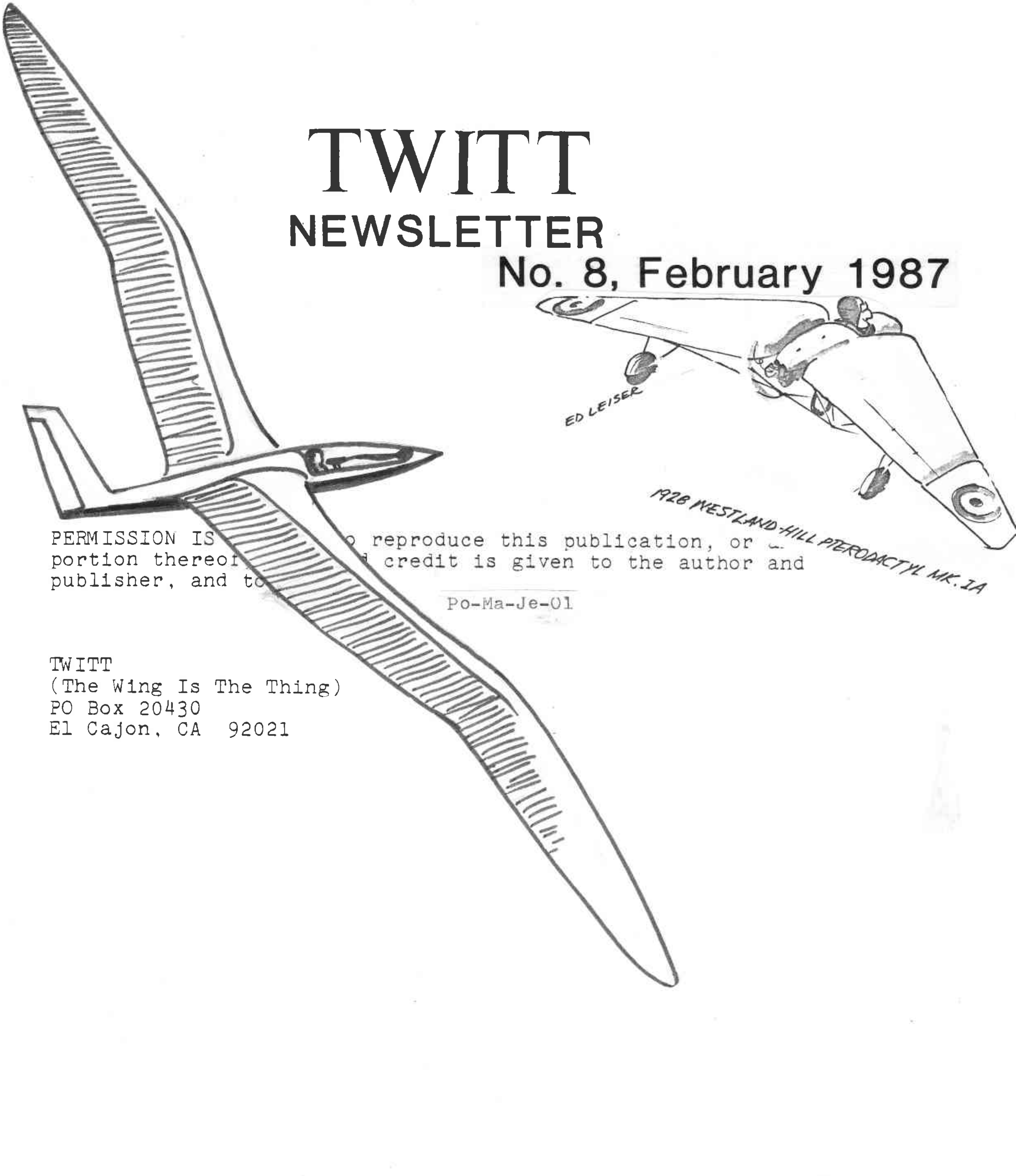
TWITT

NEWSLETTER

No. 8, February 1987



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Po-Ma-Je-01

TWITT
(The Wing Is The Thing)
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MINUTES OF MEETING, 17 JANUARY 1987

The meeting opened a bit awkwardly as the featured speaker, Karl Sanders, had not yet arrived. Bob Fronius solved the problem by coercing those present to stand up, tell the others something about themselves and discuss matters of interest to the group. Your editor cannot reproduce all the fascinating biographical and technical information which thus entered the TWITT dossiers, but two extemporaneous discussions stand out. Floyd Fronius discussed an accident that occurred at Torrey Pines to a Fledgling, a tailless hang-glider, in the hands of an inexperienced and apparently overconfident pilot. According to Floyd, the pilot entered a spin deliberately. On breaking out of the spin, the machine was in a steep dive. Tip flutter developed, followed by the failure of the wing center-section. With his wing panels folded up like those of a butterfly, the pilot wisely resorted to his hand-deployed parachute, which brought machine and pilot to earth with only minor additional damage to both. Asked whether the accident revealed a hitherto-unsuspected flaw in the Fledgling's design, Floyd said that the owner of the machine had warned the pilot not to do aerobatics. Flying has always been afflicted with persons with hypertrophied glands and atrophied brains....

Danny Howell showed your editor a letter he had received from the Akaflieg Braunschweig in response to his earnest and enthusiastic inquiry about the SB-13 tailless sailplane [mentioned in an earlier TWITT newsletter]. Danny plans to go to Germany and see the machine to get the information he needs to complete an article on it. Danny is also designing a [tailless?] hang glider under Fiberite sponsorship.

After the introductions and ad lib discussions, Bob asked Hernan Posnansky to review his concept of an artificially stabilized tailless high-performance sailplane. Several questions punctuated his discussion. Q: Why was construction proceeding in advance of detail design? A: Key factor was the availability of Harald Buettner to do the work of "pulling" a female mold from the Diamant wing which we're using as the pattern for the TWITT machine's outer wing panels. The TWITT machine will, however, have wider-chord control surfaces than the 17% deep Diamant flaps. Q: What is the range of sweep angle? A: Seven degrees, adjusted by a hand-cranked leadscrew mechanism acting on the wing auxilliary spar. Q: What are TWITT's goals in building this sailplane? A: To achieve the high speed range typical of tailed gliders, but with a tailless machine. Q: What performance is required of the servomechanisms? A: It must be fast, which dictates an hydraulic system with an accumulator rather than electric servos. Key component is the control valve, which must have a 15-20 Hz response. The pump will be electric. Q: What engine will be used in the powered version? A: Not selected yet; power required is about 40 hp. We will build two center sections: one for power and one for the sailplane version. In response to another question, Hernan reviewed the reason for a slightly swept-forward configuration: allows wing attach point behind pilot, giving good field of vision; small sweep angle produces minimal lifting-line interference; when swept back slightly from the forward, unstable position, the 'plane becomes statically stable with adequate pitch damping. Q: Isn't the vertical tail volume too small? A: We'll just have to make the tail surface quite large and/or add artificial damping in yaw. Forward sweep gives directional instability at small angles of attack, but stabilizes at large angles. The biggest perturbation on entering a gust comes from the fuselage. The absence of a tail is an advantage in this situation!

A break ensued, during which Karl Sanders and John Krause arrived with Phil Burgers. After the break, Karl gave a talk on flying-wing aerodynamics consisting mainly of a review of Al Backstrom's paper published previously in this Letter. In Karl's opinion, the figures illustrating the lift distribution on forward and aft swept wings were switched in the article. He discussed the interaction of structural and aerodynamic properties of fore- and aft-swept wings, noting that a forward-swept wing is divergent unless special precautions are taken in structural design. He also noted that both fore and aft sweep decrease the slope of the lift curve. John discussed the problem of installing high-lift devices in an all-wing airplane. Marc de Piolenc mentioned extensive NACA work on that problem in the forties which culminated in a series of flap designs for mildly aft-swept wings which gave zero pitching moment increment and a moderate increase in maximum lift. The meeting then dissolved into small discussion groups and your Editor rested his hand.

A SUMMARY OF HENRY JEX' TALK AT THE LOS ANGELES AIAA MEETING

(contributed by Phillip Burgers)

On Wednesday 14 January Bob, June, Ed, Hernan and myself drove to Los Angeles to attend a very interesting meeting of the AIAA. The featured speaker: Henry Jex..., the subject: stability and control of a flapping scale model of the Quetzacoatlus Northropi, better known as the pterodactyl, a giant flying reptile that lived some 65 million years ago. By remarkable good fortune, a few of its fossilized bones, which provide clues to its size and appearance, have survived and been found. These clues suggest that the creature had a wingspan of 36 feet, making it the largest natural flyer known. Henry showed us some movies: there we could see the whole team, directed by Paul McCready, working in the workshop and at the field during the first flight tests. During takeoff, the bird was winched into the sky and sported an auxilliary boom attached to its tail to give it some static stability (the real bird was unstable on all three axes and relied on active control to stay in the air, just as modern birds do.). Once the bird was flying under radio control, this tail would be jettisoned. The feat was so difficult that a definition of a successful flight is in order: this would occur if and only if "the auxilliary tail would hit the ground before the bird did." When the break was over, after the movies, Henry gave us some details of the technical lessons learned from the project. After the meeting, those who attended the meeting could be divided into two groups: those who didn't understand those Bode viewgraphs that he showed and those who still could not pronounce Quetzacoatlus Northropi...

4- ELEMENTS OF THE ACTIVE PITCH STABILIZATION SYSTEM

The primary elements of the stabilization system are:

a) pitch ATTITUDE sensor

b) electronic controller

c) control surface actuator

d) pitch command input device

e) power source for the actuator and other elements

Other secondary elements are also required depending on the particular mechanization.
A number of configurations are possible. For various reasons not fully discussed here, the author has chosen a few for possible implementation.
Costs constraints eliminate a fully redundant system. The need to maintain flight safety in the event of a failure is still the driving constraint that determines the design choices:

The attitude sensor is a vertical gyro which generates both a roll and a pitch angle signal (the roll angle signal is not used) from gimbal mounted low noise plastic potentiometers.

The pitch command is derived from a low noise potentiometer mounted on a command lever.

The electronic control processor takes the pitch command and compares it with the gyro pitch angle signal and processes the resulting error signal to a flap angle command signal, in turn routed to a control surface servo actuator. The control surface actuator could be implemented with an electric motor (part I) or with an electrohydraulic servo system as presented in Figures 6 and 7.

5- CONTROLLER DESIGN CONSIDERATIONS

Using flaps for pitch control makes it unavoidable that in addition to producing a pitch moment, the flaps also strongly affect lift. Flap motion can excite flexible modes (bending and torsion) of the wing if the flap motion frequency is close to a flexible mode resonant frequency. Since the sailplane uses variable wing sweep, wing bending vibrations will also produce pitch perturbations at all but one sweep angle. These are sensed by the gyro and acted on by the controller which in turn commands flap motions at the bending mode frequency. Depending on the phase angle, the bending vibrations may be amplified or attenuated. A bending mode filter is used by the contoller to avoid any resulting control system induced instability. (A similar pilot induced instability was encountered by the Voyager aircraft).
Symmetric wing torsional modes are also present and are controlled in a similar way. Flutter results from aerodynamic-inertial coupling of torsional (wing or flap) flexible modes with wing bending. In principle, certain symmetric flutter modes could be controlled with somewhat modified versions of this system, (addition of sensors).

Large aspect ratio wings are flexible (much more so than a low aspect ratio airplane). The flexible characteristics can, within limits, be chosen by structural design of the wing. Because of the control system, flexible wing interactions mentioned earlier, it is advantageous to pursue an integrated design aproach for the actively stabilised aircraft. This requires an analytical approach using adequate computer models.

6- ACTUATOR CHARACTERISTICS

It seems clear that the most critical design decision concerns the selection of the actuator mechanism. In a broad sense this system (Figure 6) consist of

a) the pitch control flap

b) the linkage to the servo actuator

c) the servo actuator loops: servo valve amplifier, shielded electical cable to the valve, electrohydraulic valve, hydraulic cylinder, position feedback sensor and cable; and

c) the hydraulic power unit consisting of: a motor driven pump, check valve, hydraulic accumulator, pressure and return lines, storage tank, filter and pressure control elements.

Why not avoid all hydraulics and use the electric motor directly to drive the flaps ?
The answer is that an electric motor actuator's response is too slow, considering that reasonably sized electric motors must be geared down to provide the nessary torque to drive the flaps against the aerodynamic hinge torques. The motor time constant is proportional to the product of the rotor moment of inertia and the square of the gear reduction ratio. A small actuator time constant is absolutely essential for control loops stability.
For the hidraulic power unit, the motor driving the pump must generate only the average power. The much larger peak power requirements are available from the energy stored in the hidraulic accumulator.

7- FAILURE MODE CONSIDERATIONS

The automatic stabilization system discussed here is not a full-time system. During critical phases of flight the system is disabled and disconnected. This is also the case during a system malfunction. During these phases the sailplane wing is swept back to the stable position where the AC is behind the CG. The primary concern is the transition process after a failure. the worst case failure is a malfunction in a rapid hardover excursion of the hidsraulic cylinder. The linkage configuration depicted in Figure 8 prevents a pitch over condition (but not a pitchup). Ideally, a system failure should result ,in at most, a gradual degradation of the system to give the pilot time to reconfigure to a stable configuration. When possible, the electronics will be configured with that goal in mind.

The pilot can disable the servo actuator at any time by opening a switch which releases a solenoid dump valve and removes the rigid connection between the hidraulic cylinder and the flap, by depressurizing a collapsing link as shown in Figure 8.

8- OPERATION

When the system is operating, the command input lever commands the desired pitch attitude; the control system will continuosly position the "flap-elevators" to maintain that attitude within prescribed limits of the average flap position. The average flap position is determined by pitch trim requirements (pitch moment sum of all contributions due to CG shift, flap moment and wing moment, etc, equals zero). The pilot selects the wing sweep angle by manually cranking the wing sweep mechanism; together with the pitch attitude input, the control system will reach a corresponding average flap angle continuosly modulating the flap about this value in response to pitch moment perturbations. This value is also displayed to the pilot.
Flight speed is therefore controlled by pitch attitude and flap angle by wing sweep (or weight shift).
As shown in Figure 9, for each speed (indicated airspeed [IAS] to be more precise), there is an optimum flap angle. At higher speeds the optimum flap angle is negative and the wing configuration is passively stable and the use of the active system must be always be disabled above maneuvering speed.
The greatest performance improvement that the active stabilization system offers, occurs at the low speed end, where, with large flap angles, high lift coefficients can safely be achieved, allowing the sailplane to approach the theoretical minimum sinking speed (again see Figure 9).
In turbulent conditions (circling in thermals) the system permits the pilot to precisely control the airplane, reducing his workload accordingly.

9- SUMMARY

Active stabilization of a tailless high performance sailplane is not only feasible but offers substancial performance benefits over a basically stable flying wing specially at low airspeeds. Its implementation is straightfoward but not so simple. High demands are placed on the individual components.
An integrated design approach, where the airframe and the control system are designed as a system, is indicated for wich access to a computer and control system synthesis and analysis software is a must. The components of the system must be tested gradually and as a complete system on a conventional aircraft before installation on a tailless sailplane.

Hernan Posnansky

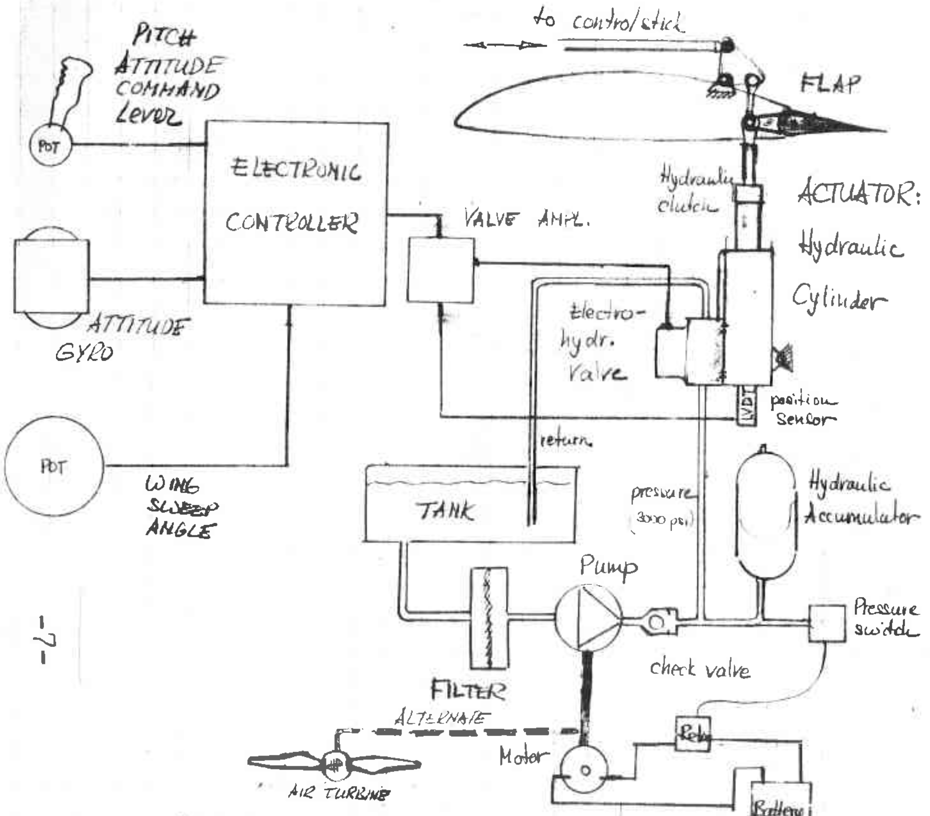


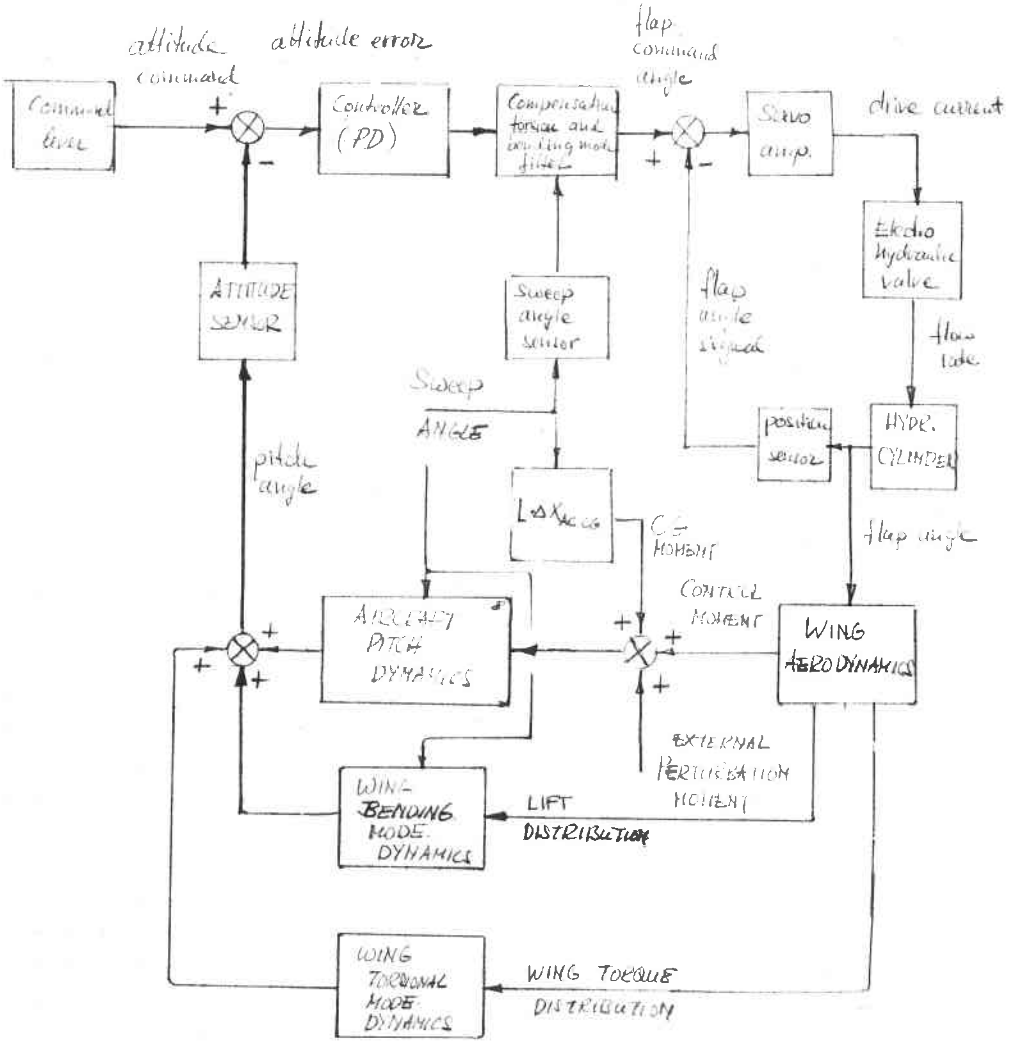
Figure 6

SIMPLIFIED SCHEMATIC
FOR AN ELECTRO HYDRAULIC STABILIZATION SYSTEM

Cover, a design by Posnansky, MacCready,
Jex and Oldershaw- Po-Ma-Je-Ol TWITT

Figure 7

STABILIZATION SYSTEM
SIGNAL BLOCK DIAGRAM



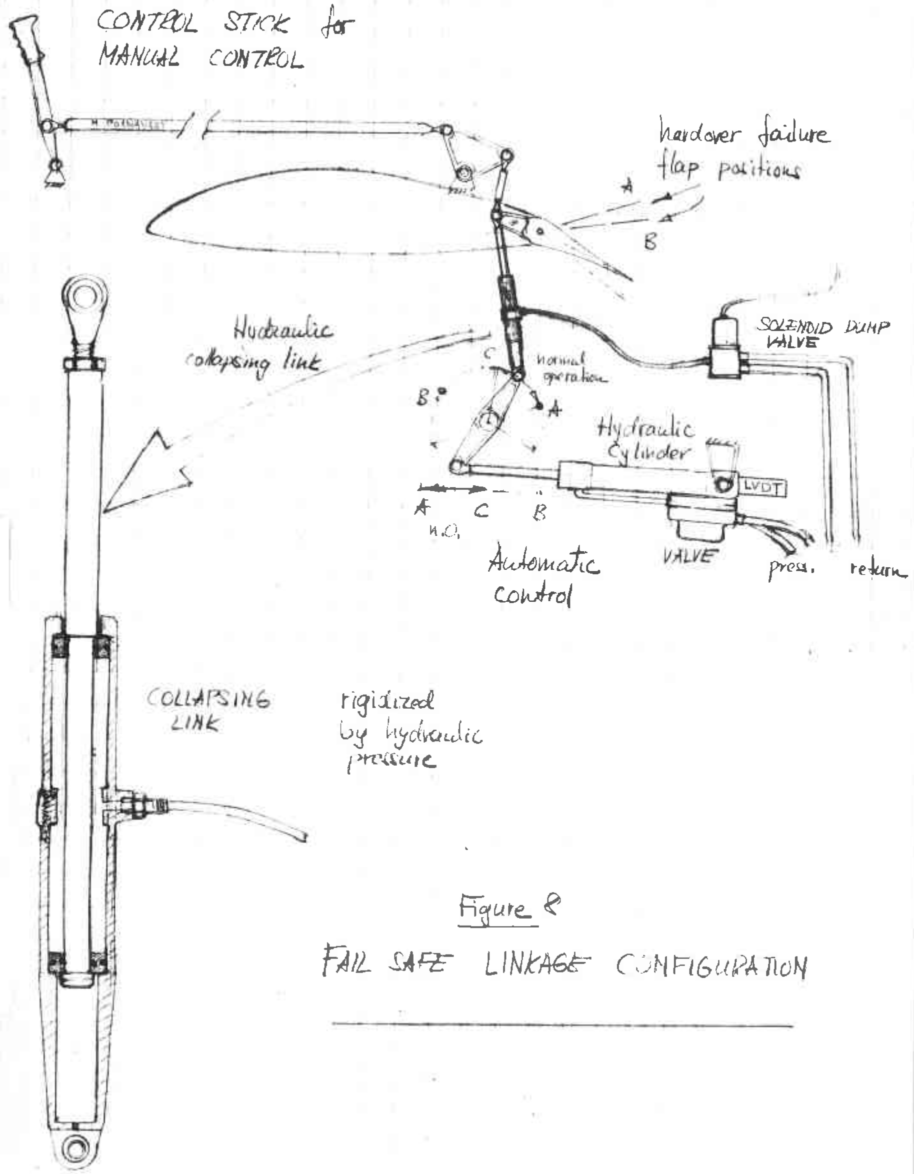
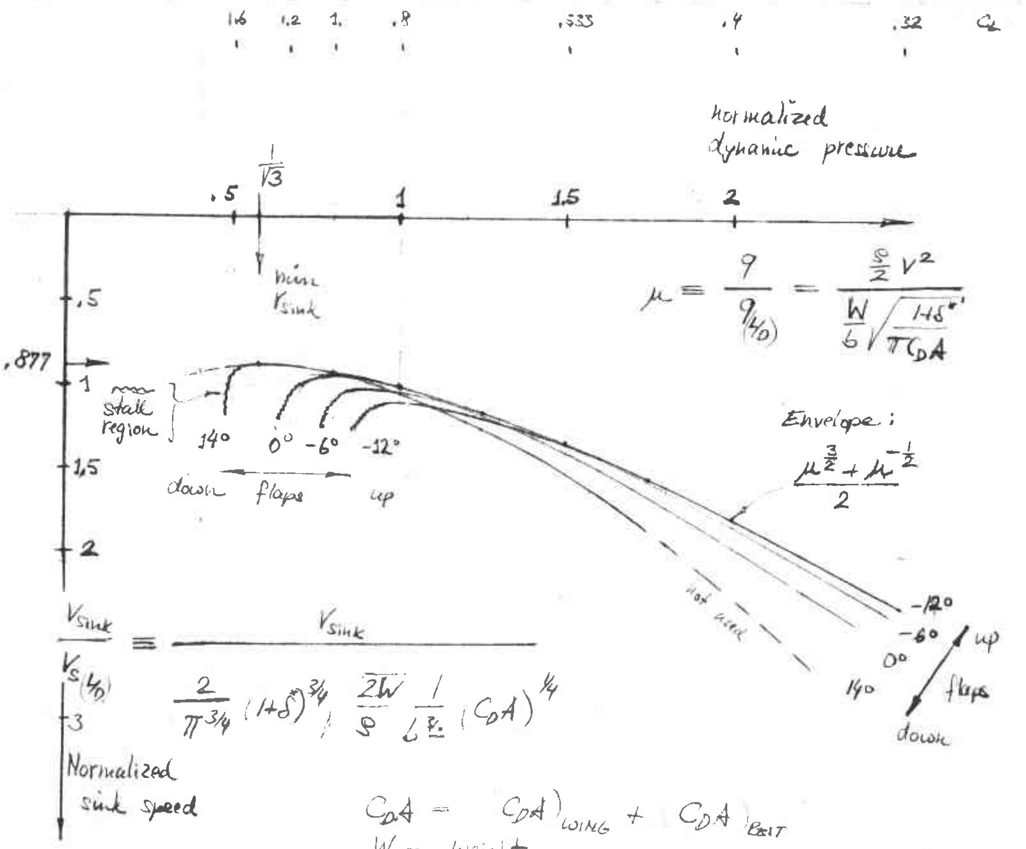


Figure 8

FAIL SAFE LINKAGE CONFIGURATION



$$\mu \equiv \frac{q}{q_{(4/D)}} = \frac{\frac{\rho}{2} V^2}{\frac{W}{b}\sqrt{\frac{1+\delta^{*}}{\pi C_D A}}}$$

Envelope : $\frac{\mu^{\frac{3}{2}} + \mu^{-\frac{1}{2}}}{2}$

$$\frac{V_{sink}}{V_{S(4/D)}} \equiv \frac{V_{sink}}{\frac{2}{\pi^{3/4}}(1+\delta)^{3/4}\sqrt{\frac{2W}{\rho}}\frac{1}{b^{3/2}}(C_DA)^{1/4}}$$

$C_DA = \left.C_DA\right)_{WING} + \left.C_DA\right)_{BAIT}$

$W =$ weight

$$\frac{V_{sink\ min}}{V_{sink\ (4/D)}} = 0{,}877 \qquad \frac{q_{V_{sink\ min}}}{q_{(4D}} = 0{,}577 \qquad \frac{V_{V_{sink\ min}}}{V_{4/D}} = 0{,}761$$

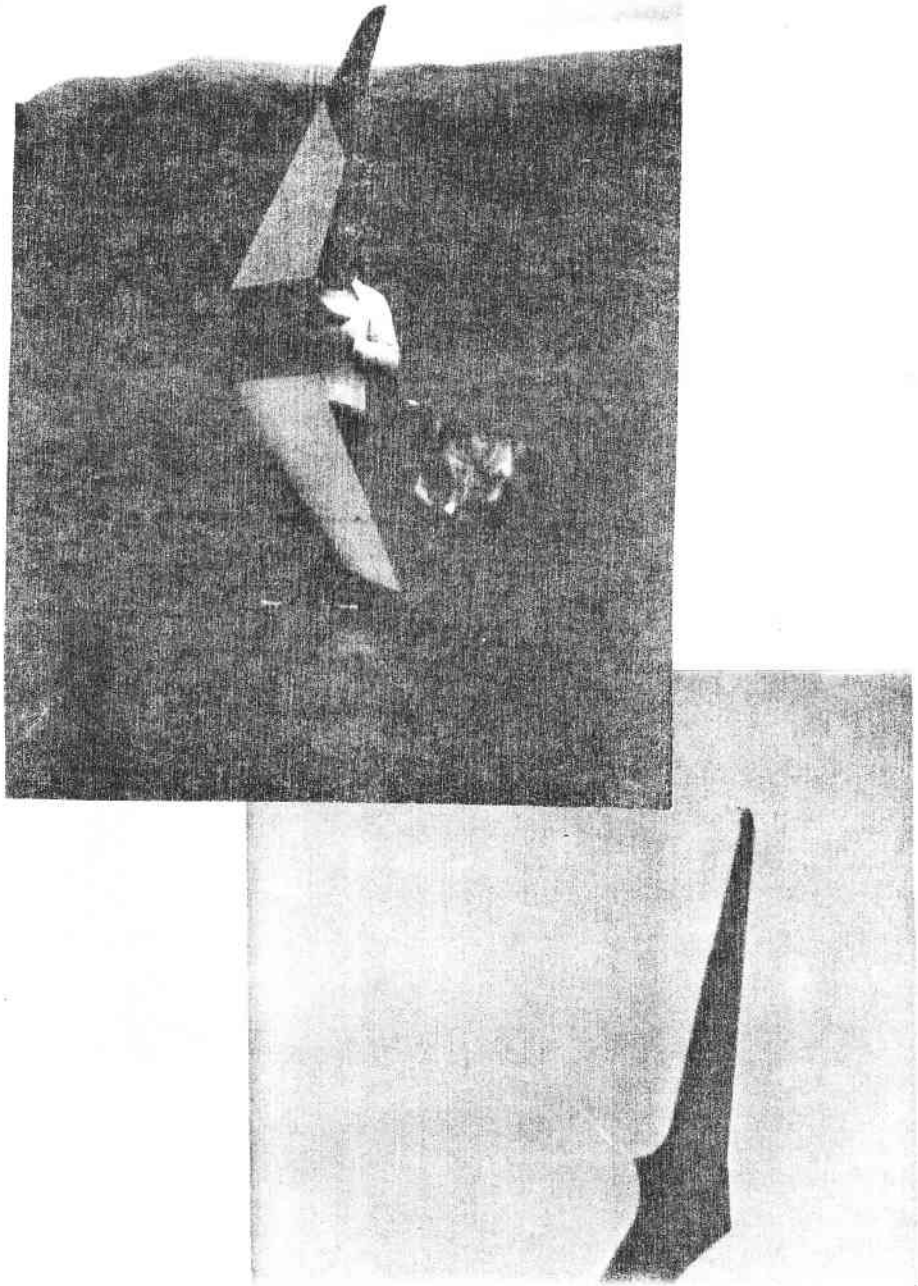
$q = (\text{const}) \cdot \text{IAS})^2$

SAILPLANE SINKING SPEED (non turning flight):

as a function of dynamic pressure and flap angle

Figure 9

Horten IV by Klaus Sauve



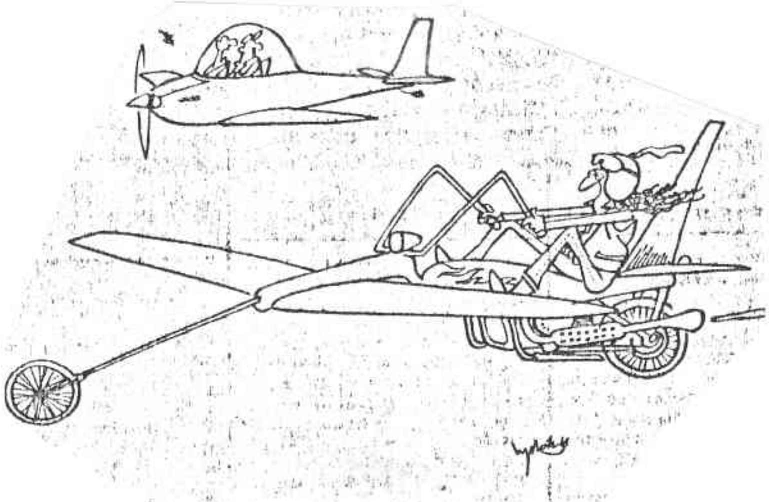
HENRY JEX

Henry Jex is one of a number of brilliant model airplane building aeronautical engineering students from MIT who became involved with soaring flight and light airplanes while building outstanding careers in aeronautics. Henry's specialty lies in the field of stability and control, in which he has done original work and explored new regions. His work on man-powered aircraft, and more recently on the scale model pterodactyl conceived by Paul McCready, are outstanding examples of scientific endeavor requiring that the researcher examine new problems with both imagination and discipline. PS: Henry is also a very nice human being. [Editor's note: this confirms my suspicion that he is not a tunafish sandwich or a convertible sofa.] On February 14th he will be our featured speaker! Henry' work has enriched the field of aeronautics; at our next meeting he will enrich all of us with his experience.

FRANCISCO

(contributed by Monica Burgers, with Phil's help)

Francisco Burgers, uncontestably the youngest TWITT, was born 26 January 1987. He arrived weighing 8.5 pounds dry. Max. gross has not yet been determined. Mother and child are in good shape; Phil is another matter.



"It was bound to happen..."

"I can tell you what I'd drop in his hand if he asked ME for a flight plan."

Always listen to experts, they will tell you what can't be done and why. Then do it.