No. 344 FEBRUARY 2015

T.W.I.T.T. NEWSLETTER

Fritz with his BIG (4m) flying wing. Majestic flight, but difficult to control. Source: http://www.ofremmi.info/F3F/CoolPictures/cool_glider_pictures.htm

T.W.I.T.T.
The Wing Is The Thing
P.O. Box 20430
El Cajon, CA 92021

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TWITT

THE WING IS THE THING

THE WING IS THE THING (T.W.I.T.T.)

T.W.I.T.T. is a non-profit organization whose membership seeks to promote the research and development of flying wings and other tailless aircraft by providing a forum for the exchange of ideas and experiences on an international basis.

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Meetings are held on the third Saturday of every other month (beginning with January), at 1:30 PM, at Hanger A-4, Gillespie Field, El Cajon, California (first row of hangers on the south end of Joe Crosson Drive (#1720), east side of Gillespie or Skid Row for those flying in).

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PRESIDENT'S CORNER

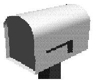
I can't believe another month has gone by and it time for another issue. This month I decided I needed to get busy and start publishing material out of our archives. We have collected a wide variety of things so I hope as the months go by you will find something interesting or just add to your knowledge base.

So as not to lose what is happening in the present, I will continue to include pertinent topics from the Mitchell U-2 and Nurflugel groups. The message traffic for these groups picked up lately but the topics have not been that interesting.

For those of you who are true flyers, I hope you have been in areas where the weather has been good. I live in southern California and the weather has generally been clear and warm, but the soaring conditions have been lousy for several months so I am itching to get back in the air with the glider.

Don't forget that I can always use your letters and articles so send in anything you would like to share with the group. I know some of you are doing things, especially in the modeling area, so let us know how it is going. You can see from the first piece under the letters section, there are folks out there working on great projects. Be sure to watch the videos since the one where the test model really goes through the paces like any other type of airplane. Hopefully they will stay funded so the true prototype can be flown.

Andy



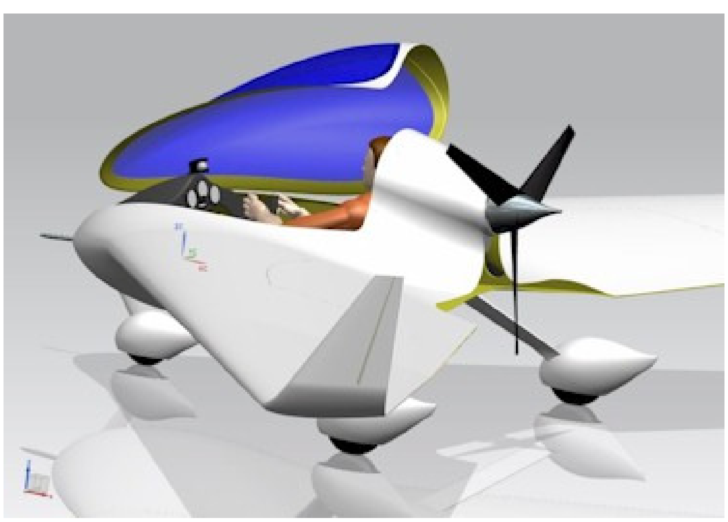
LETTERS TO THE EDITOR

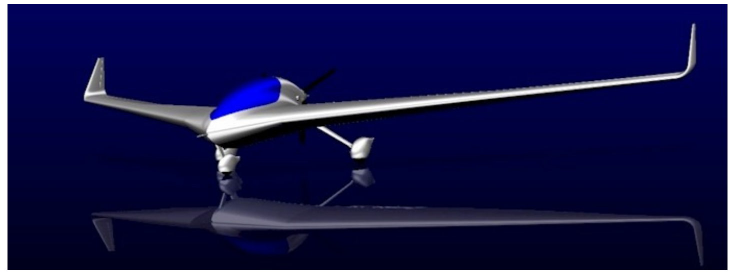
(ed. – The following was sent to me by Dean Sigler, one of my contacts from ESA. He thought this would be of interest to TWITT members with the comment that they may want to consider changing their name due to the current world situation.)

This is the link to the home page for the Isis Flying Wing that is under development in the UK. There are a couple of videos on the RC model that shows it flies extremely well at the hands of an experienced pilot. This sort of looks like a single seat version of the PUL 10 that got a lot of interest a number of years ago.

http://isisflyingwing.com/index.htm

Here are a few shots from the website to get you started.





(ed. – A long time ago I told myself I would start putting items from the TWITT archives into the newsletters so everyone could share in what we have collected over the years. Now that I am retired there doesn't appear to be any reason why I can't spend more time going through the archives and picking out those items with the most interest and publishing those that are not copyrighted or I can't get permission. This is one I found that I thought would be a good start since the text was brief but I had a lot of illustrations and tables. I will include as much of them in next month's issue.)

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS TECHNICAL PAPER NO. 388 A COMPARISON OF THE AERODYNAMIC CHARACTERISTICS OF THREE NORMAL AND THREE REFLEXED AIRFOILS IN THE VARIABLE DENSITY WIND TUNNEL

By George L. Defoe

Summary

An investigation was made of the aerodynamic effects of reflexing the trailing edge of three commonly used airfoils. Six airfoils were used in the investigation: three having the normal profiles of the Navy 60, the Boeing 106, and the Gottingen 398, and three having these profiles modified to obtain a reflexed trailing edge with the mean camber line changed to give $C_{mc}/4 = 0$

The tests were conducted at a value of the Reynolds Number of approximately 3,100,000 in the variable density wind tunnel of the National Advisory Committee for Aeronautics. Measurements of lift, drag, and pitching moment were made on each of the six airfoils. The expected reduction of the center of pressure travel was obtained. The maximum lift was reduced approximately 12 per cent and the minimum profile drag approximately 4 per cent.

Introduction

In the past few years several airplanes of the observation and bombing types intended for high-speed diving have been developed and tested in flight. If a normal form of airfoil section is used, the aerodynamic forces on the wing during a dive cause large pitching moments producing high stresses in the airplane structure.

The Navy Department therefore requested the National Advisory Committee for Aeronautics to conduct an investigation on three commonly used airfoil sections in their normal forms and then with the forms modified toward the trailing edge to produce airfoils having small pitching moments.

Previous work by the British Advisory Committee for Aeronautics in an atmospheric wind tunnel (references 1 and 2) between 1912 and 1914 has shown that, if the correct amount of reverse curvature be placed near the trailing edge of an airfoil, the center of pressure may be considered stationary within practical limits. The reduced center of pressure travel was obtained by sacrificing about 18 per cent of the maximum lift.

Twenty-seven airfoils having a small center of pressure travel were tested during 1924 by the National Advisory Committee for Aeronautics (reference 3) in tie variable density wind tunnel. The most favorable sections were found to be those of the M6 type. A small center of pressure travel was found to be generally accompanied by a reduced maximum lift coefficient.

The present investigation is intended to show, by direct comparison, the effects of reflexing the trailing edge of a normal airfoil section on the aerodynamic characteristics: lift, drag, and pitching moment. These characteristics have also been compared with the unpublished results of a recent test of the M6 airfoil. All tests were made at a large value of the Reynolds Number in the variable density wind tunnel of the National Advisory Committee for Aeronautics, Langley Field, Va.

Apparatus and Methods

The normal airfoils used in this investigation were the Navy 60, the Boeing 106, and the Gottingen 398, hereinafter abbreviated the N60, the B106, and the Gott. 398. To obtain the reflexed airfoils, designated N60R, B106R, and Gott. 398R, the normal airfoils were modified by substituting a new mean camber line from the 30 per cent point to the trailing edge. The following form of the equation of the mean camber line was chosen because, according to thin airfoil theory, this equation gives an airfoil having a pitching moment of zero about the quarter-chord point:

$Y = hx (1 - x) (l - 8/7 x)$, where $c = 1$, (reference 4).

The x-axis was taken parallel to the chord line of the original section and the origin was taken at the leading edge of the original airfoil. The value of the factor h was so determined that the ordinate of the new mean camber line at the 30 per cent point was equal to the ordinate of the old mean camber line at the same point. The nose ordinates of the profile from x = 0 to x = 0.3 remained unaltered, and both upper and lower surface ordinates were shifted by the amount of the difference between the old and new camber line. The profiles of both the normal and reflexed airfoils are shown in Figure 1, and the ordinates of each airfoil are given in Table I. An airfoil of duralumin was made from each group of ordinates in this table.

The standard method of airfoil test was used; measurements were taken of the lift, drag, and pitching moment at a large value of the Reynolds Number, approximately 3,100,000. The accuracy of these results is of the same order as those discussed in reference 5.

Results

The results of these tests are given in Tables II to VII and are plotted in Figures 2 to 7. The coefficients of the corresponding normal and reflexed airfoils, (the N60 and N60R, the B106 and B106R, the Gott. 398 and. Gott. 398R), plotted against angle of attack, are shown in Figures 2 to 4. The profile drag and the moment coefficients plotted against lift coefficient are shown in Figures 5 to 7.

Discussion

The pitching moment coefficients for the reflexed airfoil are practically zero in the range of angle of attach from that of zero lift to +6 degrees for the N60R, from that of zero lift to +4 degrees for the Gott. 398R, and from that of zero lift to +12 degrees for the B106R.

The lift curves for the corresponding normal and reflexed airfoils have the same slope. The angle of zero lift for the reflexed airfoil occurs at a higher angle of attack. The maximum lift is approximately 12 per cent lower than that of the normal airfoil although it is obtained at approximately the same angle of attack. The useful range of the angle of attack thus differs by the amount of the change of angle of zero lift for the two airfoils.

The minimum profile drag of the reflexed airfoils (figs. 2, 3, and 4) is 4 per cent lower than that of the normal airfoil and occurs at a slightly higher angle of attack. However, if the profile drag coefficients are compared at equal values of the lift coefficient (figs. 5, 6, and 7), the normal airfoil will be seen to have the lower profile drag except at small values of the lift coefficient.

A comparison of the characteristics of these airfoils with those of the N.A.C.A. M6 is given in the following table.

Table of Characteristics

Airfoils	Gött. 398	B106	N60	Gött. 398R	B106R	N60R	M6
C_L max	1.572	1.535	1.616	1.369	1.386	1.407	1.405
C_{D_o} min	0.0106	.0098	.0099	.0099	.0093	.0092	.0092
C_m at C_L=0	-0.082	-.052	-.080	-.007	-.001	-.001	.002
$\frac{C_L \text{ max}}{C_{D_o} \text{ min}}$	148.5	161.6	163.3	138.2	149.1	153.0	152.8
Thickness per cent of chord	13.85	13.06	12.45	13.85	13.06	12.45	12.01

The characteristics of the M6 given in the foregoing table were obtained from a test of this airfoil under practically the same conditions as the tests of the normal and reflexed airfoils. The results of this M6 test are unpublished at the present time, but will be published in the near future together with the results of several other well-known airfoils.

A reference to the table of characteristics to compare the N60R and M6 shows that these two airfoils have practically the same characteristics even though the N60R is one-half percent thicker than the M6. A comparison of the characteristics of the B106R and of the Gott. 398R with the N60R and the M6 shows the minimum profile drag coefficients of the B106R and the Gott. 398R to be larger than those of the N60R and the M6, possibly due to the greater thickness. The maximum lifts for the B106R and Gott. 398R are lower than those of the N60R and M6. The smaller maximum, lift and the higher minimum profile drag account for the factor of general efficiency CL max/C_{Do} min being lower for the B106R and the Gott. 398R.

Conclusions

The general conclusions of early tests of reflexed trailing edge airfoils in atmospheric tunnels are substantiated by these tests at a large value of the Reynolds Number - approximately 3,100,000. The reduction of the pitching moment and the accompanying small center of pressure travel were in agreement with theoretical prediction. The maximum lift was reduced approximately 12 per cent and the minimum profile drag only 4 to 5 per cent.

Langley Memorial Aeronautical- Laboratory, National Advisory Committee for Aeronautics, Langley Field, VA., August 14, 1931.

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2. Bramwell, F.H.: Further Experiments with Airfoils Having Reversed Curvature towards the Trailing Edge. Britch A.C.A. R. and M. No. 110, Section III, 1913-1914.

3. Munk, M. M., and Miller, E.W.: Model Tests with a Systematic Series of 27 Wing Sections at Full Reynolds Number. N.A.C.A. Technical Report No. 221, 1925.

4. Glauert, H.: The Elements of Aerofoil and Airscrew Theory, Chapter VII, pp. 91-93, Cambridge, The University Press, 1926.

5. Jacobs, E.N.: Tests of Six Symmetrical Airfoils in the Variable Density Wing Tunnel. N.A.C.A. Technical Note No. 385, 1931.

N.A.C.A. Technical Note No. 388 Fig. 1

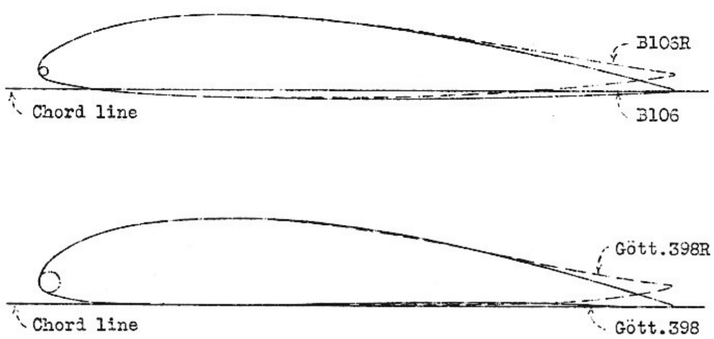

Fig. 1 Profiles of normal and reflexed airfoils.

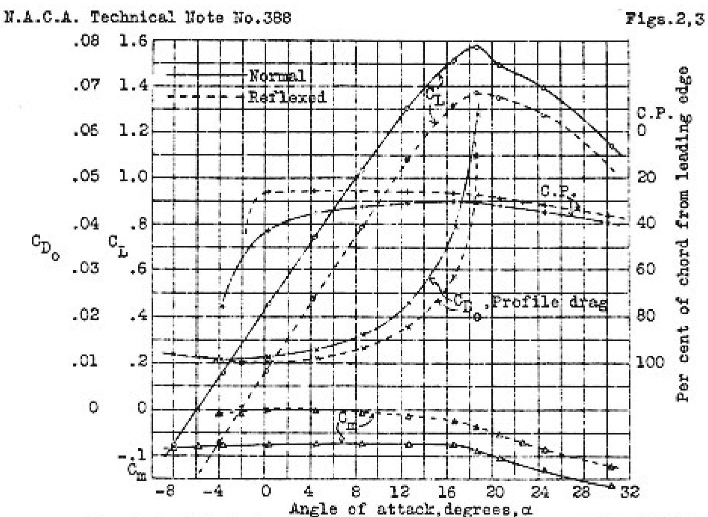

Fig.2 Coefficients of Göttingen 398 and Göttingen 398R airfoils.

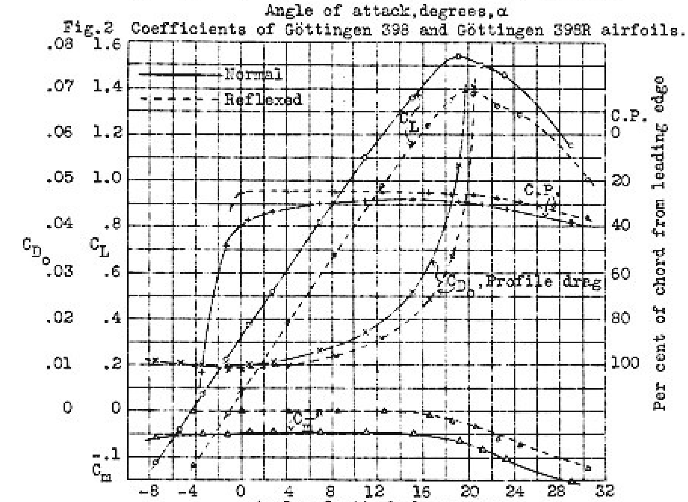

Fig.3 Coefficients of B106 and B106R airfoils.

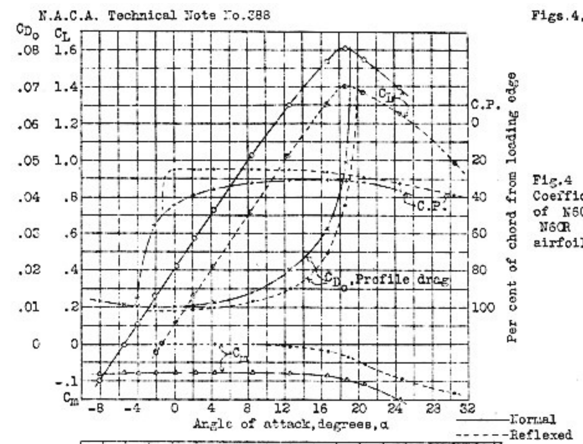

Fig.4 Coefficients of N60 and N60R airfoils.

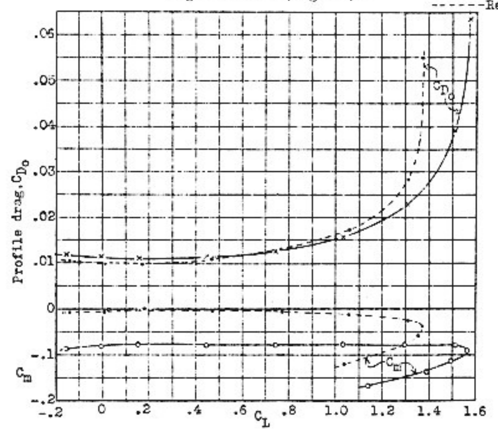

Fig.5 Profile drag and moments of Gött.398 and Gött.398R airfoils.

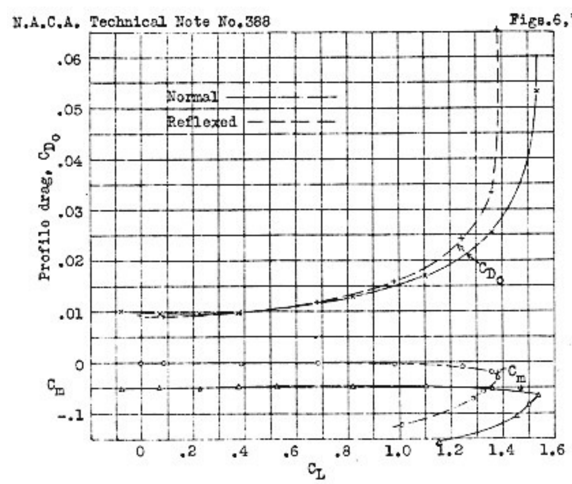

Fig.6 Profile drag and moments of B106 and B106R airfoils.

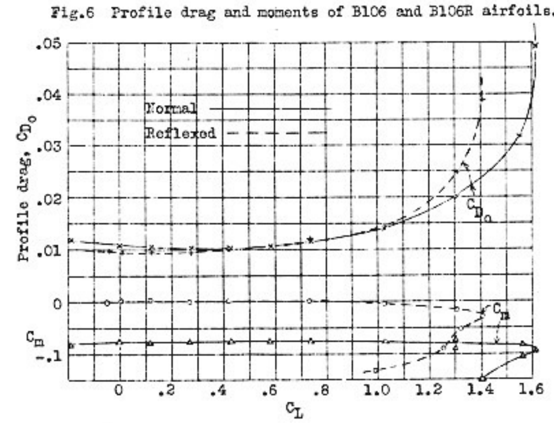

Fig.7 Profile drag and moments of N60 and N60R airfoils.

TABLE I

Ordinates of N60 and N60R

Station per cent of chord	N60 per cent of chord		N60R per cent of chord	
	Upper	Lower	Upper	Lower
0	3.40	3.40	3.40	3.40
1.25	5.60	1.91	5.60	1.91
2.50	6.76	1.46	6.76	1.46
5.00	8.24	.96	8.24	.96
7.50	9.33	.62	9.33	.62
10.00	10.14	.40	10.14	.40
15.00	11.32	.15	11.32	.15
20.00	11.98	.04	11.98	.04
30.00	12.41	.04	12.41	.04
40.00	12.03	.22	11.95	.14
50.00	11.06	.48	10.79	.21
60.00	9.55	.71	9.18	.34
70.00	7.66	.78	7.42	.54
80.00	5.50	.64	5.75	.89
90.00	3.04	.37	4.28	1.61
95.00	1.72	.19	3.66	2.13
100.00	.40	.00	3.20	2.80
	L.E. Radius - 1.27 per cent			

TABLE I (Continued)

Ordinates of B106 and B106R

Station per cent of chord	B106 per cent of chord		B106R per cent of chord	
	Upper	Lower	Upper	Lower
0	2.98	2.98	2.98	2.98
1.25	5.26	1.54	5.26	1.54
2.50	6.14	1.04	6.14	1.04
5.00	7.54	.42	7.54	.42
7.50	8.56	.04	8.56	.04
10.00	9.44	-.28	9.44	-.28
15.00	10.62	-.64	10.62	-.64
20.00	11.34	-.90	11.34	-.90
30.00	11.88	-1.18	11.88	-1.18
40.00	11.54	-1.28	11.62	-1.20
50.00	10.54	-1.30	10.70	-1.14
60.00	9.08	-1.22	9.35	-.95
70.00	7.18	-.98	7.66	-.50
80.00	4.96	-.72	5.90	.22
90.00	2.54	-.42	4.23	1.27
95.00	1.29	-.23	3.48	1.96
100.00	.04	-.04	2.84	2.76
	L.E. Radius - 0.70 per cent			

TABLE I (Continued)

Ordinates of Gött. 398 and Gött. 398R

Station per cent of chord	Gött. 398 per cent of chord		Gött. 398R per cent of chord	
	Upper	Lower	Upper	Lower
0.00	3.74	3.74	3.74	3.74
1.25	6.20	1.89	6.20	1.89
2.50	7.40	1.28	7.40	1.28
5.00	9.17	.69	9.17	.69
7.50	10.37	.35	10.37	.35
10.00	11.25	.18	11.25	.18
15.00	12.53	.03	12.53	.03
20.00	13.34	.00	13.34	.00
30.00	13.80	.05	13.80	.05
40.00	13.34	.17	13.30	.13
50.00	12.27	.27	12.08	.08
60.00	10.63	.33	10.39	.09
70.00	8.53	.35	8.42	.24
80.00	6.12	.27	6.50	.65
90.00	3.40	.13	4.77	1.50
95.00	1.92	.06	4.02	2.16
100.00	.40	.00	3.40	3.00
	L.E. Radius - 2.00 per cent			

TABLE II

Coefficients of Airfoil Gött. 398

α	C_L	C_{D_0}	C_m	c.p. per cent of chord from L.E.
-8.1	-0.156	0.0117	-0.086	-
-6.0	- .007	.0112	- .083	-
-3.9	.152	.0106	- .078	76.8
.2	.449	.0111	- .079	42.6
4.3	.745	.0126	- .078	35.5
8.4	1.032	.0159	- .077	32.5
12.5	1.303	.0227	- .078	31.0
16.6	1.514	.0393	- .078	30.3
18.6	1.572	.0638	- .090	30.8
20.6	1.495	.1335	- .111	32.5
24.5	1.392	-	- .137	34.7
30.4	1.139	-	- .166	38.3

TABLE III

Coefficients of Airfoil Gött. 398R

α	C_L	C_{D_0}	C_m	c.p. per cent of chord from L.E.
-4.1	-0.144	0.0106	-0.008	-
-2.1	.006	.0099	- .007	141.6
.1	.167	.0099	- .003	26.8
4.2	.472	.0109	- .004	25.8
8.3	.774	.0130	- .008	26.0
12.4	1.059	.0175	- .014	26.3
16.5	1.311	.0285	- .024	26.8
18.5	1.369	.0551	- .036	27.6
20.5	1.350	.1060	- .057	29.3
22.5	1.316	-	- .072	30.5
24.5	1.274	-	- .088	31.8
30.4	1.037	-	- .122	36.0

TABLE IV

Coefficients of Airfoil B106

α	C_L	C_{D_0}	C_m	c.p. per cent of chord from L.E.
-7.6	-0.231	0.0108	-0.060	-
-5.5	- .084	.0102	- .052	-
-3.5	.064	.0098	- .050	103.7
-1.4	.220	.0097	- .051	48.2
0.6	.370	.0098	- .045	37.2
2.7	.517	.0106	- .046	33.9
6.8	.813	.0127	- .047	30.8
10.9	1.095	.0170	- .046	29.2
15.0	1.352	.0256	- .051	28.8
19.1	1.535	.0533	- .064	29.3
21.1	1.494	-	- .083	30.8
23.1	1.453	-	- .106	32.3
28.9	1.146	-	- .155	37.6

TABLE V

Coefficients of Airfoil B106R

α	C_L	C_{D_0}	C_m	c.p. per cent of chord from L.E.
-4.1	-0.226	0.0099	-0.002	-
-1.1	- .006	.0094	-0.001	-
0	.082	.0093	0	25.0
4.1	.386	.0100	.000	25.0
8.3	.682	.0119	.000	25.0
12.4	.980	.0158	- .002	25.2
16.5	1.247	.0242	- .008	25.6
18.5	1.355	.0335	- .020	26.5
20.5	1.383	.0704	- .031	27.2
22.5	1.320	-	- .057	29.4
24.5	1.286	-	- .071	30.6
30.4	1.007	-	- .122	36.1

TABLE VI

Coefficients of Airfoil N60

α	C_L	C_{D_o}	C_m	c.p. per cent of chord from L.E.
-8.1	-0.196	0.0117	-0.082	-
-5.5	- .006	.0106	- .078	-
-4.0	.114	.0103	- .079	94.8
-1.9	.267	.0101	- .080	55.2
+0.2	.425	.0099	- .079	43.6
2.2	.578	.0105	- .079	38.7
4.3	.731	.0112	- .077	35.5
8.4	1.026	.0138	- .079	32.7
12.5	1.301	.0200	- .084	31.9
16.6	1.542	.0313	- .085	30.6
18.6	1.616	.0493	- .096	31.0
20.6	1.557	-	- .108	32.0
24.5	1.398	-	- .152	35.7

TABLE VII

Coefficients of Airfoil N60R

α	C_L	C_{D_o}	C_m	c.p. per cent of chord from L.E.
-2.0	-0.048	0.0094	-0.001	-
-1.4	.002	.0092	- .001	80.0
0	.112	.0093	.000	25.0
2.1	.265	.0092	- .001	25.4
4.3	.419	.0099	- .001	25.2
8.3	.723	.0116	- .002	25.3
12.4	1.028	.0143	- .007	25.7
16.5	1.305	.0244	- .018	26.4
18.5	1.407	.0386	- .027	27.0
20.5	1.367	.0994	- .054	29.1
24.5	1.256	-	- .091	32.1
30.4	.992	-	- .133	37.2

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(ed. – These videos are also now available on DVD, at the buyer's choice.)

VHS tape containing First Flights "Flying Wings," Discovery Channel's The Wing Will Fly, and ME-163, SWIFT flight footage, Paragliding, and other miscellaneous items (approximately 3½+ hours of material).
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

VHS tape of Al Bowers' September 19, 1998 presentation on "The Horten H X Series: Ultra Light Flying Wing Sailplanes." The package includes Al's 20 pages of slides so you won't have to squint at the TV screen trying to read what he is explaining. This was an excellent presentation covering Horten history and an analysis of bell and elliptical lift distributions.
Cost: $10.00 postage paid
Add: $ 2.00 for foreign postage

VHS tape of July 15, 2000 presentation by Stefanie Brochocki on the design history of the BKB-1 (Brochocki,Kasper,Bodek) as related by her father Stefan. The second part of this program was conducted by Henry Jex on the design and flights of the radio controlled Quetzalcoatlus northropi (pterodactyl) used inthe Smithsonian IMAX film. This was an Aerovironment project led by Dr. Paul MacCready.
Cost: $8.00 postage paid
Add: $2.00 for foreign postage

An Overview of Composite Design Properties, by Alex Kozloff, as presented at the TWITT Meeting 3/19/94. Includes pamphlet of charts and graphs on composite characteristics, and audio cassette tape of Alex's presentation explaining the material.
Cost: $5.00 postage paid
Add: $1.50 for foreign postage

VHS of Paul MacCready's presentation on March 21,1998, covering his experiences with flying wings and how flying wings occur in nature. Tape includes Aerovironment's "Doing More With Much Less", and the presentations by Rudy Opitz, Dez George-Falvy and Jim Marske at the 1997 Flying Wing Symposiums at Harris Hill, plus some other miscellaneous "stuff".
Cost: $8.00 postage paid in US
Add: $2.00 for foreign postage

VHS of Robert Hoey's presentation on November 20, 1999, covering his group's experimentation with radio controlled bird models being used to explore the control and performance parameters of birds. Tape comes with a complete set of the overhead slides used in the presentation.
Cost : $10.00 postage paid in US
$15.00 foreign orders

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