No. 287 MAY 2010

T.W.I.T.T. NEWSLETTER

This seemed timely since there is the first part of a technical paper featuring Jack Northrop in this month's issue.

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

The number after your name indicates the ending year and month of your current subscription, i.e., **1005** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, May 15, 2010, beginning at 1:30 pm at hanger A-4, Gillespie Field, El Cajon, CA (first hanger row on Joe Crosson Drive - Southeast side of Gillespie).

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. T.W.I.T.T. is affiliated with The Hunsaker Foundation, which is dedicated to furthering education and research in a variety of disciplines.

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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

We have two nice articles for you this month, one on something new and one by a legend in world of flying wings.

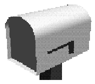
Larry Witherspoon brings us up-to-date on Boeing and NASA's progress with the X-48B BWB concept test bed. We have shown pictures of this model in the wind tunnel, but now there are pictures of it in the air.

Steve Torpey sent us a big stack of copied documents some time back and I have taken the one featuring Jack Northrop giving a presentation at the 35th Wilbur Wright Memorial Lecture in 1947. I have included as much of the lengthy paper in this issue and will either continue it next month, depending on space, and/or get enough of it transcribed to put it on the web site. In doing some Internet searching for pictures to include I came across the fact the Doug Bullard has an abridged version on his web site (www.nurflugel.com) if you want to get a head start. I will eventually get the entire paper up so you can fill in the blanks later.

Speaking of the Nurflugel group, they continue to be very quiet and the Mitchell U-2 group also hasn't had much activity in the past month that would be of interest to our group. If you are at all interested in a U-2 project, read the letters section since there is a partially completed one available for free from Dean Sigler in Oregon.

Until next month,

Andy



LETTERS TO THE EDITOR

March 31, 2010

The X-48B takes off during its 79th test flight on March 17, 2010 at Edwards Air Force Base, Calif. (NASA photo) With 80th flight, X-48B successfully completes flight testing

Boeing Research & Technology engineers and technicians in California, working closely with NASA researchers, earlier this month successfully flew the unmanned, remotely piloted X-48B Blended Wing Body flight-research vehicle for the 77th, 78th, 79th and 80th times, completing a multi-step flight-test effort that began in 2007.

"We couldn't be more pleased with the results of this project," said Bob Liebeck, BR&T's BWB program manager. "We have proven that a BWB aircraft can be controlled as effectively as a conventional tube-and-wing aircraft during takeoffs and landings and other low-speed segments of the flight regime."

Since July 2007, when the X-48B flew for the first time at NASA Dryden Flight Research Center on Edwards Air Force Base, Calif., Boeing and NASA researchers have methodically pushed the research aircraft to test and validate the BWB data and flight-control system, and gather detailed information on BWB stability characteristics throughout a variety of regimes, including stalling and recovering the aircraft in flight.

"It's truly been a privilege to work with the talented flight-test professionals at Boeing and NASA on the X-48B program," said Mike Kisska, BR&T's X-48B project manager. "We've accomplished a great deal during the 80 test flights, including such maneuvers as power-on and power-off stalls, sideslips, engine-out maneuvering and a successful matrix of departure limiter assaults. Also, we believe the X-48B holds the NASA Dryden Flight Research Center record for the number of test flights performed by a single unmanned X-Plane - doubling the previous record of 40 flights held by the X-45 Joint Unmanned Combat Aircraft."

With a 21-foot wingspan, the 500-pound aircraft is an 8.5 percent scale model of a heavy lift, subsonic airplane with a 240-foot wingspan that possibly could be developed in the next 15 to 20 years for applications such as aerial refueling and cargo hauling.

The X-48B flight-research is a collaborative effort of BR&T's Enterprise Strategic Growth organization, NASA and the U.S. Air Force Research Laboratory. Two X-48Bs were built for Boeing by Cranfield Aerospace Ltd., in the United Kingdom in accordance with Boeing's requirements and specifications. Boeing Defense, Space & Security's Phantom Works organization has been closely monitoring the research based on the BWB's potential as a flexible, long-range, high-capacity military aircraft.

"My congratulations go out to the entire flight-test team for the 100 percent successful and safe flights on a small-scale BWB aircraft," said David Whelan, BDS's chief scientist and vice president of Strategic Innovation for BDS Phantom Works. "Our plan is to continue to build on this hard work, with the goal of someday creating a large-scale BWB demonstrator for military applications."

"This project is a huge success," added Fay Collier, NASA's Environmentally Responsible Aviation project manager overseeing the X-48B project. "The NASA, Boeing, Cranfield, Air Force Research Lab team working with the X-48B has very effectively addressed the low-speed flight controls with this four-year effort.

Bottom line: the team has proven the ability to fly tailless aircraft to the edge of the low-speed envelope safely."

Unlike a traditional airplane design in which a tube-like fuselage is fitted with wings, the BWB merges the fuselage with the wing. The result is a cross between a conventional aircraft and a flying wing such as the B-2 stealth bomber. The blending of the wing into a wide, flat tailless fuselage helps to get additional lift with less drag than an airplane with a circular fuselage.

Boeing and NASA researchers believe the design offers such potential benefits as increased volume for carrying capacity, efficient aerodynamics for as much as 20 percent reduced fuel burn compared to traditional tube-and-wing aircraft and significant reductions in noise because of the way the engines are integrated into the vehicle - on top of instead of underneath the wings.

During the "Phase 1" flight-testing, the X-48B team focused on three main technical objectives: flight-envelope expansion, aircraft performance characterization, and validation of flight-control software limiters.

The first objective - envelope expansion - was met during the first 20 flights, when the team put the aircraft through a variety of maneuvers intended to define the overall flight capabilities and discern the general stability and handling characteristics of the aircraft. When these flights were completed, the team had a good understanding of a preliminary flight envelope adequate for transition to higher-risk testing.

The second objective - aircraft performance characterization - was accomplished during 52 flights that took place between July 2008 and December 2009 involving stall testing, engine-out maneuvering, and parameter identification flights. Stall characterization maneuvers helped define the boundaries beyond which normal controlled flight is not possible. Engine-out maneuvers were used to assess the controllability of the aircraft if one or more of the aircraft's three engines malfunctioned and the aircraft could not provide symmetric thrust. The parameter identification maneuvers allowed the performance of the aircraft to be evaluated through pre-planned flight-control surface movements. Computer commands to the flight-control surfaces allowed engineers to measure how quickly the plane responded in flight to those inputs, helping them to quantify the dynamic response.

The third objective - validation of flight-control software limiters - was met during the eight flights this year. Tests validated that the flight-control computer's software could keep the aircraft in controlled flight even as the pilot attempted to deliberately exceed the defined boundaries of controllability. Flight characteristics such as angle of attack, sideslip angle, and acceleration software limiters were "assaulted." The flights validated the programmed limiters and gave the team confidence that a robust, versatile, and safe control system could be developed for such an aircraft.

Kisska said the X-48B currently is undergoing major maintenance, including the installation of a new flight computer. More parameter identification flights are slated for later this year during the project's "Phase 1.5." This new phase will be the introductory flights for NASA's new Environmentally Responsible Aviation Project, aimed at reducing noise, greenhouse emissions and fuel consumption in aircraft.

A modified version of the Boeing X-48B, given its own X-plane designation by the U.S. Air Force in August of last year as the X-48C, also soon will be tested. Configured with two turbofan engines instead of three and with twin canted fins mounted on the aft body section, the X-48C will be used to evaluate the impact of noise shielding concepts on flight characteristics.

According to Dhar Patel, BR&T's X-48C project manager, the X-48C is expected to take to the air in late 2011.

Larry Witherspoon
<Ssspoon@aol.com>

(ed. – Thanks for the update and the links to some great photos. I especially liked the last one since it gives the impression that the BWB is a full sized aircraft. It is also great to see that NASA and Boeing are still pursuing this concept for the real world.)

April 13, 2010

Thank you very much.

I have just downloaded the first four numbers of 2010 and they are just great. I was asking myself if it is possible to gradually download all the newsletters.

I'll let you know about the flying wing models I'll build.

Thank you again

Francesco Pampanoni
<francesco.pampanoni@studiopampanoni.it>

(ed. – This was in response to his becoming a new member of TWITT. In response to his comment on downloading the newsletter issues I offered to send him a CD with the current issues saved in yearly groups. So if anyone else out there would like the back issues on a burnable disk where you can add new ones from the web site as to you along, they can be provided for $5 for US addresses and $6 for foreign addresses.)

April 18, 2010

Hello.

I have for years sought to procure a copy of the Flying Plank EPB-1C plans from the Vintage Sailplane Association. I paid for plans but received something else instead. Recently I found the package, which had been moved by my Father and repeated my report to the VSA. They claim I will received a set soon.

I also have done posting about soaring at very low cost on my Yahoo Group named Soar1K - meant to summarize the $1,000 US cost of a flying plank ultralight sailplane.

Recently I came across your page at http://www.twitt.org/FacetOpal.html while looking for Facet Opal specifics.

I also found the videos below which may be of interest to your members and worthy of linking on your site:

http://www.youtube.com/watch?v=h2wrSa8mCcI

http://www.youtube.com/watch?v=5RrN7sCtbOM

Note the spelling errors in the above, which perhaps make them hard to locate. ;) Engineers sometimes suffer from dyslexia.

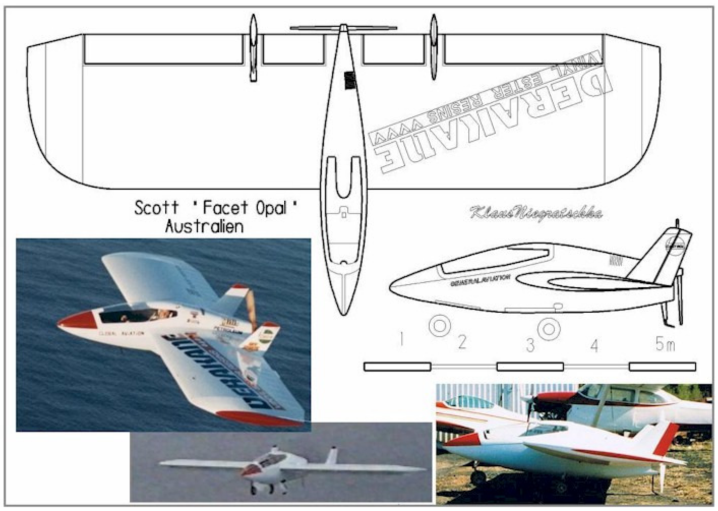
A 3-view sketch on nuricom.de is somewhat accurate, in my opinion, however based on numerical analysis and some CAD work by me, the control surfaces are not correctly drawn, again, in my opinion. The elevons are too wide and the surfaces inside the fins are very unlikely.

It seems a crying shame that this very efficient aircraft plan form has not been further applied. I hope to rectify that.

Fly right,

Nicholas Cafarelli
< nickec@gmail.com>

(ed. – These are some interesting videos and he is right that I need to add them to this section of web site, which I will get to shortly. Below is the sketch he was talking about.)



April 23, 2010

Hi Andy

Geoff Steele was nice enough to suggest I contact you regarding the Horten. My name is Mike Smock. I develop and market larger scale (1:4/1:3) vintage and classic sailplane kits.

I currently sell the DFS Reiher III and the Condor IV in 1:3 scale and I am now considering adding a Horten.

Geoff happened to come across my web site and told me more about your efforts and his interests, which made for perfect timing.

I would enjoy opening up a conversation with you about:

1. The best Horten for kitting - I'm leaning towards the III.
2. Sources of full-scale plans that might be adaptable to 1:3 scale.
3. Suggestions for "beta" builders - anybody you know who is familiar with Hortens and might be interested in building the first kit (they get the kit for free but have to commit to a timely build and provide photos and written instructions).
4. Your interest in contributing content to the Aerosente web site. If you follow the link below you can see how I try and build a complete story around each kit.

http://www.aerosente.com/dfs-reiher-iii-13-scale.html

I am visiting Germany in July to meet with my partners there. I would also be grateful for any suggestions on where I might be able to further research Hortens firsthand for photos, and viewing plans, exhibits, etc.

Thanks in advance for any help you might provide!

Mike Smock, Proprietor
Aerosente Glider Workshop
Classic Sailplanes and Gliders
NORCAL - 415.234.6757
bolt55@aerosente.com
www.aerosente.com

(ed. – Mike has some interesting things on his web site so it is worth taking a look. These are large sailplanes and it would be nice to add a Horten design to it. I will write back to him that the Horten III would probably be one of the easier ones to put into a model of the scales he uses. It would probably be less complex than trying to do everyone's favorite, the H IV with those long slender wings.

I know we have a number of modelers out there so if you are interested in participating in the construction program, please contact him directly. These appear to be very high-end models so you would be getting a good aircraft when you completed the build.)

May 3, 2010

My good friend and prospective U-2 Mitchell Wing builder, Edwin Brekke, passed away a few months ago, and his brother and sister-in-law were nice enough to gift me with his unfinished U-2 kit. I would like to make it available, gratis, to a builder who will power it electrically, a dream that Edwin and I had for it for many years. I need the room in my garage for building a project I've been working on for several years, and am ready now to tackle.

Brek built the wing ribs to a high standard, and the kit has all the necessary pieces, wood, etc. Here's the "BUT." Brek had a massive head trauma seven years ago, and deteriorated between then and his death, suffering several major and minor strokes. The kit was stored in an unheated area, and did suffer some condensation damage. Some plywood is marred, but not separated, and most pieces seem useable with some cleanup. The steel tubing probably suffered most, with scaling and light rust evident. The aluminum pieces are oxidized, but I cannot comment on their true condition.

Plans are there but rough, and I cannot determine if they are complete. Prospective builders could get a full, newly edited set from Carol Avalon at a very reasonable price if necessary.

If anyone is interested, contact me at muchcatfur@comcast.net. The lucky recipient will be responsible for taking it away, so I would like someone within a reasonable driving distance, possessing at least a full-sized van or having access to one, to take this on. Packing and shipping costs would probably exceed the true value of what's there, otherwise Thank you.

Dean Sigler

(ed. – Dean lives in Oregon for anyone who might be interested in contacting him and wanted to know how far the drive might be to pick up such a project.)

May 4, 2010

I just found your page on the Internet. Very nice birds, nicely build. Are there any buildings plans for these kinds of birds?

Many thanks

Harry Wever
<wever@xs4all.nl>
The Netherlands

(ed. – The e-mail link from the web site includes sending a copy to Bob Hoey, who provided this information that I know we have published before but it never hurts to bring it out again.)

Hello, Harry:

I have had two "bird" construction articles published. The first was in the Jan 1994 issue of Radio Controlled Modeler Magazine, with a follow-up article in March, 2001 covering the construction of "Raven II". Although the magazine is no longer in publication, I believe the plans (No. 1160 - $12.00, and 1160A - $6.00); are still available from;

RCM
P.O. Box 487
Sierra Madre, CA 91025 USA.

The second was published in the June 2002 issue of Model Airplane News covering the construction of the "Turkey Vulture" - (plan No. FSP0602 - $19.95); available from;

Air Age Mail Order
P.O. Box 407
Mt. Morris, IL 61054-0407 USA

I have had good feedback from builders of both models.

Feel free to ask any questions, and keep me posted on progress. Good luck with your project.

Bob Hoey
<bobh@antelecom.net>

(ed. – The following is the start of one technical paper from the 1940's that were sent to us by Steve Torpey in Bakersfield. Since I am very shy of current material for the newsletter I will start with this one from the 35th Wilbur Wright Memorial Lecture in 1947. My thanks to Steve for contributing these, which I hope will eventually find their way onto the web site like the Farnborough paper.)

"The Development of All-Wing Aircraft"
by J. K. Northrop

Royal Aeronautical Society Journal (Vol. 51, #438)
June 1947 (RFD# 117122)

Preface: Mr. Northrop was well known on both sides of the Atlantic for his work on all-wing aircraft. Indeed, he was one of the great pioneers in that field an probably knew more about this particular type of aeroplane than anyone. He was chief designer, President, and everything else – in fact he was the Northrop Aviation Company. He had been designing and developing the all-wing type since about 1923. *(ed. - Mr. Northrop gave the following lecture on the difficulties and successes connected with that development.)*

One cannot undertake the presentation of one of the long series of Wilbur Wright Memorial Lectures without a deep sense of appreciation of the tremendous contributions made by the illustrious group of scientists and engineers who have given such great distinction to this event. The happy precedent of inviting individuals from without the United Kingdom to make this presentation in alternate years has gone far in the past toward improving the understanding, cooperative effort and fellowship of the English- speaking peoples, and I am deeply honoured to have been among those chosen to further this very worthy cause.

INTRODUCTION

In choosing the title, "The Development of All-Wing Aircraft," as the subject of my lecture I run some risk of being accused of writing a company history rather than a paper of the broad scope ordinarily presented before this time-honoured institution. This is far from my intent, but being sincerely convinced that the all-wing aeroplane is a valuable step in the development of aeronautics, and desiring to contribute a maximum amount to the available data in the limited time at my disposal, my paper must be confined largely to experience gained by our company in its work on this subject.

Outside the efforts of the Horten Brothers in Germany there has, until a comparatively recent time, been little physical accomplishment in the development of the all-wing aeroplane except by our company. The contemporary Horten development has been fully described in technical reports emanating from Germany since the close of the European war. In many instances the Horten conclusions were surprisingly similar to our own. Their work was not carried so far, however, and I doubt that they had the sympathetic and responsible governmental backing and the resultant opportunities for development accorded us.

In considering the development of all-wing aircraft I would like first to distinguish between all-wing and tailless aeroplanes. Most tailless aeroplanes are not all-wing by our definition. There is a tremendous background of development in tailless types, which has been fully reported by Mr. A. R. Weyl in *Aircraft Engineering*. These articles outlined a surprising number of reasons for building tailless aircraft, which have motivated the various designers and constructors over the years. Only one of the many advantages to be gained through such development has inspired our work, namely improved efficiency of the aeroplane.

More recently, through the rapid development of turbo-jet power plants, a second advantage has arisen, which is the elimination of design difficulties attendant upon the impinging of high speed high-temperature jets on tail surfaces. Still more recently a third possible advantage has appeared, this being the (as yet unproved) probability that problems of stability in the transonic and supersonic ranges may be somewhat more simple of solution in the tailless type than in the older and more conventional arrangements.

Only the first of these basic advantages, namely that of improved efficiency, has been readily apparent over a number of years and, as a result, virtually all our efforts have been directed toward the reduction of parasite drag and the improvement of the ratio of the maximum trimmed lift coefficient (C_{Lmax}) to the minimum drag coefficient (C_{Dmin}). It is natural, then that we were not interested particularly in tailless aeroplanes as such; if we could not eliminate vertical tail surfaces, fuselages, and a substantial portion of interference drag, the gains to be made seemed not worth the effort necessary for their accomplishment.

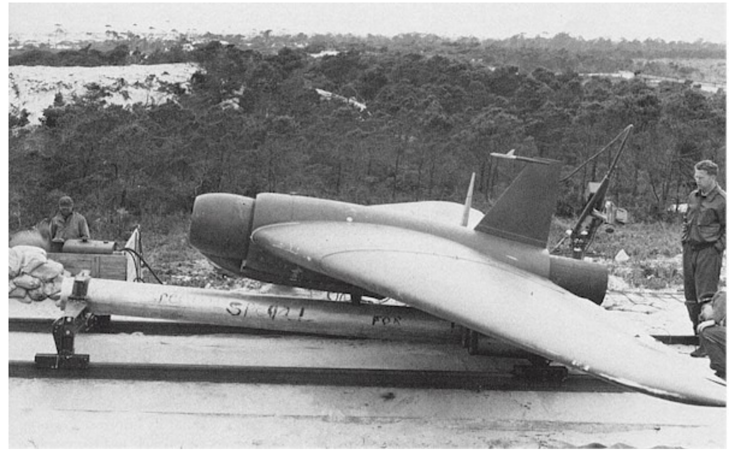
Our work, therefore, through the years has been directed solely to all-wing aircraft, by which I mean a type of aeroplane in which all of the functions of a satisfactory flying machine are disposed and accommodated within the outline of the aerofoil itself. Of course, we have not as yet built any pure all-wing aircraft. All have had some excrescences, such as propellers, propeller drive shaft housings, jet nozzles, gun turrets and the like. We have, however, built a number of aeroplanes in which the minimum parasite drag coefficient has been reduced to approximately half that ordinarily attained in the best conventional aircraft of like size and purpose, and in some of the designs completed and tested the excrescences and variations from the aerofoil contour have been responsible for less than 20 percent of the minimum aeroplane drag.

BASIC ASSUMPTIONS

A surprisingly large number of people both within and without the aircraft industry, still appear to question the economic reasons for going to all the trouble to build an all-wing aeroplane. "Sure," they say, "after a lot of practice people can learn to walk on their hands, but it's most uncomfortable and unnatural, so why do it when nothing is gained thereby?" Actually, there are startling gains to be made in the aerodynamic and structural efficiency of an all-wing type, provided that certain basic requirements fulfilled by the type under question. These requirements can be simply stated as follows:

First, the aeroplane must be large enough so that the all-wing principle can be fully utilized. This is a matter closely related the density of the elements comprising the weight empty and the useful load to carried within the wing. The dimensions of the average human body may also at times be the limiting factor but, ordinarily, in larger types of transport or bombardment aircraft in which we are most interested, it will be found that excessive sizes are not necessary in order to secure, within a wing of reasonable thickness ratio, adequate volume for a commercial cargo or bomb load plus the necessary fuel.

The extremes explored and satisfactorily flown to date in our experience range from a "buzz" bomb having a span of 29 feet, in which the warhead was cast as a portion of the aerofoil, to the 172-foot XB-35 long-range bomber aeroplane. These two aircraft are shown to scale in Fig. 1. *(ed. – The image was not good enough to print, I couldn't find anything on the Internet but I have included a shot of the buzz bomb.)* The buzz bomb was practical because of the comparatively high specific gravity of the warhead, plus the fact that the configuration permitted almost all of the wing to be used as a fuel tank. The XB-35, on the other hand, is considerably larger than would be necessary to provide ample space for passenger and crew comfort and ample volume for payload, be it cargo or bombs. It was designed larger than necessary because we desired to keep the wing loading comparatively low in this first large experimental venture. It has a normal gross weight of 165,000 lb., an overload gross weight of 221,300 lb., and sufficient volume within the wing envelope so that the maximum gross weight at take-off might well be increased to over 300,000 lb., somewhat over half of which could be devoted to bombs, fuel and miscellaneous payload. It may be seen, therefore, that there is a practical range of size within which the all-wing aeroplane can be used. If the requirements of space and volume do not permit the full use of the all-wing principle, a rudimentary nacelle may be added without losing its economic advantages.



The second basic requirement is that the all-wing aeroplane be designed to have sufficient stability and controllability for practical operation as a military or commercial aeroplane. We believe this requirement has been fully met by hundreds of flights completed with this type, and we are fully convinced of its practicability embodying scores of different configurations incorporating the all-wing principle.

In comparing all-wing and conventional types, we may fairly assume that spans of comparative aircraft having the same gross weight are equal, and as a further simplification we may for the moment neglect compressibility affects in our comparison of the advantages of all-wing and conventional types of large bombardment or transport aircraft having maximum velocities up to approximately 500 m.p.h.

COMPARISON OF MINIMUM DRAG AND MAXIMUM TRIMMED LIFT

Based on these assumptions and on the following proved data on the all-wing type, a comparatively simple analysis of advantages may be made.

The ratio of the minimum parasite drag coefficient (C_{pmin}) for all-wing aeroplanes to that for conventional types is approximately 1:2. Minimum drag coefficients for a number of large bomber and transport aircraft such as the B-29, B-24, C-54 and others average approximately .023. The minimum drag coefficients for several all-wing types have been measured both in model and full-scale configurations and vary from less than .010 to about .0113, which is the figure for the XB-35 including armament protuberances, drive shaft housings, rudimentary nacelle for gun emplacements, and so on.

The ratio of maximum trimmed lift coefficient (C_{Lmax}) for all-wing to conventional types is approximately 1.5:2.3. The latter figure is typical for a number of the large aeroplanes of conventional arrangement previously mentioned. The former is readily attainable in a configuration such as that of the XB-35 and may be subject to considerable improvement through the use of several types of high-lift devices yet to be proved.

For comparative aeroplanes of the same span and gross weight the selection of the required wing area will depend either on flight conditions, including take-off without flaps, or landing conditions. If the flight conditions govern, the ratio of required wing areas of all-wing to conventional aircraft will be 1:1 because the two wings are equally effective except under conditions of maximum lift. If landing conditions govern, the ratio will be 2.3/1.5 :1, assuming the same landing speed in each case. If take-off with partial flap deflection governs, the ratio will be somewhere between the above two figures.

In large all-wing bombers and transports, and to a growing extent in conventional long-range transports as well, the ratio of gross weight at take-off to landing weight will approach 2:1. Therefore flight conditions are likely to govern the selection of wing area more than landing conditions. In the following calculations both extremes are used as indicative of the range of advantage to be gained by the use of the all-wing configuration. Referring to Fig. 2, it may be seen from equation (1) that the total minimum parasite drag of the all-wing aeroplane in terms of the conventional aeroplane will vary from 50 percent. If flight conditions govern, to 77 percent if landing conditions govern. In this equation $(D_p)_j$ and $(D_p)_c$ represent the parasite drags of all-wing and conventional aeroplanes while S_a and S_c represent the respective wing areas.

$$1.\quad \frac{(D_p)_a}{(D_p)_c} = .50 \times \frac{S_a}{S_c}$$
$$= .50 \times 1.0 = .50 \text{ (flight condition)}$$
$$= .50 \times \frac{2.3}{1.5} = .77 \text{ (landing condition)}$$

$$2.\quad \frac{P_a}{P_c} = \frac{D_a}{D_c} \times \frac{V_a}{V_c} = \frac{D_a}{D_c} \text{ (at equal speeds)}$$
$$D_a = (D_i)_c + (.50 \text{ to } .77) \times (D_p)_c$$
$$= (1.5 \text{ to } 1.77) \times (D_i)_c$$
$$D_c = 2(D_i)_c$$
$$\text{Therefore } \frac{P_a}{P_c} = \frac{1.5}{2} \text{ to } \frac{1.77}{2} = 75\% \text{ to } 88.5\%$$

$$3.\quad \frac{R_a}{R_c} = \frac{P_c}{P_a} = \frac{1}{.75} \text{ to } \frac{1}{.885} = 133\% \text{ to } 113\%$$

Fig. 2.

It is a well-known fact, based on the Breguet range formula, that with conventional reciprocating engines and propellers the speed for maximum range is approximately that at which parasite drag and induced drag are equal. Therefore, at the same cruising speed as the conventional aero plane the all-wing type will require from 25 percent to 111 percent less power, as shown in equation (2), and with the same amount of fuel will fly from 33 percent to 13 percent farther, as indicated by equation (3). In these equations *P* represents power required, and *D* total drag. *V* is aeroplane velocity and *R* range, with the suffices a and c again denoting the all-wing and conventional configurations. If the all-wing aeroplane is operated at *its* most economical speed, instead of the most economical speed of the conventional aeroplane, it will fly 19 percent to 7 percent faster and the range will be from 41 percent to 14 percent greater with the same amount of fuel, as indicated in equation (4) of Fig. 3.

$$4.\quad \frac{R_a}{R_c} = \sqrt{\frac{(C_{Dp}S)_c}{(C_{Dp}S)_a}} = \sqrt{\frac{1.0}{.5}} \text{ to } \sqrt{\frac{1.0}{.77}} = 1.41 \text{ to } 1.14$$
and
$$\frac{V_a}{V_c} = \sqrt[4]{\frac{(C_{Dp}S)_c}{(C_{Dp}S)_a}} = \sqrt[4]{\frac{1.0}{.5}} \text{ to } \sqrt[4]{\frac{1.0}{.77}} = 1.19 \text{ to } 1.07$$

$$5.\quad \frac{P_a}{P_c} = \frac{D_a}{D_c} \text{ (at equal speeds)}$$
$$D_a = (D_i)_c + (.50 \text{ to } .77) \times (D_p)_c$$
$$= (D_i)_c + (.50 \text{ to } .77) \times (D_i)_c \times 4$$
$$\text{and } D_c = (D_i)_c + (D_i)_c \times 4$$
$$\text{Therefore } \frac{P_a}{P_c} = \frac{1 + (2 \text{ to } 3.08)}{1+4} = 60\% \text{ to } 81\tfrac{1}{2}\%$$

$$6.\quad \frac{R_a}{R_c} = \frac{P_c}{P_a} = \frac{1.0}{.60} \text{ to } \frac{1.0}{.815} = 166\% \text{ to } 122\%$$

Fig. 3.

ADVANTAGES OF LOW PARASITE DRAG

Under high-speed conditions with any type of power plant the parasite drag becomes a much larger percentage of the total drag than for cruising conditions with reciprocating engines. At high speed the parasite drag may account for 80 percent or more of the total, while the induced drag drops to 20 percent or less. Using an assumed figure of 80 percent parasite drag, which is probably correct to ±10 percent for most aircraft, the power required to drive the all-wing aeroplane at the same speed as the conventional aeroplane will be from 40 percent to 18.5 percent less, as shown in equation (5), and the range, at the high speed of the conventional aeroplane, will be from 66 percent to 22 percent greater, as indicated in equation

(6). As turbo-jet and turbo-prop power plants both operate at relatively high speed for best fuel economy, the advantages of the all-wing configuration, when used in combination with these power plants, will closely approach the above figures for maximum range as well as high speed.

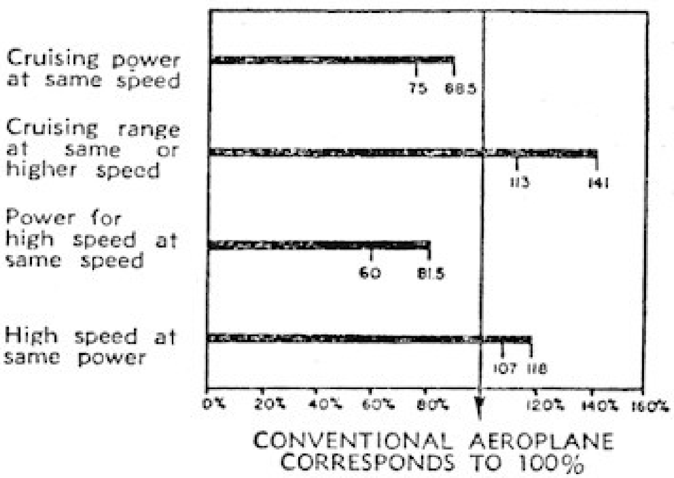


Fig. 4.
Graph of performance characteristics of all-wing aeroplane.

These advantages are summarized graphically in Fig. 4 and are all based on the simple aerodynamic values obtained with all-wing aeroplanes; namely, that C_{Dmin} equals 50 percent of conventional; C_{Lmax} equals 65 percent of conventional. The probabilities are that the minimum parasite drag can, within a comparatively short time, be reduced, at least for commercial types, to about 40 percent of the conventional figure and that the maximum trimmed lift coefficient (C_{Lmax}) may, within a similar short time, be increased to at least 75 percent of conventional values.

METHODS FOR INCREASING MAXIMUM TRIMMED LIFT

One of the most interesting devices for increasing maximum lift is, of course, the judicious use of boundary layer control in conjunction with turbo-jets or gas turbines. Another involves the development of a better combination of low pitching moment flaps and trimming devices which will permit of "lifting ourselves by our boot straps" in a more successful manner than we have achieved to date. Model configurations tested up to this time, employing such methods, have shown improvements of .1 or .2 C_L over the figure now used of 1.5.

A third possibility of rather unconventional nature remains to be proved in the all-wing aeroplane. This consists of placing the C.G. behind the aerodynamic centre of the wing, eliminating inherent longitudinal stability by so doing and replacing this characteristic, which heretofore we have always considered as an essential to satisfactory aircraft design by highly reliable (and perhaps duplicate) automatic pilots which take over the function of stability from the airframe and may perhaps do a better job of maintaining the proper attitude than the present classical method. While unconventional and possibly a bit horrifying to those unaccustomed to the idea, it may have practical application to very large aircraft where the pilot's skill and strength are largely supplanted by mechanical means of one sort or another, and wherein the pilot controls the mechanism which in turn places the aeroplane at the desired attitude. If the C.G. is located aft of the aerodynamic centre the aeroplane will trim at a high angle of attack with the flaps or elevator surfaces deflected downward rather than upward from their normal position, thereby increasing the camber and rendering the whole aerofoil surface a high-lift device. It is possible that trimmed lift coefficients in the order of 2.0 may be achieved by this method, and experiments completed to date with such a device on conventional aircraft show that the C.G. may be displaced at least 10 percent of the mean aerodynamic chord aft of a normal position without any uncomfortable results in the flying characteristics of the aeroplane.

When these improvements in C_{Lmax} and C_{Dmin}, can be realized, further startling gains in performance will accrue, as will be outlined later. It would seem, however, that the present accomplishments offer sufficient incentive to warrant all they have cost in time, effort and money, and that the question, "why bother with an all-wing aeroplane?" is already well answered.

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