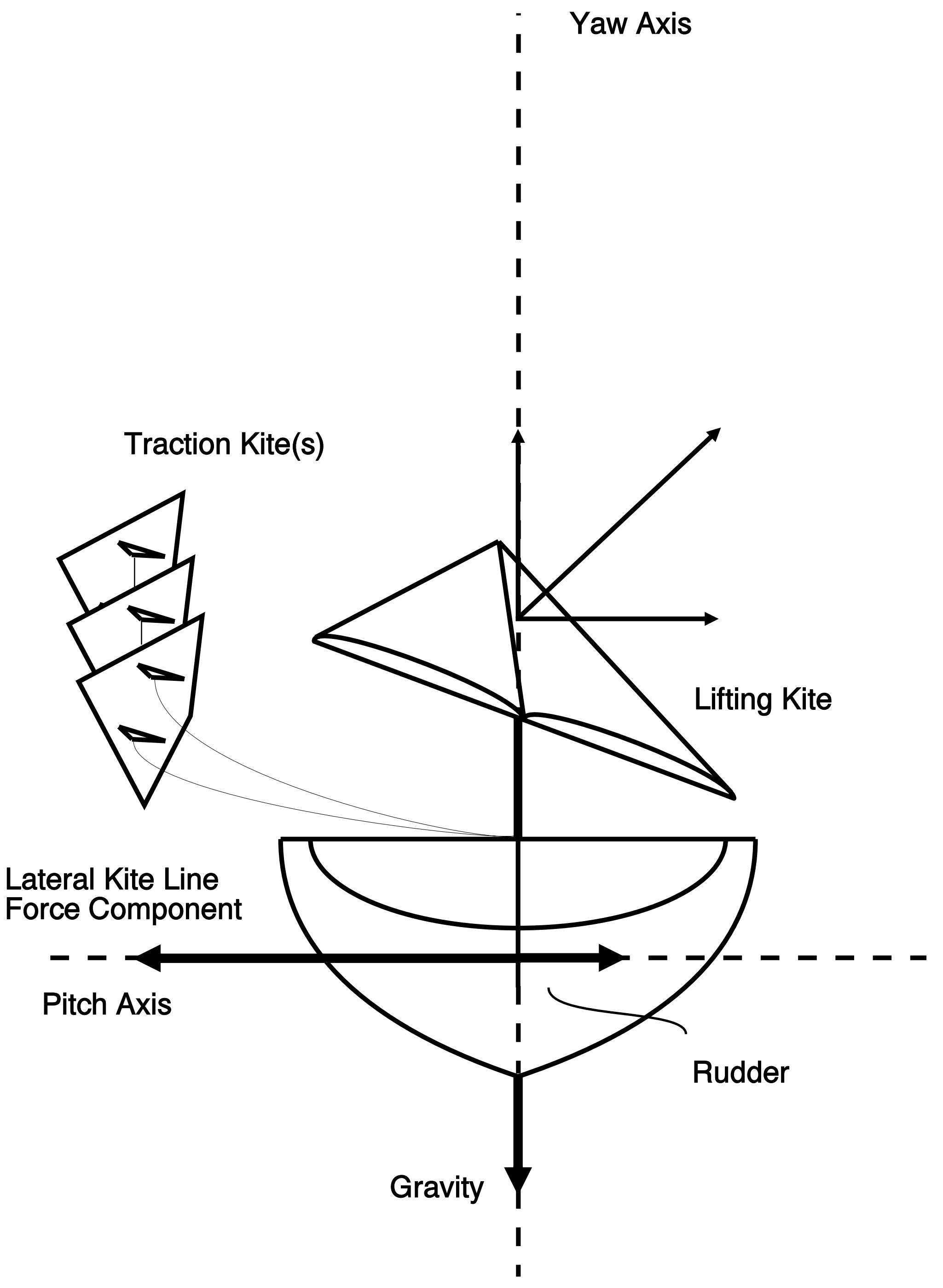


Figure 17: The Kite Plane

The clubs should consist in ordinary people who like or might like to fly, sail, fly kites, and things of that nature. There should be no restriction on age or education: A naive viewpoint is often more effective in solving a problem than a highly informed one. Membership should be open to anyone who wants to join. Membership recruiting efforts should make no assumptions concerning fitness for membership. You just never know who's going to make the most important contribution.

Clubs should adopt specific interests of their members as projects. These should provide a loose project structure, so that project members know precisely what tasks they're responsible for, and so that things can be done on some kind of schedule. If you're in a club, after all, it's because you want to work on a team.

The first meeting of the first Daedalus chapter is set for Saturday, December 12, 1992 at one in the afternoon. Place to be announced.