Aug. 15, 1967 R. P. HOLLAND, JR 3,335,984

KITES

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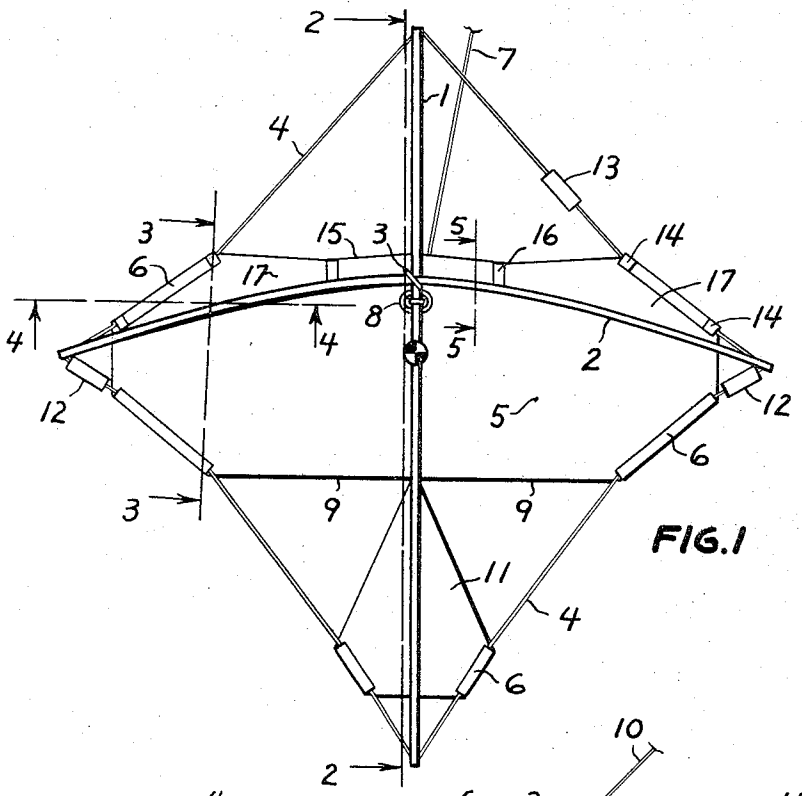


FIG. 1

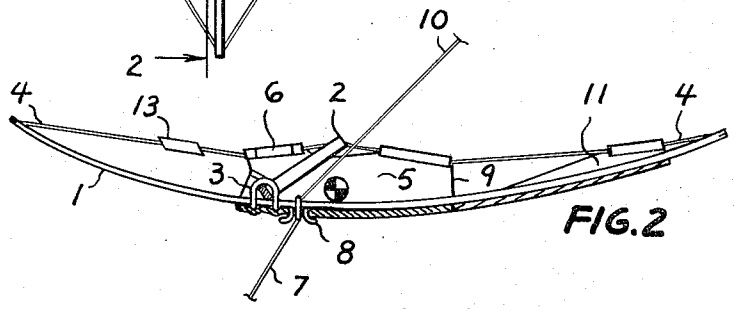


FIG. 2

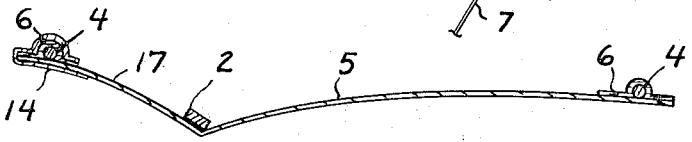


FIG. 3

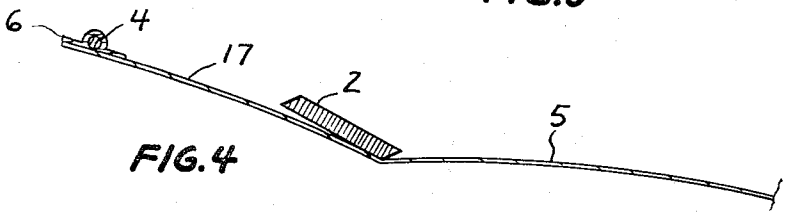


FIG. 4

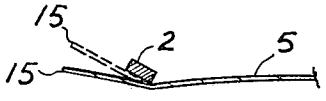


FIG. 5

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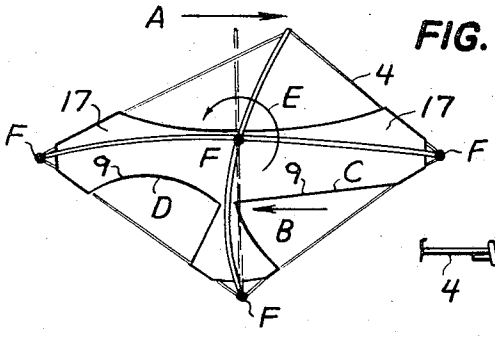


FIG. 6

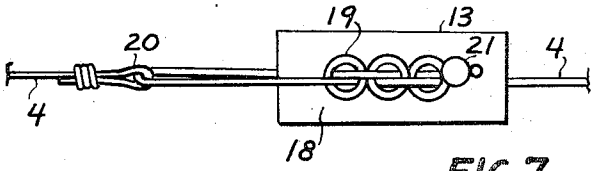


FIG. 7

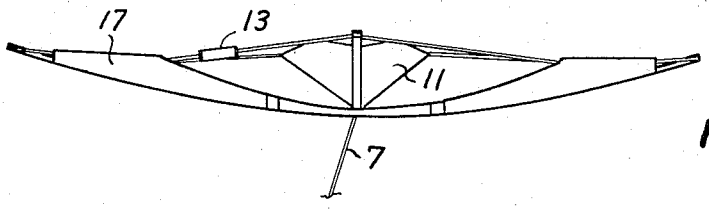


FIG. 8

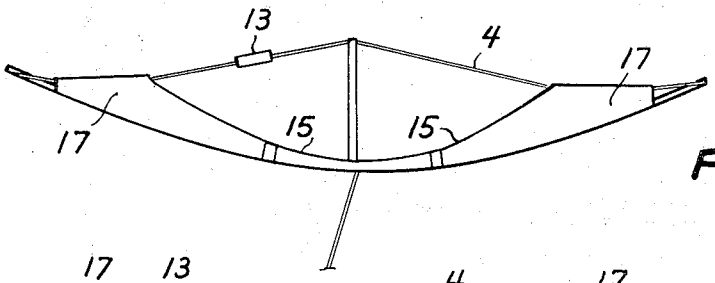


FIG. 9

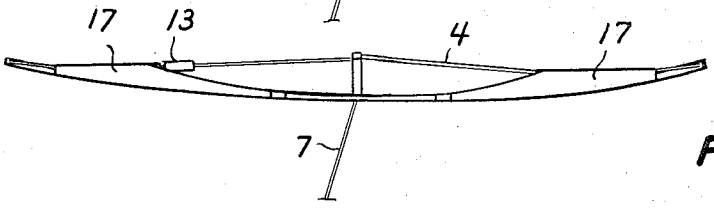


FIG. 10

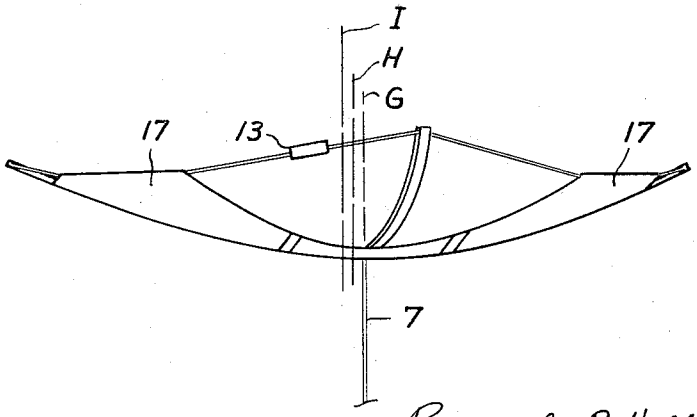


FIG. 11

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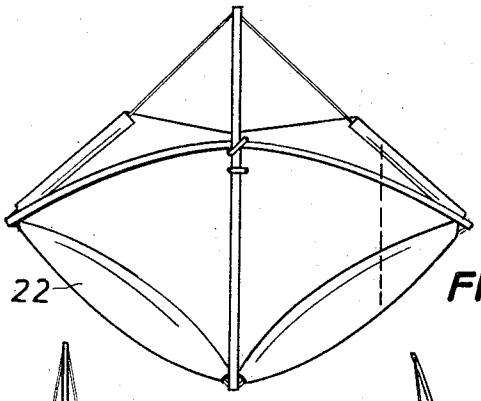


FIG. 12

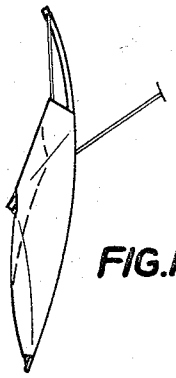


FIG. 13

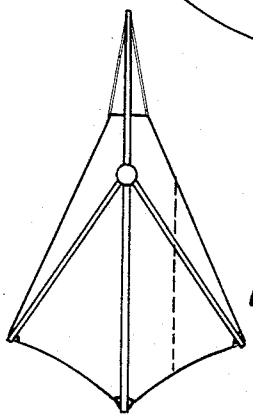


FIG. 14

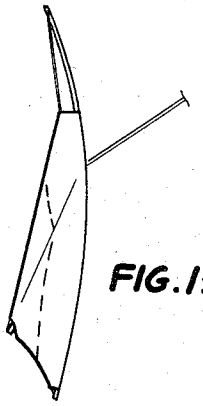


FIG. 15

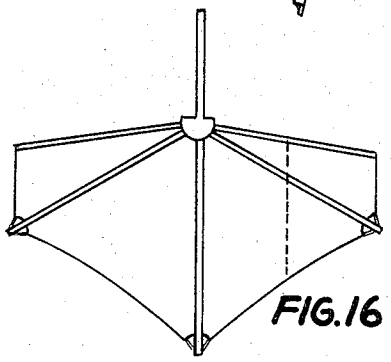


FIG. 16

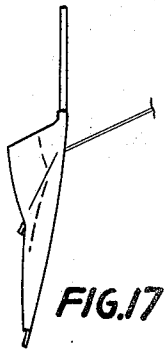


FIG. 17

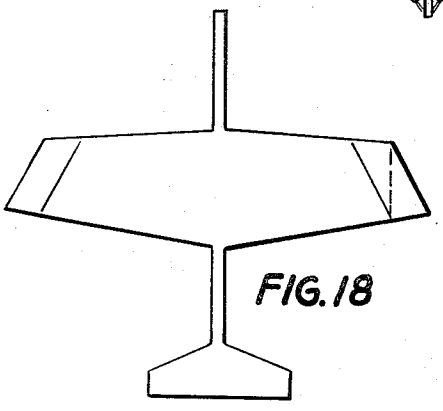


FIG. 18

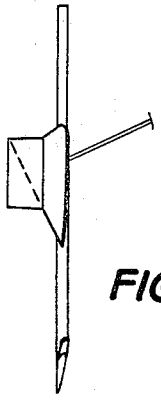


FIG. 19

Raymond P. Holland, Jr.

United States Patent Office

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3,335,984

KITES

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Filed Apr. 1, 1965, Ser. No. 444,550
14 Claims. (Cl. 244—153)

This invention relates to kites and particularly to aerodynamically balanced kites of the types described in U.S. Patents 2,562,789 and 2,698,724. The improved kites will be of simpler construction, without a bridle and without a trailing tail, and may be flown in stable flight or in aerobatic flight, at the choice of the kite flier, in a wide range of wind conditions.

In a kite intended for popular use as a toy or for sport the desirable characteristics are: simplicity; light weight; durability; economical construction and packaging; ease and infallibility of assembly by the user; ease of launching; certainty of satisfactory flight, whether the wind is light or strong, or whether it is steady or gusty; aerodynamic stability in flight without the use of a rag tail or other auxiliary device; rigidity of form in flight; resiliency of structural members to reduce accidental breakage; efficient aerodynamic form resulting in high flights or aerobatic flights at the choice of the kite flier; light string pull enabling thin string to be used, reducing string drag and permitting high flights to be performed; ability to fly very high with several kites on one string; striking appearance, preferably like a plane or a bird; and unique flying abilities which set it apart distinctly from all other kites.

Heretofore no kite has accomplished all of these desirable features in one construction.

The object of this invention is to provide all the desirable features listed above in one novel structure.

It is a further object of this invention to provide novel means of flight stabilization for kites, and means for their adjustment.

This invention in its preferred form employs a novel structure which uses a border string around the tips of two crossed sticks, one of which extends forward well clear of the lifting surface, both sticks being bent concave upwardly, the wing stick also being bent concave rearwardly, these sticks supporting wing and tail cover material concave upwardly both laterally and directionally, and having unique upwardly forwardly sloping, rearwardly outwardly skewed jib-like stabilizer surfaces at the wing tips. These stabilizers and the tail surface contribute to a striking bird-like appearance, which is most pronounced in flight when wind pressure is on the wing cover material.

The construction of the kite will be seen from the drawings, which show the preferred embodiment of the invention and several alternate forms.

FIGURE 1 is a top plan view of the preferred embodiment of the invention having the flight appearance of a hawk. FIGURE 2 is a sectional side view along line **2—2** of FIGURE 1 showing the cross section and all portions of the kite lying beyond the cross section. The front of the kite is at the top in FIGURE 1 and at the left in FIGURE 2. In its flight attitude the front end of the kite is relatively higher than is shown in FIGURE 2. The upwardly concave form of the kite, both longitudinally and laterally, is to be seen in FIGURE 2. FIGURES 3 and 4 are enlarged sections of the wing tip of the kite taken at **3—3** and **4—4** respectively of FIGURE 1, showing the form of the jib-like stabilizer surfaces. These produce locally increased upward concavity of form at the wing tips, both longitudinally and laterally. The section through wing stick **2** in FIGURE 4 appears broad because line **4—4** cuts through the stick at a small angle. FIGURE 5 is an enlarged section through the leading edge of the wing root at **5—5** of FIGURE 1. The curvature of the sheet material in FIGURES 3, 4, and 5 is due to the wind pressure; the forms shown are those which exist in flight.

FIGURE 6 is a diagram representing the kite as seen from the rear and somewhat above showing how wing warping is accomplished for trimming the flight position of the kite laterally, by sliding the front of the nose stick sidewardly on the front border string loop.

FIGURE 7 shows the rig adjuster used for shortening and lengthening the front border string loop to obtain the configurations shown in FIGURES 8, 9, and 10.

FIGURES 8, 9, and 10 are front views of the kite taken in a direction parallel to the local air flow over the wing, showing the effect of shortening and lengthening the front border string loop on the aerodynamic frontal aspect of the kite, for the purpose of varying the drag and the stability of the kite.

FIGURE 11 is a view along the direction of the relative wind across the wing when the kite is yawed, showing the effect of the wing tip stabilizer surfaces on the frontal aspect of the yawed kite. These stabilizer surfaces have the purpose of imparting directional stability to the kite.

In FIGURES 8 through 11 the amount of frontal bow in the wing stick is exaggerated to show more clearly the differences caused by rigging. Horizontal tail **11** is omitted from FIGURES 9–11 for clarity.

FIGURES 12–19 show four alternate embodiments of the invention. Even numbered figures show plan views and odd numbered figures show side views. Each plan view shows a fore and aft dashed line on the right wing, and each side view shows the shape of this line in side view, to illustrate the form of the jib-like wing tip stabilizers.

FIGURES 12–17 show all-wing versions of the invention. In FIGURES 12–13 a rearwardly bowed wing stick is used. In FIGURES 14–15 two sweptback lateral spars anchored rigidly in a central socket member replace the bowed wing stick, producing a kite having the appearance of a supersonic airplane. In FIGURES 16–17 the forward loop of the border string has been eliminated, its form-preserving function being performed by rigid leading edge sticks secured rigidly in a central socket member integral with a rigid forwardly extending member the function of which is to move the center of gravity of the kite forward. It will be observed that the leading edge member is elevated higher than is the lateral member lying behind it, so that the angle of attack of the jib-like stabilizer surface is greater than is the angle of attack of the remainder of the lifting surface. This is true of all forms of the invention. The constructions in FIGURES 14–17 are adaptable to demountable structure with short sticks which can be packed in a short package. It will be observed that the central body member in these kites is held concave upwardly by the tension of the wing cover material and of the border string. This concavity is somewhat exaggerated in the figures in order to be plainly visible.

FIGURES 18–19 show an embodiment of the invention in the form of an airplane without a vertical tail but with wing tips upturned and skewed, performing as

directional stabilizers in accordance with the teaching of this invention. This version of the invention would be fabricated using a rigid foamed plastic material molded in a single piece. The forwardly extending fuselage member has the function of moving the center of gravity forward.

In U.S. Patent 2,562,789 the trim and stability of kites was improved by the use of a forwardly extending member moving the center of gravity of the kite forward, bringing the center of pressure, the center of gravity, and the point of action of the pull of the flying string closer to each other than previously, so that any changes in the major forces acting on the kite would produce smaller distributing moments on the kite than previously. In U.S. Patent 2,698,724 these benefits were retained and in addition the kite was provided with longitudinal concavity in an upward direction, so that the ballasted trailing tail and the flying string bridle of the previous patent were no longer needed. At the same time a simpler, lighter structure was accomplished.

In the present invention this trend of improvement is continued. Means of providing directional stability have been invented which require neither a trailing tail nor a vertical tail. In addition means were invented for adaptability to light, strong, steady, or gusty winds, and for enabling the kite flier to select steady flight or aerobatics, or high angle free-wandering soaring flights or low angle flights with a minimum of lateral movement. This has all been accomplished in a structure simpler and lighter than that of the aerodynamically balanced kites referred to by patent number above. The result is a tailless, bridleless, kite structure of marked simplicity and lightness, having unique stability and versatility.

The results achieved by the present invention are produced by constructional features which combine and interact with each other in a most critical and delicate manner, and yet when they are combined as taught in this invention the results are insensitive, such that even small children can fly the kite with reliability and satisfaction.

The use of jib-like stabilizers at the wing tips for producing directional stability and increasing lateral stability, would produce directional instability rather than directional stability if there were not a forward-extending exposed body stick at the front of the kite to cause the center of gravity of the kite to be well forward. The forward end of the body stick, in turn, provides a simple light weight support for the jib-like stabilizers, properly positioned by virtue of the upward bend of the body stick to give the stabilizers their required upward tilt. The combined result exceeds the individual contributions of the components; the elimination of either the bare nose stick or the jib-like stabilizer would result in an unstable kite and an incomplete supporting structure.

The combined directional stability effect of the jib-like stabilizers and the forward center of gravity is like that of a snow plow pulled from a forward point. In the kite, stability must be achieved in gusty air, when the kite is battered by side gusts. In these conditions the point which is equivalent to the towing point of the snow plow is the center of gravity of the kite. A rearward center of gravity on the kite is like a rearward towing point on the snow plow. It is obvious that a snow plow towed forward by a rope attached to the rear of the plow would be unstable, but that when it is towed from a more forward point it becomes stable. The same is true of kites having V-forms. Although they may be stable in steady air when flown from a string tie point forward of the center of gravity, they are unstable in gusty air when the dynamic inertia reaction acts at a rearwardly located center of gravity, and not at the string tie point. Then a side gust turns the kite further to the side, like a weathervane facing backward.

Although this invention employs a sort of "snowplow" stability, it need not resemble the snow plow in appearance. This is because the center of gravity of the kite is relatively well forward, due to the forwardly extending body stick. Consequently, the kite may employ wings at right angles to the direction of flight, and may accurately simulate the appearance of birds or of subsonic airplanes. Such appearance is a valuable feature in kites to be sold as toys.

There have been relatively few kite constructions which produce a steady kite position in choppy winds. Most steady kite forms depend on either some kind of trailing tail or upon large aerodynamic drag. But the trailing tail is an inconvenience and high drag prevents aeorbatic flights which are desirable for sport. The present invention solves both of these problems.

It has long been believed that a kite without a trailing tail requires a bridle. The present invention shows that this is not true; it is tailless and uses no bridle. This has practical advantages for the sport of kite flying; the present invention permits a kite to take off from the ground like a plane, unencumbered either by a bridle beneath or a tail behind. As a result it can take off and land by itself as the wind rises and falls. It is always in trim in pitch, whether at the ground level or at its greatest angle of elevation. This is not true of any kite which uses a bridle or the equivalent of a bridle, such as a keel, or any other rigidly held flying string tie point well below the lifting surface of the kite, by whatever name called.

The present invention adds to the kite art means for attainment of directional and lateral stability in the proper relative proportions, means for adjusting the stability and for adjusting the drag, and means for trimming the kite so that it will fly directly downwind, or either to the right or to the left at the kite flier's option. These benefits are accomplished without any significant increase in weight or structural complexity.

Directional stability in aircraft is conventionally accomplished by vertical tail surfaces. In an aerodynamically balanced kite any weight added at the rear of the kite due to vertical tail surfaces requires at least as much weight to be added at the front of the kite to restore balance. As a result of this and because of the practical difficulties encountered in designing a simple kite embodying vertical tail surfaces, such surfaces are very seldom used successfully, and are never used efficiently. In the present invention the simple jib-like stabilizers on the wing tips accomplish directional stability and contribute to lateral stability, without affecting the balance or the weight of the kite.

An aerodynamically clean kite has an inherent tendency toward active motions in gusty air, being able to draw sufficient energy from the wind to perform large lateral movements. These movements generate additional velocity at the kite over that due to the natural wind. A sufficiently clean kite which responds to gusts, flying in sufficiently gusty air must unavoidably becomes disoriented. This is because the wind speed at the kite due to the kites own movements becomes large as compared to the natural wind speed and the kite as a responsive mechanism has no way of sensing the direction from which the natural wind is coming, and its random flight sooner or later carries it to the ground. It is therefore desirable to be able to increase the drag of a kite conveniently to adapt it to steady flight in gusty wind. This invention provides that adjustment, with no significant increase of weight or complexity.

For a kite without a trailing tail to remain aloft in the fastest possible wind it must have no avoidable movements laterally. Any kite has a certain limited rigidity of structure. As the wind speed increases, all the forces on the kite including the pull of the flying string increase as the square of the wind velocity, except the kite weight, which remains constant. The weight is the only force which provides the tailless kite as a responsive mechanism with a "sense" of the vertical direction. At some particular high speed the unsymmetrical forces on the

kite due to unsymmetrical structural deflections must overpower the kite's ability to react correctively in response to its vertical weight force, and flight disorientation due to speed alone must occur. Such disorientation occurs at a relatively slower wind speed when the kite has lateral movements of its own—for two reasons: (1) the lateral movement increases the true resultant airspeed at the kite, and (2) the lateral acceleration of the kite causes the mass acceleration reaction force to move away from the vertical. Consequently, lateral movements must be reduced to a minimum if a tailless kite is to stay aloft in the strongest possible winds. This may be done in part by increasing the drag of the kite, causing the kite to seek a downwind position at all times. But a large drag is undesirable at slower wind speeds in that it prevents aerobatics and high angle flight. Therefore, for these additional reasons, the drag of a kite should be adjustable, as it is in this invention.

The kite of the present invention is able to fly in very light breezes, because of its light weight structure. Its structural features also permit it to fly in relatively strong winds. It is a pre-stressed, pre-deflected structure, with both sticks bowed and with a stretch-resistant border string in tension around its perimeter. No important distortion of its supporting frame can occur until the wind bows these sticks more than they are already bowed. When the kite is rigged for steady flight, both sticks are deeply bowed so that a correspondingly very strong wind is needed to bend them further. In addition the rearward bend of the wing stick places that member partly on edge so far as air loads are concerned, increasing its mechanical stiffness against air loads.

These aspects and other aspects of the invention will be seen more explicity by reference to the drawing. In the figures the thicknesses of some of the parts are greatly exaggerated in order to be visible.

In FIGURE 1 body stick crosses wing stick **2** at its midpoint where the sticks are bound together by cord **3**. Border string loop **4** engages in the tips of sticks **1** and **2**, in thin slots not shown, and holds the sticks bent in an upwardly concave form, with wing stick **2** also bent concave rearwardly. Wing lifting surface **5** is a thin film material, attached to border string **4** by means of adhesive tape **6**. Flying string **7** is tied around stick **1** at a single point, passing through eyelet **8**, slightly forward of the center of gravity of the kite. The center of gravity is closer to the leading edge of surface **5** than it is to its trailing edge **9**. Flying string **10** ties through eyelet **8** from above the kite and extends to another kite flying higher. Horizontal tail surface **11**, of thin film material, is attached to border string loop **4** by tape **6**, in a construction similar to that at the wing tips. Wing surface **5** and tail surface **11** are attached to body stick **1** by adhesive tape not shown. Wing tip flags **12** are attached to border string loop **4** outboard of the tips of wing surface **5** and rearward of the tips of wing stick **2**; they are held in place by adhesive tape not shown. Flag **12** is a folded card which serves as an identification or instruction label and also occupies the rearward portion of the exposed border string beyond the tips of wing surface **5** to prevent the assembly of wing stick **2** to border string **4** in that region. In this way flags **12** assure symmetrical assembly of the kite. Rig adjuster **13** is attached in border string loop **4** between the nose end of body stick **1** and the tip of wing surface **5**. Rig adjuster **13** is indicated here diagrammatically by a rectangle. Its construction is shown in FIGURE 7. Tapes **14** wrap around tapes **6** and the wing film material, above and below, at the ends of adhesive tape **6** at the forward outer tips of wing surface **5**.

Leading edge **15** of lifting surface **5** extends from body stick **1** to border string loop **4**. At one point on each side of the kite a tuck is taken in leading edge **15** to remove slack. This tuck is covered and held in place by adhesive tape **16**.

The function of the thin upturned leading edge **15** is twofold: (1) It serves to produce a local airflow separation along the leading edge of the wing causing the areodynamic center of pressure of the wing to move rearward. This is just as effective for stability in pitch as moving the center of gravity of the kite forward by the same amount, and is accomplished more easily and without the increase of weight which would be required otherwise. (2) Being elastic and held in tension by the outward thrust of bent wing stick **2** and by the forwardly spreading action of tension in string loop **4**, edge **15** take a relatively flat low drag position in a light breeze, as shown in FIGURE 5 in solid lines, and blows up to a more steeply inclined high drag position in stronger winds, as shown by dotted lines in FIGURE 5. This action automatically increases the drag of the kite to some extent when greater drag is needed for increased stability.

The portion of the leading edge of wing surface **5** which is outboard of edge **15** is supported by border string loop **4**. This edge is also upturned so that it also serves to produce a local airflow separation as described above.

Jib-like stabilizer surface **17** is the region of wing surface **5** forward of stick **2** and outboard of tape **16**. FIGURES 3 and 4 show sections of stabilizer **17**. FIGURE 3 shows the forward-upward general slope of its surface in a vertical fore and aft cross section. The general slope of the surface of stabilizer **17** is that of a forwardly-upwardly tilted outwardly-rearwardly skewed rim on the forward outward tip of wing surface **17**.

In FIGURE 4 the section through wing stick **2** is at an angle, producing the large section shown. In FIGURES 3, 4, and 5 the thicknesses of **4**, **5**, **6**, **14**, and **15** are enormously exaggerated, as required to show thicknesses.

Tail surface **11** as shown in FIGURE 1 contributes to the bird-like appearance of the kite, and performs the function of horizontal stabilizer. With this construction there need be no rag tail or trailing tail of any kind to detract from the kite's appearance or to cause inconvenience, or to be lengthened or shortened as wind conditions change, and there is less weight to be supported and less drag to be encountered than would be the case if a trailing tail were used.

Tail surface **11** is supported at its outer rear edges by being taped to border string **4**. The rear portion of border string **4**, being that portion rearward of wing stick **2**, is held in tension at all times, regardless of the adjustment of the front portion of the border string, by the rearwardly concave bend of wing stick **2**. The tension in the rear loop of border string **4** holds the rear portion of body stick **1** bent concave upwardly, thereby setting tail surface **11** at a smaller angle of attack than that of wing surface **5**, as is necessary to hold the nose of the kite high in flight. This feature is essential in a bridleless kite having a forward center of gravity.

The rearwardly concave bend in wing stick **2** also produces the required form for stabilizer surfaces **17**, which in turn produces many benefits, to be described in detail below. As seen in FIGURE 1 the rearward slope of wing stick **2** near its outer ends determines the slope of the rearward edge of stabilizer surface **17**. Also, as may be seen in FIGURES 2, 3, and 5, the cross section of wing stick **2** is a rectangle having a shorter depth in the plane of the bend of the stick than it has in a direction transverse to the plane of the bend. When the stick is bent rearward the stick is stiffened so far as air loads are concerned. Its cross section is rotated to produce a greater effective beam depth to resist the major wing bending loads. These loads act in a direction normal to the surface of wing **5**.

The use of adhesive tape to attach border string **4** to lifting surface **5** and tail surface **11**, by applying the tape to only one side of the surface and by creasing it down along both sides of the string to adhere closely around the string, as shown in FIGURES 1, 3, and 4, solves

several problems of long standing in the manufacture of kites employing thin plastic film supported at the edges by string. Suitable plastic films for such kites are mylar and polyethylene, both of which have been difficult to attach in the past. For example, the attachment of string to polyethylene using liquid adhesives is unsatisfactory. The adhesives are not reliable and they often run out of place and spoil the product by discoloration and by sticking the wrong parts together. Heat sealing distorts the film and does not hold the string. Various sorts of coated strings and strings having fibers projecting from them for the purpose of being held between two heat sealed or glued surfaces have been tried. Strings have been held by the use of double coated pressure sensitive tape folded around the string, and with the plastic film fold around the outside, where it was either taped or glued down. This was expensive in materials and labor, requiring the kite assembler to work on both sides of the film, and it did not hold satisfactorily.

These problems were solved by the very simple construction taught in this application. The resulting joint is superior for thin-film string-rigged kites because the load is distributed from the string into the film. There is no rigid mechanical restraint holding the string at any one point, except at terminal reinforcing tapes **14**, the function of which is to keep border string **4** from coming out completely from between the film surface and tape **6**. The construction permits border string **4** to slip sidewardly somewhat at points of maximum stress until an adjacent portion of the string (and of the film to which it is attached) carries as much stress. The border string takes the form of a catenary curve which is highly desirable for uniform distribution of stresses but which could not be put in by even the most elaborate tooling, even if its form could be computed. The tapes and strings are simply assembled in straight lines, and in their first use they take permanent catenary curves. This novel string anchoring construction permits a thinner film to be used, saving weight and cost, and prevents distortion of the film material, improving appearance and flight performance. The string is held at every point because of its intimate contact with the adhesive on the tape and will not slip lengthwise, a result not previously accomplished with complete reliability by any other method. Labor costs of kite assembly dropped markedly when this construction was introduced in production.

A wing warping action is accomplished in this invention by sliding the front end of nose stick **1** sidewardly along border string **4**, as indicated by arrow A in FIGURE 6. This figure is a view of the kite as it would be seen in flight from a position downwind from the kite and somewhat higher, after the front end of the nose stick has been displaced along the border string to the viewer's right. This bows the body stick sidewardly, moving it to the left at the trailing edge of the wing, as indicated by arrow B. Due to this movement, the trailing edge **9** of the wing is pulled taut at C and is slackened at D, points F at four locations being held in place by the structure described above. The wing warping so accomplished lowers the trailing edge of the wing at C, having the effect of a lowered aileron on the right wing, and raises the trailing edge at D, having the effect of a raised aileron on the left wing. As a consequence the kite experiences an aerodynamic rolling moment in the direction of arrow E, lowering the left wing and raising the right wing, and consequently rolling the kite to the left.

Secondary but important effects of this wing warping are as follows: Horizontal tail surface **11** is warped directionally and stabilizer surface **17** on the right wing is made to stand up higher than stabilizer surface **17** on the left wing. These actions produce a yawing moment on the kite in a direction to move the nose of the kite to the right.

The combined action of the primary and secondary effects described above is that of applying "crossed" controls to the kite, as used in an airplane to make its sideslip rather than to make it turn. The secondary action converts the roll of the primary action into a sideslip and the kite simply moves over to the observer's left into a new stabilized position.

Rig adjuster **13** in FIGURE 7 consists of plate **18** in which are mounted three eyelets **19**. One end of string **4** is tied into a terminal loop **20**. The other end of string **4** is threaded in and out through eyelets **19**, through loop **20**, and back through eyelets **19**, each in the opposite direction this time, and through bead **21**. The end of string **4** is knotted so it cannot slip back through bead **21**, and bead **21** is too large to pass through eyelet **19**. String loop **4** is shortened by pulling bead **21** away from loop **20**, and is lengthened by the opposite movement. Plate **18**, when placed in the position shown in FIGURE 7, crimps string **4** and prevents slippage. To permit slippage for adjustment, string **4** is slackened locally at plate **18**.

The effects of using rig adjuster **13** are illustrated in FIGURES 8, 9, and 10, which depict the frontal aspect of the kite as it presents itself to the local wind direction at the wing. In FIGURES 8 and 9 (and in FIGURE 2 above and FIGURE 11 below) the amount of bowing preferably employed in the kite is somewhat exaggerated for clarity.

FIGURE 8 shows a medium amount of bowing of the kite, with rig adjuster **13** a moderate distance from the nearby stabilizer surface **17**. FIGURE 9 shows a larger amount of bowing, with rig adjuster **13** a greater distance from stabilizer **17**, and with the length of border string loop **4** shortened accordingly. FIGURE 10 shows a minimum amount of bowing, with a maximum length of string loop **4**, and with rig adjuster **13** directly adjacent to stabilizer **17**.

A medium adjustment (FIGURE 8) is used for most flying conditions; a heavily bowed adjustment (FIGURE 9) is used for strong gusty winds; and a flat adjustment (FIGURE 10) is used for smooth winds and for aerobatics in gusty winds.

It is apparent from the figures that the aerodynamics drag of the kite is greater as the border string loop is shortened, causing stabilizer surfaces anl leading edge **15** to rise. This produces more force to hold the kite downwind, and absorbs energy which might otherwise impart lateral velocities to the kite.

When rigged as in FIGURE 10 the kite is clean aerodynamically; the frontal area is small and the span is long; the kite is capable of riding rising thermal currents until it seems to be directly overhead, with the flying string slack, and if energized by gusty air and if controlled by properly timed pulls and releases of the flying string the kite can be made to perform complete loops in the air or long dives at the earth with last-second pull-outs.

The action of stabilizers **17** in producing directional stability is due to the rearward outward slope of these surfaces in combination with a relatively forward center of gravity, in an action which could be characterized as "snowplow drag stability." Both stabilizers produce drag. When the kite faces directly into the wind the drag on the two sides is equal. But when the right wing tip moves forward stabilizer **17** on the right side develops more drag than stabilizer **17** on the left side, because the right side faces the wind more nearly squarely and the left side slopes away more. The role of the center of gravity is that the kite rotates around its center of gravity when sharply disturbed by gusty wind, and the position of this dynamic axis of rotation determines whether the moment arms at which the drag forces act are favorable or unfavorable for stability. A relatively forward center of gravity causes the effects of the moment arms to be small, even though the center of gravity may not be sufficiently far forward to produce a stabilizing effect from the changes of moment arms. (It would be necessary for the center of gravity to lie forward of a line connecting

the centers of pressure of stabilizer surfaces **17** for such a stabilizing effect to exist.)

The more sharply the stabilizer surfaces are skewed back and the more rearwardly they are located on a kite, the more rearward may the center of gravity be, in obtaining a given degree of directional stability in gusty wind. But the difficulties arise from pitching stability when the center of gravity is allowed to be rearward, and of course, as described above, it is desirable to achieve directional stability in a kite which has no perceptible sweepback to the casual observer, in order that the kite may have the form of a soaring bird or a subsonic airplane. Such a form has a wing of relatively high aspect ratio. This has the further advantage of having less induced drag than is possible with kites of short span and swept form. The achievement of small induced drag enables the bird-like kite to fly higher and at a steeper angle of elevation, particularly when rigged relatively flat to keep other forms of aerodynamic drag at small values, than is possible with the highly swept short form of wing. The large wing span of the bird-like kite produces still another advantage: the lateral distance between stabilizers **17** is large, so that a relatively small distance of drag on the two opposite stabilizers produces a relatively large stabilizing moment. Consequently stabilizer surfaces **17** may be relatively small in area, and therefore they increase the drag of the kite only a relatively small amount to produce the desired degree of directional stabilization. Some small amount of drag increase is always desirable in any case to avoid excessive sensitivity to wind turbulence.

The disclosed structure of the invention leads inherently to the required relatively forward center of gravity. Body stick **1** extends well forward of lifting surface **5**. Open space exists between leading edge **15** and the front portion of string loop **4**. The forward extension of body stick **1** is long and slender; this reduces weight for a given balancing action as compared to a shorter broader member, and it provides a favorable forward pulling angle enabling border string loop **4** to keep stabilizer surfaces **17** well spread forwardly.

The directional stability action of jib-like stabilizer surfaces **17** is shown in FIGURE 11, which is a drawing in true proportions of the kite rigged as in FIGURE 9 and yawed slightly. The angle of yaw in FIGURE 11 is the same as the angle of flying string **7** as shown in FIGURE 1. It will be seen that the forwardly displaced stabilizer surface **17**, to the readers left, in FIGURE 11, is noticeably larger in frontal area than is the rearwardly displaced stabilizer **17** to the reader's right. Therefore the forward wing tip (to the reader's left) is pushed rearward by air drag more strongly than is the rearward wing tip (to the reader's right). That is, a differential force exists which, if the moment arms on the two sides of the kite were equal, would act to restore the kite toward a position of zero yaw. Whether or not the kite is rotated in the desired stabilizing direction, however, depends upon the relative moment arms at which these tip drag forces act.

In smooth air, in response to very gradually applied forces the kite rotates around pivot axis G in FIGURE 11 which passes through the string tie point; around this axis it may be seen that the moment arm to the outer end of the forward wing tip (at the left) is greater than the moment arm to the outer end of the rearward wing tip (at the right). It is easily understood, then, that static directional stability exists around axis G, under the conditions specified. In sharply gusty air the kite rotates in yaw on pivot H through the center of gravity. Now the moment arms on the two sides are changed by the amount of the separation of axes G and H, in a direction to decrease static stability. The static directional stability of the kite may become marginal if the center of gravity is not sufficiently far forward (if axis H is very much to the left of axis G on FIGURE 11). If the kite did not employ the projection of body stick **1** forward of leading edge **15**, the center of gravity of the kite would be farther rearward and the kite would rotate in gusty air around axis I of FIGURE 11. In this event the moment arm to the forward wing would be shortened and the moment arm to the rearward wing would be lengthened to such a degree that the kite would be unstable directionally in gusty air, despite the greater drag on the forward wing tip. In addition static pitching instability would exist, which, coupling with the yawing instability, would make the kite totally unmanageable in all winds but those which are ideally smooth.

For kite stability it is necessary that the kite have lateral stability, as produced by the dihedral of the wing, and have it in an amount which is in the proper proportion to the kite's directional stability, described above. It is desirable, further, that both these stabilizing effects be strong when needed for the purpose of achieving stability in strong gusty winds, and that they be weak for the opposite purpose of permitting aerobatics to be performed. Furthermore, whether strong or weak, these two forms of stability must remain in proper relative strengths. The desired adjustment of the power of stabilization and the correct balance between the two forms are achieved in this invention, in a very light simple structure. When rig adjuster **13** is used to increase the amount of bowing of the wing as seen from the front, the effective dihedral angle of the kite is increased. At the same time and in approximately the same proportion the tip stabilizers are caused to be raised, increasing their frontal area and increasing directional stability. This one action achieves all the desirable effects described.

Referring again to FIGURE 11, and considering the design of a kite which is able to perform aerobatics, it is necessary to have only a small margin of static directional stability around axis H through the center of gravity, including any contributions to directional stability from the tail surfaces. Then the kite will exhibit a tendency toward instability in gusty air when rigged flat as in FIGURE 10 but will correct itself during brief recurring moments when the air is steady.

In flying the kite when rigged for aerobatics, the tendency toward instability in a gust of wind is increased by a pull on the string. This is especially effective when the kite already has a laterally inclined heading. It gives the kite an impulse toward further deviation, producing greater lateral velocity, greater total airspeed at the kite, and greater structural deflection, all of which decrease stability and lead to stunts. To return to steady flight, the flying string is momentarily allowed to run out. This lowers the relative airspeed at the kite, allows the lateral velocity to decrease, and reduces the structural loads on the kite, all of which increase stability. The kite will resume a normal position right side up, headed into the natural wind, in this invention. When this occurs, the string is held or may be drawn in smoothly and the kite will climb normally, until the kite flier chooses to make it stunt again.

In flying the kite of this invention recovery from stunting maneuvers will often occur naturally because, in descending, the kite will enter wind layers which have been slowed down by the frictional influence of the surface of the earth, producing effects similar to those which may be accomplished by allowing string to run out.

The alternate version of the invention shown in FIGURES 12 and 13 employs details of construction typically like those of the preferred version shown in FIGURE 1, except that a single piece lifting surface replaces the two piece wing and tail, and flaps **22** are used rearward of the rear portion of the border string loop, to produce any desired planform at the wing trailing edge.

The details of the alternate forms of the invention shown in FIGURES 16 through 19 will be apparent to anyone who is well versed in the art of kite construction. These kites have been described earlier in this application.

It is apparent that many other variations of the inven-

tion could be described, for example using aerodynamic slots in the jib-like stabilizers and numerous other such refinements, without departing from the spirit of this invention. Accordingly, the invention is to be limited in scope only as defined in the appended claims.

I claim:

1. A kite comprising a lifting surface, the forward region of said lifting surface comprising a jib-like stabilizer surface of generally triangular form lying in the region immediately forward of a lateral stick member, said lateral stick member sloping rearwardly and outwardly near its outer tip, said stabilizer surface being supported along its rearward edge by said lateral stick member, said stabilizer surface being held spread forwardly by a tension member attached to its outer forward edge, said tension member being attached to the lateral extremity of said lateral stick member and to the forward extremity of a longitudinal stick member, said longitudinal stick member being attached to said lifting surface and extending forward well clear of said jib-like surface and well clear of said lifting surface.

2. A kite comprising a lifting surface having a lateral tip at a lateral extremity thereof, said lifting surface having an upwardly concave form, a longitudinal support member of relatively dense material supporting said lifting surface and extending forward well clear of said lifting surface, and a lateral support member supporting said lifting surface situated rearward of the leading edge of said lifting surface, said lateral support member supporting the region of said lateral tip of said lifting surface, said lateral support member sloping rearwardly and outwardly near its outer tip.

3. A kite comprising two crossed sticks, a border string in tension forming a loop around the ends of said sticks, said border string being attached to said tips and holding said sitcks bent concave upwardly, a lifting surface attached to said border string, the forward portion of the first of said crossed sticks extending forward well clear of said lifting surface, the outer tip of the second of said crossed sticks sloping rearwardly and outwardly, and the leading edge of said lifting surface being situated forward of the second of said crossed sticks.

4. A kite comprising frame members including a longitudinal member and a lateral member, a string attached to one end of said lateral member thence directly to the rearward end of said longitudinal member and thence directly to the other end of said lateral member, a laterally arranged wing surface attached at its lateral ends to said string close to the ends of said lateral frame member and attached in its central region to said longitudinal member, and a trailing edge on said wing surface lying rearward of said lateral member and lying between said string and said longitudinal member, said trailing edge being located at all points well forward of the rearward end of said longitudinal member, leaving an open space of substantial size at the rear of said kite bordered by said trailing edge and by the rearmost portion of said string member.

5. In the kite of claim 4, a tail surface member attached to said string partially filling said open space.

6. A kite comprising frame members including a longitudinal member and a lateral member, said lateral member sloping rearwardly and outwardly near its outer tip, a string attached to one end of said lateral member thence to the forward end of said longitudinal member and thence to the other end of said lateral member, a laterally arranged wing surface attached at its lateral ends to said string close to the ends of said lateral frame member and attached in its central region to said longitudinal member, and a leading edge on said wing surface located at all points well rearward of the forward end of said longitudinal member.

7. A kite comprising lifting surface means which includes all lifting surfaces on the kite, said lifting surface means comprising a lifting surface having lateral tips at opposite lateral extremities thereof, said lifting surface having an upwardly concave form laterally and longitudinally; a narrow longitudinal stick member of relatively stick member of relatively dense material attached longitudinally across said lifting surface and extending forward well clear of said lifting surface and well clear forwardly of the most forward portion of said lifting surface means; and a lateral stick member of upwardly and rearwardly concave form extending laterally across said lifting surface supporting said surface and supporting the regions of said lateral tips of said surface.

8. A kite comprising lifting surface means which includes all lifting surfaces on the kite, said lifting surface means comprising a lifting surface having lateral tips at the laterally outward extremities thereof; a narrow member of relatively dense material supporting said lifting surface and extending forward well clear of said lifting surface and well clear forwardly of the most forward portion of said lifting surface means; said lifting surface having an upwardly concave form laterally and longitudinally, said lifting surface having locally increased concavity of form laterally and longitudinally in the forward region of said lateral tips thereof.

9. A kite comprising lifting surface means which includes all lifting surfaces on the kite, said lifting surface means comprising a lifting surface; a narrow member of relatively dense material attached to said kite and extending forward well clear of said lifting surface and well clear forwardly of the most forward portion of said lifting surface means; and a forwardly-upwardly sloping, rearwardly—outwardly skewed stabilizer surface attached to said lifting surface adjacent to a lateral extremity thereof.

10. In the kite of claim 9, adjustment means attached to said stabilizer surface for adjusting the angle of tilt of said stabilizer surface.

11. A kite comprising lifting surface means which includes all lifting surfaces on the kite, said lifting surface means comprising a lifting surface, said lifting surface having a lateral tip at a laterally outward extremity thereof; a narrow member of relatively dense material attached to said lifting surface extending forward well clear of said lifting surface and well clear forwardly of the most forward portion of said lifting surface means; a leading edge at the forward boundary of said lifting surface, a forward region of said lifting surface adjoining said leading edge, said forward region extending laterally from said narrow member to said lateral tip of said lifting surface, said forward region of said lifting surface sloping forwardly and upwardly.

12. In the kite of claim 11, the outer portion of said forward region of said lifting surface skewing rearwardly and outwardly.

13. A kite comprising lifting surface means which includes all lifting surfaces on the kite, a wing stick and a body stick crossed and attached together, a border string in tension forming a loop encompassing said sticks and attached to the tips thereof, said border string holding said sticks bowed concave upwardly, said lifting surface means comprising a lifting surface, said lifting surface attached to said string loop, said body stick extending forward well clear of said lifting surface and well clear forwardly of the most forward portion of said lifting surface means, and upwardly-forwardly sloping outwardly-rearwardly skewed jib-like stabilizing surfaces adjacent to the lateral tips of said lifting surface.

14. In the kite of claim 13, the midpoint of said wing stick being attached to said body stick at a point relatively more forward than the points of attachment of the tips of said wing sick to said border string, the described attachment of said wing stick holding it concave rearwardly.

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