CALIBRATING SAILPLANE PERFORMANCE USING GROUND-BASED DATUM FEATURES, A PROPOSAL

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SUMMARY

The Fairchild Flight Analyzer is a stationary, ground-based camera which records 58 spaced images of a tracked aircraft on a glass slide of 22.8 cm width (9 inches). It has a 15.24 cm (6 inch) Metrogon Reconnaissance lens with a field of view of 93°. One fixed background is recorded. The time of every spaced exposure is shown on each image with an accuracy of one millisecond.

For sailplane calibration the background should include features that define the length of the surveyed course above which the glider flies and to provide a true horizontal reference.

By using a Mann Comparator to measure the altitude lost as shown on the glass slide and comparing this to the indicated length of the course, the L/D ratio for each constant speed run can be found. The glider's ground speed is found by course length divided by elapsed time.

In the glider, a sepalate camela records the airspeed to establish how steadily it indicates during each test run. By conducting the tests in fair weather, near dawn, and using devices to record ambient air movement it should be possible to obtain results which are accurate and which become permanent records.

INTRODUCTION

As the performance of sailplanes has approached a glide slope of less than one degree below the horizontal, the influence of very minor convection in the atmosphere, errors of airspeed calibration, timing of altitude loss and accuracy of altimeters becomes a larger part of the effort to discriminate between sailplanes.

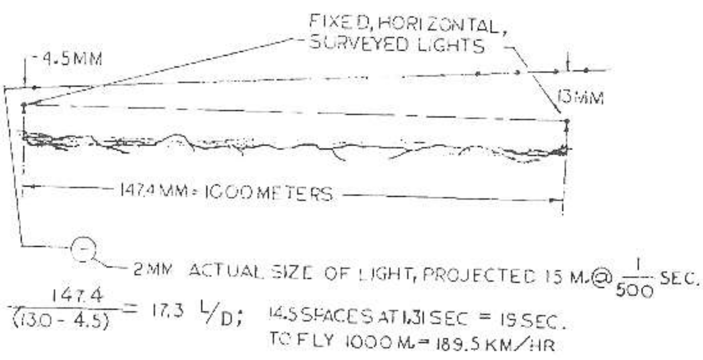

FIGURE 1. (Abstract) path of glider on film.

Consider a situation where sailplane A has an L/D = 60 and B an L/D = 100. The difference in points of L/D is 40. The reduction in angle below the horizontal is just 22.8 minutes of arc. To discriminate between L/Ds of 60 and 61 becomes a daunting challenge, especially if some of the cumulative aspects of the present techniques of measurement are considered: accuracy of time measure by stopwatch, accuracy and constancy of airspeed, which is the L factor of L/D. Accuracy of sink rate (stopwatch and altimeter, plus observation errors) which are the D factor of L/D.

The desired alternative would be to conduct the performance trials under conditions where these kinds of cumulative errors are compensated for or minimized, the costs of operation are not significantly increased and each of the factors can be recorded in detail as a permanent record. While the methods to accomplish these tasks, which will be described in this paper, have not been reduced to practice they do not offer any unusual problems nor call for miracles to perform.

The least controllable anomaly in any flight method is atmospheric convection. This can be mitigated by conducting the trials near dawn in fair weather with very sensitive quantitative indicators to permit corrections to be applied to the data. There must also be thermometers to sample local air temperatures, ensuring a stable lapse rate. If the data obtained are made near the surface, but avoid ground effect, the atmosphere can be closely monitored. In effect, the performance should no longer be measured primarily by airborne instruments but by a ground-based specialized camera.

DEVELOPING THE METHOD

The development of this paper was initiated by a natural event, not by the technical analyses which are inferred in the previous introductory paragraphs. Those thoughts came later. Instead, about a year ago...

I dreamt that a sailplane, in which there was a bright light, flew across the field of view of a fixed, open-shutter, ground-based camera. Also in view of the camera was a horizontal laser beam. Even in my sleep I was aware that the angle of the light streak image that the sailplane would leave on the film, when compared to the horizontal laser datum would give the measure of its glide ratio in still air conditions for that one air speed run.

Some months later I examined the idea and evaluated parameters to be considered to make that mid-summer's night dream a valid method to permit the accurate construction of the sailplane's polar performance curve. This resulted in a brief paper, Calibrating Sailplane Performance Using Ground- Based Datum Features—A Proposal.[1] I sought the advice of persons whom I respect as to what to do with the effort, including Joseph Gera, a specialist in flight control at Dryden Flight Test Center, Bruce Carmichael and T. E. (Ted) Sharp among others, all of whom were helpful and encouraging.

Mr. Gera urged me to submit the idea to OSTIV and questioned if the optics would be accurate enough to discriminate between glide ratios of 60 and 61, which I had assumed was possible. I could not answer that optics question, but I did submit that abstract to Dipl. Engr. Winfried Feifel and to OSTIV.

Bruce Carmichael sent me a paper dated 1954 by Gilbert Hoffman of Mississippi State College[2] in which Hoffman described a model glider carrying a light and being photographed intermittently on one film as it flew in a darkened auditorium in front of a camera. This used much the same system that I had described in my abstract/proposal. I then sent a copy of that (Hoffman) paper to Mr. Feifel and to the OSTIV Secretariat.

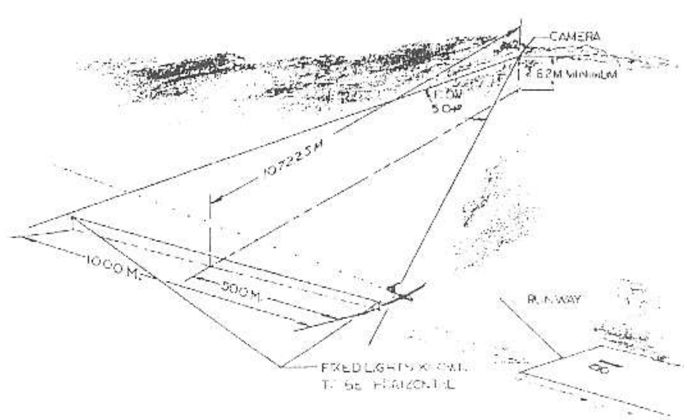

FIGURE 2. Course for a 50° F.O.V. camera (abstract).

It was Ted Sharp who put me in touch with an expert in Electro-Optics, Mr. Robert Woltz, who soon had a copy of my abstract and whose assistance to me forms the main focus of this paper, for which I am deeply in his debt.

Figures which illustrated my preliminary paper follow:

Figure 1 represents a print made from the film in the ground-based camera, essentially as I saw it in my "inspired dream."

Figure 2 is a sketch of an imaginary test flight of the sort that would produce an image as shown in Figure 1. The time of day is dawn to minimize convection and winds. The camera faces west, so that it looks "down-sun."

Figure 3 is a schematic sketch of a proposed intervalometer which illustrates a crude mechanism to ensure that the successive exposures do not unduly overexpose and thus obscure the earlier light-carrying sailplane images of Figure 1.

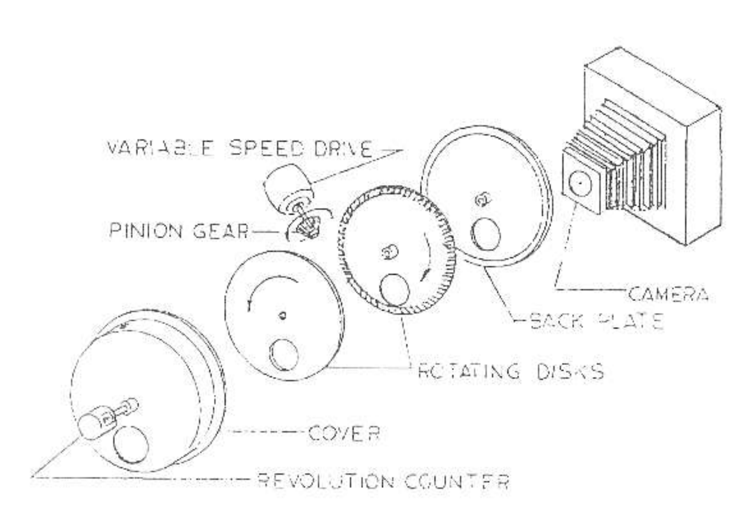

FIGURE 3. (Abstract) intervalometer (schematic).

To enlarge the detailed features to be measured from the camera's glass slide negative that holds the images of Figure 1, I proposed that the slide be projected onto a screen at about the distance of 15 meters (50 feet) and, in Figure 4 as indicated by the somewhat overlapping images, the sailplane in the rear location, with L/D = 61, is 4 mm above that with L/D = 60 at the end of the course.

The accuracy of lenses in cameras and in projectors was a question in my mind as well as in Mr. Gera's mind. It was then that Mr. Woltz came to my rescue. He wrote me that he knew of the Flight Analyzer made by Fairchild and even learned where to find one! In that same letter to me he also described the Mann Comparator which can resolve detail to about one micron. Later, I received information on the Flight Analyzer.[3]

Before describing the Fairchild photographic instrument, it is appropriate to review the size of the stage on which the action is presumed to take place and to consider the velocities and, therefore, the time required for each trial, as well as other- parameters, to ensure that the calibration will reflect reality.

As shown in Figures 1 and 2, the surveyed course was chosen to be 1 kilometer (3280 feet or 0.621 miles) in length, with fixed lights on posts marking the start and the end of the course line. These two end of course lights are also known to establish the horizontal datum.

To avoid ground effect, the sailplane, of assumed span of 28 meters (90 feet) will be at least that far but not significantly higher, above terrain at the low point of its several constant air speed runs.

These speeds may range from 50 km/hr (31 mph) to 100 km/hr, approximately, at L/D max. and to 200 km/hr, at the upper part of the test range of airspeed.

The L/D range, presently would be close to 60:1, maximum and 15:1 at high speed.

At L/D maximum of 60 the altitude loss in 1 km is 16.67 meters (54.67 feet); at 15:1 it is 66.67 meters (218.67 feet).

If the vertical and horizontal path of the sailplane is parallel to the plate in the Fairchild camera, no error of parallax is introduced when the camera is at ground level, as opposed to the sketch of Figure 2.

The times to traverse the course by the sailplane are: for 50 km/hr, 72 seconds; at 100 km/hr, 36 seconds; at 200 km/hr, 18 seconds.

So far, the numbers are quite reasonable. The first significant difficulty appears when one essays to fly the course at constant speed. Mr. Gera writes that he finds it possible to hold air speed to ± 1 knot, a little less than ± 2 km/hr, which may not be sufficient to achieve the desired constant speed performance accuracy. Of the various factors that can affect a ± 1 knot range, one is lag in the static and total pressure ducting to the instrument, where the lag on the static side is likely to be a multiple of lag in the total pressure duct. I suspect that this unbalanced lag is a candidate factor in the ± 1 knot variation in airspeed noted by Gera, as it would be difficult to "chase the needle"

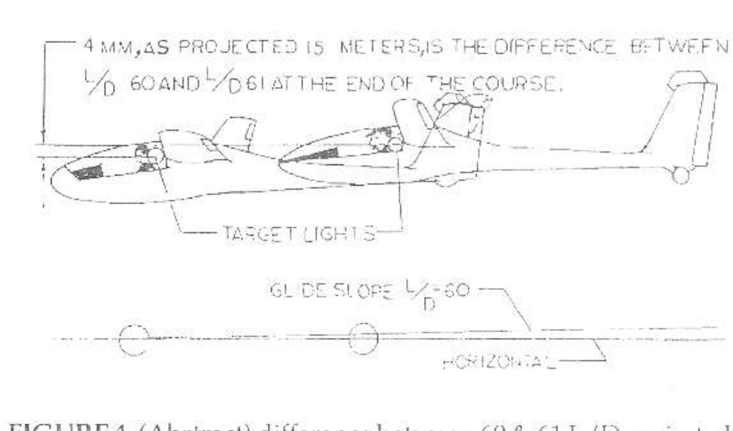

FIGURE 4. (Abstract) difference between 60 & 61 L/D projected 15 M (50 ft).

of the airspeed indicator when the lag of the static source does not match that of the total pressure. If the lags are equally matched, the ability of settling onto the desired test speed is quicker and simpler.

In the event that there is a problem with holding the control stick steady, it might be possible to use a gyroscopic device on the control.

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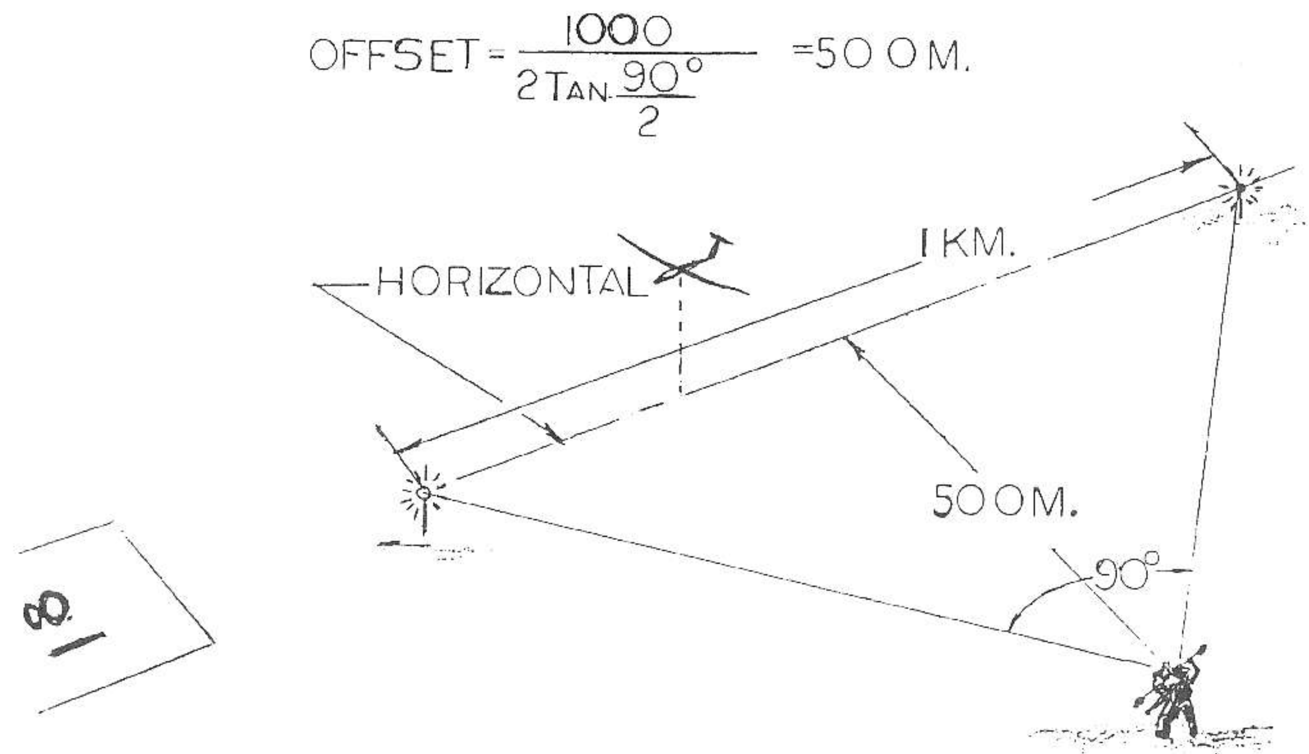

FIGURE 5. Schematic of calibration course.

binoculars and hand-held cameras. Note that the airspeed indicator needs primarily to show that the airspeed has been constant, not necessarily accurate, for the duration of each run. Friction and "stiction" is necessarily eliminated by continuous use of a vibrator on the panel. But, whatever the method used to improve airspeed constancy, an analysis of the Fairchild camera images with respect to the time indications will prove the ground-speed, point-to-point.

The technique for achieving the speed for the test run will probably require the glider being held below the target speed (for the test run) while at a considerable distance before one enters the course. He, or she, will gently increase airspeed until the approximate desired value is accurately and steadily held on the instrument.

Depending on the terrain in the vicinity of the airport near where the L/D to airspeed trials will take place, the location of the Fairchild Flight Analyzer is determined by the terrain at which this camera system can be located. The center line of the camera field of view should be horizontal and normal to the surveyed course and at its midpoint. The 1 km course length is assumed to be nominal. Objective lens of the camera should be about 500 meters (1640 feet) distance from the surveyed 1 km course line. The formulae for the location of the camera from the course is shown in Figure 5, which assumes 90° field of view.

To ensure that the operations are properly recorded, a select crew on the ground near the test course is required. One of those persons, located somewhat beyond, but in line with the start of or end of the course, should be equipped with a suitable video camera so that he can record and so verify that the sailplane flew directly above the 1 km line (within tolerances). He would simultaneously record the actions of tethered balloons or whatever features along the course were indicating air movement during the run.

In view of the fact that all but the highest speed operations would take place without the need to start each test run on the course at altitudes above 300 meters (1000 feet), it is important that the last element of the test course be close to, at, or on the designated (and, if required, illuminated) runway. Further, it may be useful and economical to accomplish the multiple launches of the sailplane by winch. This low altitude range for tests also has the minor advantage of reducing corrections to data.

DESCRIPTIVE DETAILS[3] OF THE FAIRCHILD FLIGHT ANALYZER, MODEL FDFA-044

The Fairchild Flight Analyzer is a camera with a fixed glass plate (slide) which has a horizontal dimension of 22 cm (9 inches) at the focal (film) plane. The lens is a Metrogon Reconnaissance type with a focal length of 152.4 mm (6 inches). The lens and the glass slide are fixed. Field of view is 93.°

Immediately in front of the glass slide is an opaque curtain in which there is a vertical slot. The curtain moves across the glass plate, driven by a tracking eyepiece that rotates on a vertical axis mounted above the camera. The eyepiece is binocular. To ensure its smooth operation while tracking aircraft, the handles are considerably extended and are fitted with heavy lead weights at their extremities. Holding the aircraft in the crosshairs is not difficult.

Located immediately in front of the slot in the opaque curtain are shutters which expose the sensitized glass slide at intervals equal to the width of the slot.

The resulting record is a true, undistorted graph of the observed flight path at a constant scale showing the tracked aircraft position against a fixed background and the relative time as shown by Figure 6.

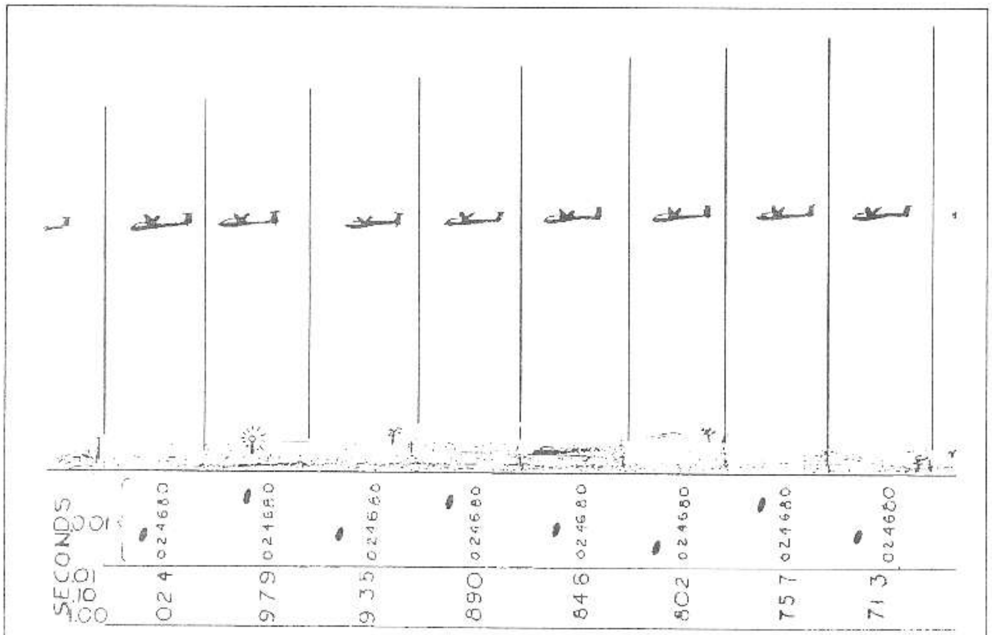

FIGURE 6. Section of Fairchild Flight Analyzer Slide.

Because the equipment was designed to be used in locations distant from conventional electrical power sources, it is provided with a power pack of six batteries of 6 volts each. It requires no elaborate timing cable hook-up and can be easily adapted to record compatible master time. It has its own battery powered precise timer.

The trigger action of the oscillating shutter is automatic. When the traversing movement equals the width of the exposed strip (slot in the curtain) of 3.93 mm (this can be altered by slight design changes) an instantaneous contact is made with a solenoid to activate the shutter. At the same time, a timing device attached to the tracking mechanism is put in line with the strip to be exposed so that time image is projected onto the base of the strip of exposed film plate through an auxiliary lens. The time of exposure is 1/5000 second for the time only and 1/2500 second for the tracked aircraft. This is accomplished by using a dual speed shutter exactly synchronized, electrically driven.

Determining the scale of the record uses the geometric relation between the distance of the flight analyzer from the surveyed course and the focal length of the lens. If the distance is 500 meters (1640 feet) and the focal length is 152.4 mm, the scale is 152.4/500,000 = 1/3281. A sailplane with a fuselage length of 8 meters would appear as 2.44 mm on the 3.93 mm slide element.

Each analyzer is supplied with two certificates certifying its lens performance. The exact focal length is stamped onto the nameplate; accordingly, lenses are not interchangeable. This attention to detail permits calibrations accurate to 0.005 mm (0.0002 inch). Figure 6 illustrates a typical section of an imagined sailplane being tracked as registered on the glass plate slide. In reading the time, the first digit is seconds, the second is tenths of a second, the third is 1/100ths of a second and the blip (above) is thousandths. The light marking the end of the course and establishing the horizontal reference is shown.

Figure 7 shows offset distances, in hundreds of feet, with F.O.V. = 70° for various horizontal and vertical locations for model IV, FDFA-044 or FDFB-041. The full-size scene

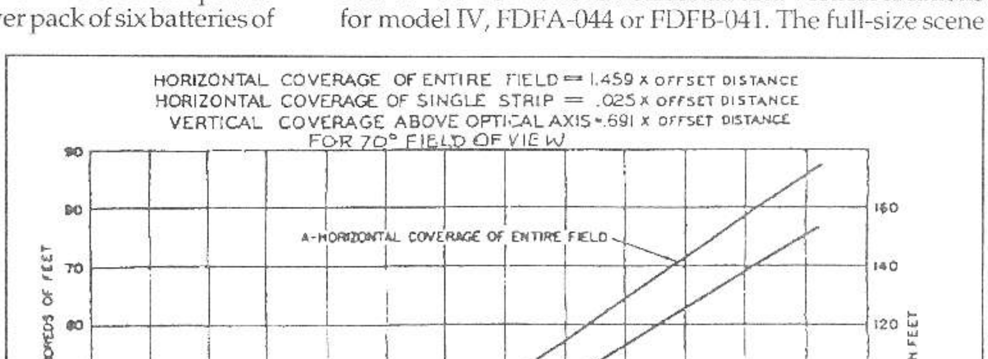

FIGURE 7. Vertical and horizontal distances recorded at varying offset distances, models FDFA-044 or FDFB-041, 70° field of view.

width photographed by a single optical frame at 500 meters (right edge) is in feet.

It is possible to correlate, point-by-point, the instrument readings of the sailplane's instrument panel by a radio link between the aircraft and the output pulse of the flight analyzer. In this way total lag can be determined in the airborne instruments. More importantly, this camera can, by sighting on a horizon or equivalent reference point or datum, establish any change of pitch, roll or yaw, during the run down the course. Such a camera is in the possession of Robert Woltz Associates. Figure 8 compares the Fairchild Flight Analyzer with a cinetheodolite.

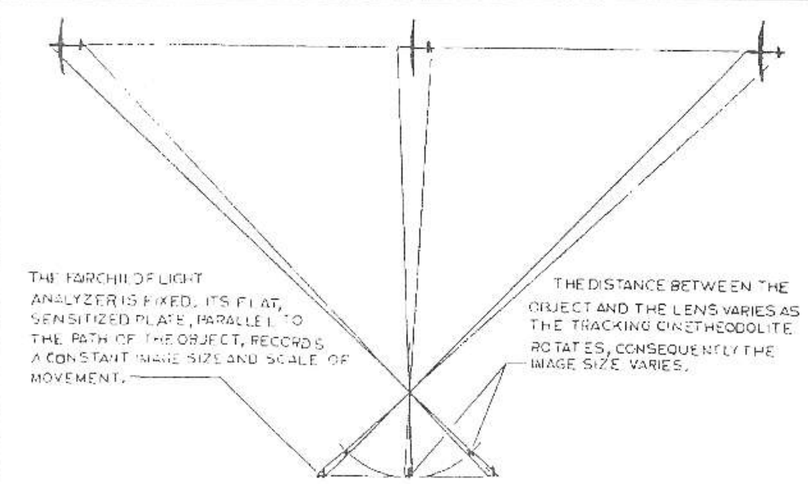

FIGURE 8. Comparison of Fairchild Flight Analyzer and Cinetheodolite images.

Mr. Woltz informs me that a flight analyzer (surplus) in an "as is condition" would cost on the order of $5,000.00. It could be made available for checkout and needed refurbishing in about two weeks. Since there are more than one units at this source and since neither Fairchild nor its successors carry flight analyzers in their inventory, spare parts would be obtained by cannibalizing the spares. I have been able to locate a photograph of the unit. Figure 9 gives its dimension, Figure 10 is the photograph of a Model IV unit.

This paper assumes the use of the Model IV instrument, with 93° field of view. However, the Model VI, with 42° field of view will perform as well. The only difference would be the distance of the camera lens from the course line which is determined by:

1/2 course length ÷ tan F.O.V. used / 2.

Mr. Woltz and persons of his acquaintance have used the Fairchild Flight Analyzer and Mann Comparator so information of the operation of these instruments is immediately available.

Emulsions and processing noted (dated about 1962) are: Eastman Kodak Tri X-B plates (non-matte) using D19 developer. Using only a closet with running water in the field, results were available in 30 minutes, approximately, after each run.

AMBIENT CONDITIONS

The foregoing has described some truly accurate equipment. It is now appropriate to examine the ambient environment to try to find compatible accurate means to measure variations from still air conditions. In the present techniques, using sailplane-borne instruments only, a measured, stable lapse rate in the early hours of the day is considered adequate. When carefully done, Bikle [5,7] was able to have almost all of the points he measured fall directly onto a smooth curve for the Polar Plots of sailplanes with approximate 35 to 1 L/D max. Dick Johnson's tests[6] are models of care, yet the "smooth curve" is a line through close clusters of points, especially now that L/D max is in the 60 to 1 range. It is possible that the clusters are primarily due to errant motions of the atmosphere and that, for the flight analyzer, one must address this problem area with innovative thinking.

It is well-known that the atmosphere is never still, or still for longish periods of time, but the hours near dawn[8] in fair weather are known to be the most quiescent. It is not possible to predict what the local conditions will be even a few minutes in the future, so the timing of any one flight down the course cannot be chosen for optimum conditions. Accordingly, chance plays a part in this concentrated time-and-place test scene.

Only practical experience and the aid of specialists in the field of measuring adolescent zephyrs will define the proper methods for instrumenting the course, so that corrections due to observed air motions can be applied to the photographic data with some degree of confidence.

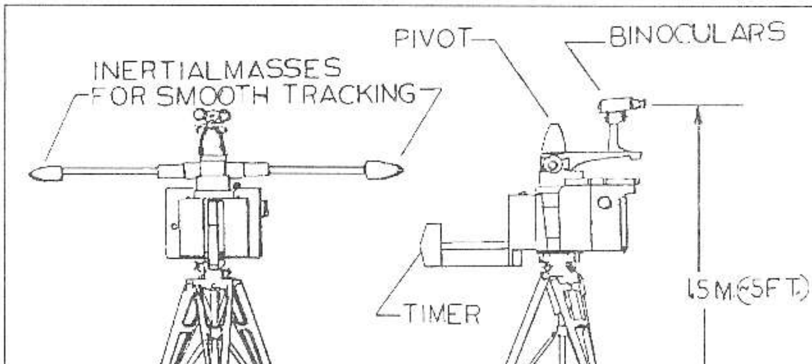

FIGURE 9. A rough depiction of a Fairchild Flight Analyzer.

One must start somewhere, however, and it is proposed that the sailplane be equipped with a sensitive outside air temperature thermopile located where it does not add to the aerodynamic drag of the glider and which is corrected

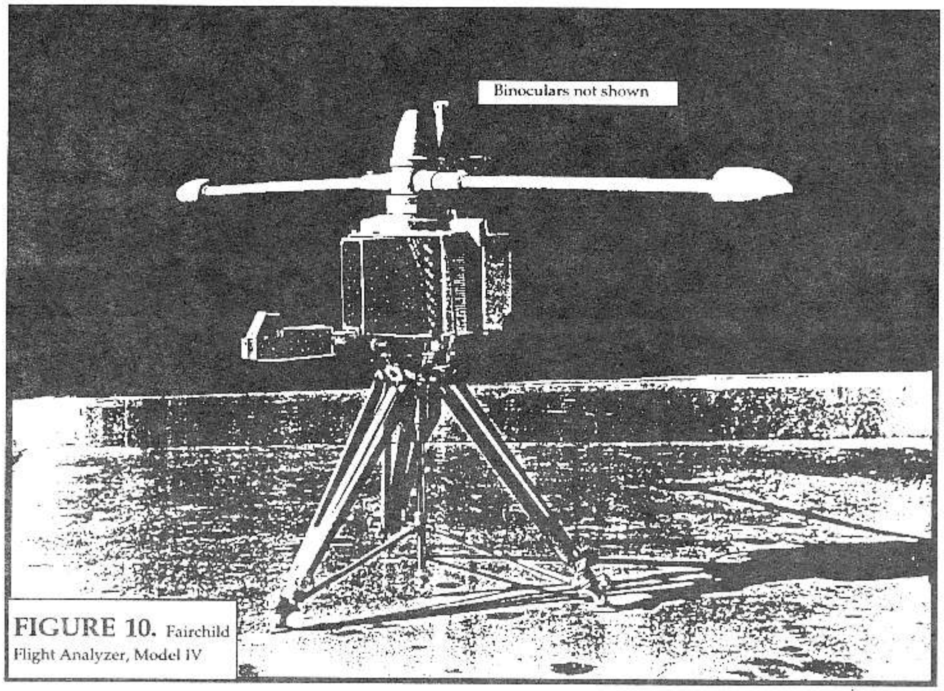

FIGURE 10. Fairchild Flight Analyzer, Model IV

for temperature rise due to airspeed as may be desired. This will establish a reasonable lapse rate as sensed by the aircraft. This should be photographed.

Along the course line there could be three or four spaced, helium-filled toy balloons tethered with strings long enough (or the balloons are weighted) so that they are barely able to support the tethers. These now are essentially identified parcels of the atmosphere. By observing and getting ground-based video records of them as the glider flies over them one can visualize with some confidence the movement, (horizontally and down primarily) of the air on the course at the instant it is being flown. One can calibrate such tethered balloons for horizontal air movement by measuring the angle made by the tether to vertical into meters per second.

No doubt there are other methods, such as observing rising smoke, but it is not the intent of this paper to go more deeply into this detail subject. It is clear that performance measurement is approaching an esimate where it becomes arguable as to its validity. At L/D = 60 (= 0.955°), the advantage of L/D = 61 (= 0.939°) is still 1.67%. At this time, such numbers (60, 61,) are of interest to sailplane racing pilots who put their dollars and their reputations into their competitions. Those of us who savor advances in the reduction of aerodynamic drag see the advantage of "improving the breed" but the question remains not only how to do it but how to prove it. It is probable that the day for the flight analyzer is here, that this kind of intense accuracy will be required to extend the limits of sailplane design.

Whether the Fairchild Flight Analyzer will be called upon to establish an era of closely controlled performance testing in the future is still to be decided, but thanks to a dream, the opportunity and privilege to learn about it and to present this paper to you was given to me.

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