No. 278 AUGUST 2009

T.W.I.T.T. NEWSLETTER

Concept for a solar-powered aircraft to explore the atmosphere of Venus. Image by Les Bossinas, NASA Glenn Research Center. See Geoffrey A. Landis, Anthony Colozza, and Christopher M. LaMarre, *Atmospheric Flight on Venus,* AIAA 40th Aerospace Sciences Meeting and Exhibit, American Institute of Aeronautics and Astronautics, Reno, Nevada, January 14-17, 2002. http://gltrs.grc.nasa.gov/citations/all/tm-2002-211467.html

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., **0908** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, September 19, 2009, 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

There is some great material in this issue that I hope all of you will enjoy. My thanks to both Jason Wentworth for an article on planetary flying wings (part 1) and Phil Barnes for his article on elliptical wings. We also have some good letters from the members and one from Al Bowers on the anniversary of the first moon landing.

We continue to slowly grow again, which is great. The new members have a diverse background and hopefully we will see some articles or other input from them in the future. As I have noted before, the newsletter depends greatly on your contributions each month, so dig deep and send me something you are working on or a question for the group the would help you better understand a concept. From what I can see there is a lot of aeronautical experience in the group and it would be a shame to see it go to waste when all it takes is a few minutes to drop me an e-mail or give me a call.

Mid-August will see he rid of my professional group's annual conference and having some time to get back to work on scanning the back issues. It will also mean I can go back through a lot of e-mails and pick up some of the relevant links people have sent me over time. So keep an eye on the web site over the next couple of months and look for the NEW balloons indicating something has been added to that particular section. If you have a link you would like to share, now is a good time to forward it to me.

I hope everyone is having a good summer and getting in some flying either the full size or model size. Both are a lot of fun.

Andy

LETTERS TO THE EDITOR

July 4, 2009

Facet Opal

I was a kid at the time, the Sapphire was built on the property/airstrip we lived on by Scott's brother Dean a master fibre-glasser.

We made throw planes from foam and had a set of RC servos and a few small engines. I believe the Opal design came from one throw model, a wing about 10cm long with a perplex counter-weight. It had so much lift with even a light throw it would do multiple loops, while it kept going for days when others die once they get dirty and knocked around a bit.

Later Scott made an RC version that had the servo mounted on a board, which pivoted and allowed another servo to use the ailerons as "flapperons". This then became the Opal. I think the wing itself is a shortened Sapphire wing without the tips, no-doubt it features similar construction techniques, as Dean really knows how to work fiberglass.

One day me and a mate made a paper plane, that only flew when dropped from the stair-well, it would come out in a zoom once the speed was high. Scott spent 2-3 hours with a ruler and calculator telling us "it shouldn't fly". A true genius.

Ben (Mr. Yellow)

(ed. – This was an unsolicited message from Ben who must have run across our web site while doing a search on the Facet Opal. Interesting history.)

July 6, 2009

I would like to buy the Nurflugel book, how do I contact the person or company to do so?

Thanks,

Fred Williams
<SWilliams568@aol.com>

(ed. – Here is what I wrote back to Fred. If anyone has better information on where to find a copy in English, please let me know so I have the information for others and can pass it along to Fred. I know Jan Scott used to sell them, but I think he ran out of copies a long time ago.

I don't know of any books in English that are still on the market unless you can find someone who would be willing to sell their copy, which is unlikely due to the rarity. The link below is to the Germany Amazon web site where they have new and used copies but the are in German. The US Amazon also have them in German but their price seems a little high at $125 for a used version versus 43 Euros, which I think is somewhat less. Shipping might bring it up so you need to check on everything before making a decision. That is the best I can tell you right now. We use to have a US dealer listing in our newsletter, but he ran out of stock many years ago.)

July 29, 2009

No need to send the newsletter, I am just printing them from the website and I like the color.

I am still trying to remember how I heard about TWITT. It may have been the talk that Al Bowers gave about the Horten wings, which I probably arrived at from doing a search on the other Horten wings that were mentioned in the more detailed write up on the San Diego Aerospace Museum's Horten jet.

I really wish I had heard of TWITT long ago, since I have been driving past your corner for the last 20 years; I would have joined then. My first solo was at El Cajon Flying Service in 1965 and I have been interested in gliders since I was in college, but I didn't start training to be a glider pilot until this year, out at Warner Springs. And I went to Northrop Institute of Technology in Inglewood for a year in 1971, so I have been interested in flying wings since then.

Thanks,

Clyde Revilee
<revilee@cox.net>

(ed. – Welcome to our newest member, who lives just a few miles from the airport. It is a shame he didn't learn about us earlier since I am sure he would have enjoyed talking with Bob Fronius. We hope he enjoys reading through all the back issues on the web site and like he said viewing them in color.)

June 8, 2009

Hello Andy,

Below is an article I've written about proposed robotic and piloted Flying Wing and tailless planetary exploration aircraft. The textual material and pictures could fill several TWITT newsletters. Also, TWITT is in a position to assist the current planetary aircraft design groups within NASA and academia. The appearance of some of the current designs suggests that some of the designers may be unaware of the finer points of tailless aircraft design, which is expertise that many TWITT members could provide. At the end of the article, I have included information about a path of liaison for any TWITT members who wish to assist these planetary aircraft projects. Here is the article:

(ed. – Jason has a number of interests and this one has a lot of flying wing associated material that everyone should enjoy. I will include images from the various web sites as the article goes along, so those of you without Internet capability can also see what is being talked about. My thanks to Jason for providing this material. I hope some of our members find the time and desire to join others on these projects through the link provided below. I didn't want to wait until the last segment of the article for you to have it.

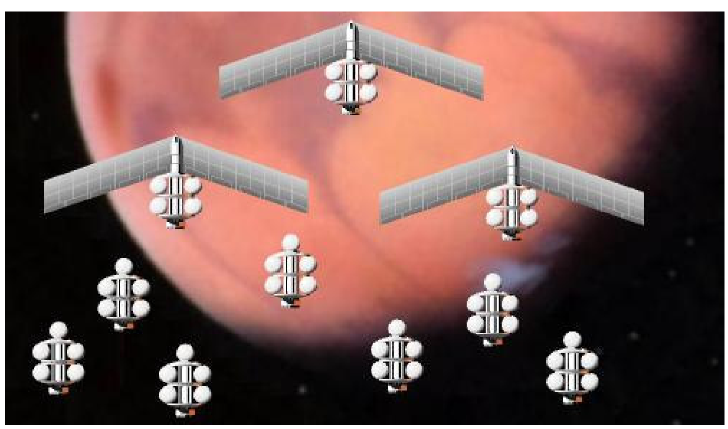
NOTE: If any TWITT members with tailless aircraft design expertise would like to assist any of these planetary robotic aircraft projects, the easiest way may be via The Planetary Society www.planetary.org/home . The society, whose headquarters are in Pasadena, California, is a citizens' space exploration advocacy organization. They have contributed instruments (such as a "Mars microphone") to previous planetary missions, and they have participated in spacecraft technology development (including work on solar sail propulsion and Mars solar hot-air balloon probes). Some of their members are current and retired NASA personnel who maintain contacts within the agency, which makes it easier for the society to avoid the typical bureaucratic red tape when working with NASA. Improving robotic planetary aircraft by using the tailless configuration is just the sort of thing that would interest them.)

"FLYING WINGS FOR OTHER PLANETS"

by James Jason Wentworth

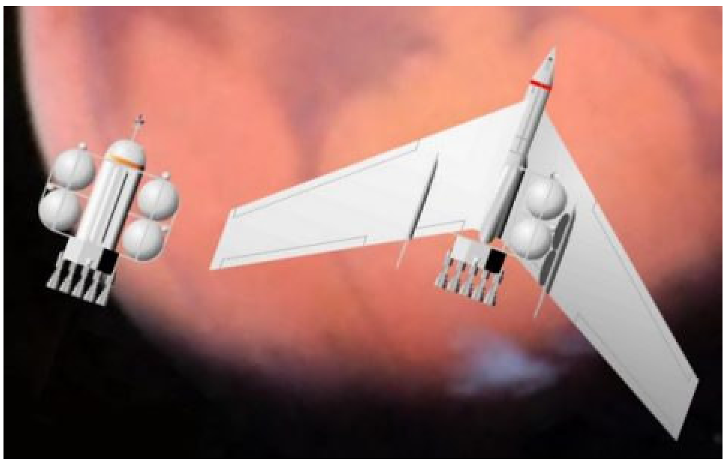
The early science fiction films introduced the public to the concept of the tail-sitting rocket ship. These spaceships, whose gracefully curved designs were inspired by the German V-2 ballistic missile, "backed down" under rocket power to the surfaces of the planets they visited. While this method is the only way to land gently on airless worlds that possess appreciable gravitational fields, it is the least efficient way to land on planets or moons that have sensible atmospheres. On such bodies, aerodynamic lift and drag can be utilized instead of brute-force rocket power. During the same time that the fictional spaceships were making their cinematic voyages, Dr. Wernher von Braun--the designer of the V-2--was drawing up plans for winged spaceships, which could fly to their landings on Earth and on other worlds with atmospheres. Interestingly, nearly every one of his designs was tailless.

In 1948, he began performance calculations and design work on two different types of interplanetary spaceships that would be used for an expedition to the planet Mars. "The Mars Project," published in 1952 (see: www.astronautix.com/craft/vonn1952.htm), called for a flotilla of no fewer than ten interplanetary spaceships, three of which included huge flying wing "landing boats" to ferry the surface exploration crews down to the Martian surface. The other seven ships were orbiters, whose crews would survey the planet from orbit and perhaps also visit Mars' two tiny moons, Phobos and Deimos. Dr. von Braun assumed a surface atmospheric pressure of about 80 millibars when he designed the winged "landing boats." Even though the Martian atmosphere is only about one-tenth as dense as he had assumed, his conservatively designed "landing boat" could still be used in an actual Mars mission. From the above-linked Astronautix.com article:



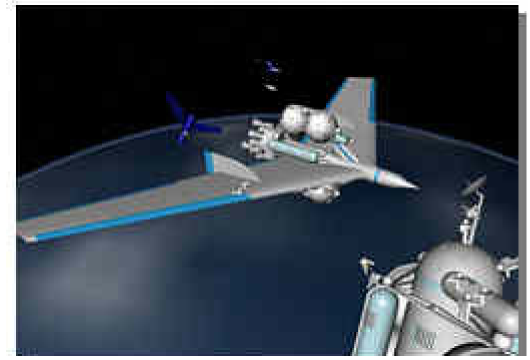
"His graceful long-winged landing boats could not have made a horizontal landing on the surface. But even this was not insurmountable. Von Braun's glider would have been subsonic at the 47 km altitude of his assumed atmosphere, corresponding to the actual surface pressure of Mars. An alternate landing scenario could have been to jettison the wings just over the surface, deploy a drag chute, and bring the fuselage/ascent stage down to a vertical rocket-powered landing on the surface. Von Braun's design had the margins and flexibility to handle even this worse-case contingency."

As his experience with ballistic missiles and sub orbital sounding rockets during the 1950s demonstrated higher rocket engine efficiencies and lighter airframes, Dr. von Braun refined and reduced the sizes of his interplanetary spaceships. In 1956 he published "The Exploration of Mars" (co-authored with Willy Ley). The new mission plan pared the Mars expedition down to



(www.astronautix.com/craft/vonn1956.htm) just two interplanetary spaceships, one with a flying wing "landing boat" and one orbiter (above). Chesley Bonestell's beautiful paintings of these Mars spaceships and of Dr. von Braun's proposed Earth-to-orbit winged space ferry can be seen here http://home.flash.net/~aajiv/bd/colliers.html

and here http://www.lepp.cornell.edu/~seb/celestia/b-vb/index.html .



The discovery that the surface-level atmospheric pressure on Mars is only about 1% of that on Earth, the apparent absence of life on the Red Planet, and the economic and political realities of the 1960s and 1970s all conspired to prevent Dr. Wernher von Braun's grand Mars expedition plans from becoming reality. However, the 1976 Viking orbiter/lander missions revealed that Mars, whether life exists there or not, has fascinating geological features (technically speaking, "areological features") that still make the planet a tempting target for exploration. The gigantic Valles Marineris canyon system, a vast network of great cracks in Mars' thick crust, stretches over half of the planet and reveals subsurface layers--up to four miles deep--that date from Mars' distant past. Mars is also home to the largest known volcanoes in the solar system. Olympus Mons, the largest, towers 17 miles above the martian surface. Thanks to Mars' relatively feeble gravitational field, the atmospheric density does not drop off with increasing altitude as quickly as it does on Earth. Thus, a Mars airplane could--in theory--fly over the summits of Olympus Mons and the other volcanoes, although the very low atmospheric pressures there (just 0.3 millibars atop Olympus Mons) would require an extremely light aircraft with a correspondingly low wing loading.

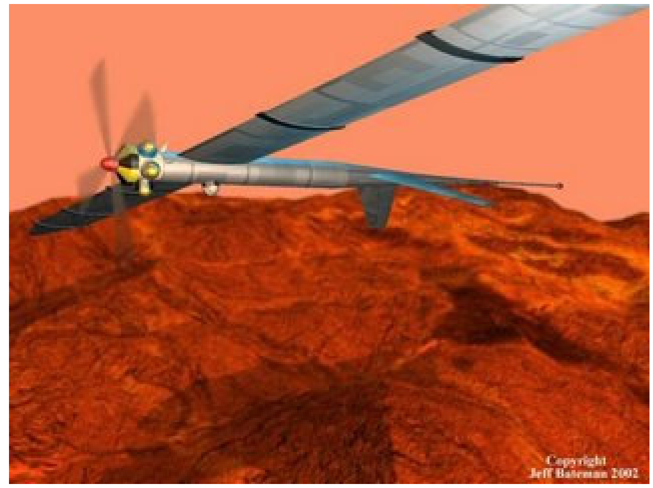
The development of very high-altitude drone aircraft in the 1970s suggested that similar aircraft (with suitable modifications) could also operate successfully in the thin martian atmosphere. But before an aircraft launched from Earth can fly over Mars it must first be delivered safely into that distant atmosphere, which requires that it must be folded up to fit inside an aeroshell heat shield. The largest aeroshells available today are 6.6 feet (2 meters) in diameter, so the aircraft must be folded into a compact package to fit inside. This series of Mars aircraft deployment images (see: http://marsairplane.larc.nasa.gov/platform.html) on the ARES (Aerial Regional-scale Environmental

Survey of Mars) web site shows the sequence of events during atmospheric entry, drogue parachute deployment, heat shield jettison, aircraft/aeroshell separation, and aircraft unfolding. (There is also a downloadable, printable paper model of the ARES aircraft on this web page.)

All of the deployment events except the unfolding of the aircraft are well-proven, having been accomplished repeatedly during several Mars lander and rover missions. The fewer aircraft parts that must be folded, the better, for each movable joint can potentially jam during the unfolding process. Both swept and plank-type flying wings have an advantage in this regard, although it took several years before designers of proposed Mars aircraft recognized this.

In 1978 a group of engineers and scientists met at the Jet Propulsion Laboratory to work toward a design for a practical robotic Mars airplane. Their initial configuration
(see: http://robotexplorers.blogspot.com/2009/01/mars-airplane-1978.html) was a tractor propeller-driven, conventional-configuration motorglider with an anhedral V-tail (top, right). It was to have been powered by a reciprocating engine that would have used hydrazine as fuel. (Hydrazine is a rocket fuel that can be used as one component of a bi-propellant system [burned with an oxidizer such as liquid oxygen, nitric acid, or nitrogen tetroxide]. It can also be used by itself as a mono-propellant, in which case it is passed through a catalyst screen which causes it to decompose into hot gases. This was the system they selected for the engine.) A more refined "pod-and-boom" variant of this aircraft appeared in "Popular Mechanics" soon afterward. The problem with both variants was the large number of movable joints necessary to allow the wings, fuselage, and tail assembly to be folded into a sufficiently small package to fit inside the aeroshell, which reduced the aircraft's likelihood of unfolding successfully.

(ed. – The last half of this article will appear in the next issue so I can include an article by Phil Barnes on his ESA 2008 Western Workshop presentation.)



The Elliptical Wing in-or-out of Ground Effect

J. Philip Barnes
Pelican Aero Group

VISIT WWW.ESOARING.COM FOR A FREE DOWNLOAD IN COLOR

INTRODUCTION

Even those of us having an extensive aerodynamic library may be surprised to learn that the well-known elliptical wing develops somewhat less lift, and somewhat more induced drag, than we may have come to expect. These "shortcomings" of the elliptical wing (actually the literature) relative to the advertised performance were perhaps first pointed out by Sighard Hoerner in his well-known book "Fluid Dynamic Drag." Herein we provide further substantiation thereof, and then extend our study of the elliptical wing to include the shape of its "planform wake" and the effects of ground proximity on induced drag, in all cases drawing from our 2008 ESA Western Workshop presentation.

We introduce a practical, two-dimensional approximation of wake rollup as seen in the plan view, then applied toward a top-level look at the formation flight of pelicans. Finally, we turn to ground effect, re-inventing "from scratch" the largely undocumented method used by Wieselsberger and Pohlhausen to compute the reduction of induced drag.

1.0 ELLIPTICAL WING LIFT AND DRAG IN FREE AIR

A wing kept well away from the ground is said to fly in "free air." Test data thereof from three sources, diverse in both time and space, are shown in Figure 1.0-1 for elliptical wings of aspect ratio 5.0, 6.0, and 6.67. The data collapses to a single curve falling 10% below the well-known lifting-line prediction. In the figure, we have normalized the lift coefficient (c_L) as a "group" which, given perfect agreement with theory, would reside precisely on the plot "diagonal." This lift group includes representative section efficiency (□) and wing aspect ratio (A). Wing angle of attack and section zero-lift *inclination* are designated (□□), respectively.

Whereas we are indebted to Ludwig Prandtl and his young associate, Max Munk, for development of the well-known *lifting-line theory*, we are also indebted to Klaus Krienes and Robert T. Jones for their more thorough analyses known as *lifting-surface theory*. The "efficiency" of an elliptical wing, in terms of the ratio of its lift via lifting-surface theory to that via lifting-line theory, is shown in Figure 1.0-2. Only for infinite aspect ratio do the two theories yield the same lift. Notice that the "efficiency" of Figure 1.0-2 for aspect ratio (A=5), predicts well the corresponding "shortfall" in Figure 1.0-1.

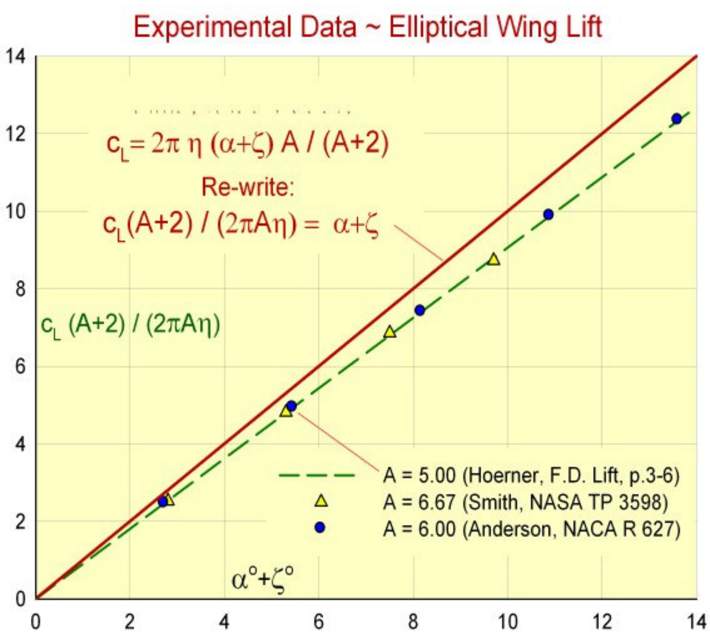


Figure 1.0-1 Elliptical Wing Lift Theory and Data

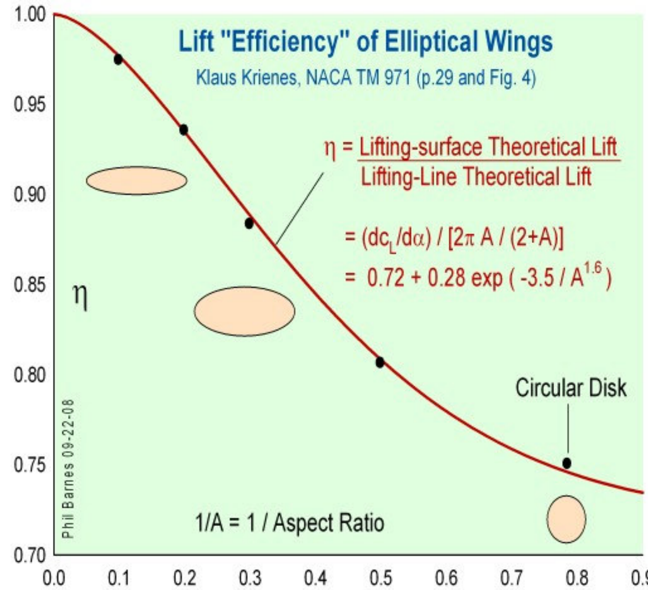


Figure 1.0-2 Elliptical Wing Lift via Lifting Surface Theory

In Figure 1.0-3 (next page), we characterize a "vortex drag group" for the test data which, given perfect agreement with theory, would lie on the plot diagonal. Again, we see a 10% reduction of performance. Yet notwithstanding the limitations of the lifting-line theory, it remains a powerful method which we will put to good use in our numerical analysis of induced drag later herein.

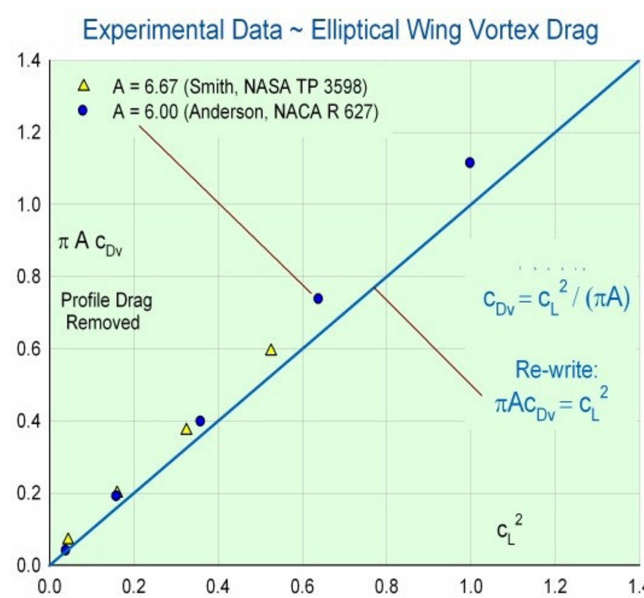


Figure 1.0-3 Elliptical Wing Vortex Drag ~ Theory and Data

2.0 WAKE ROLLUP

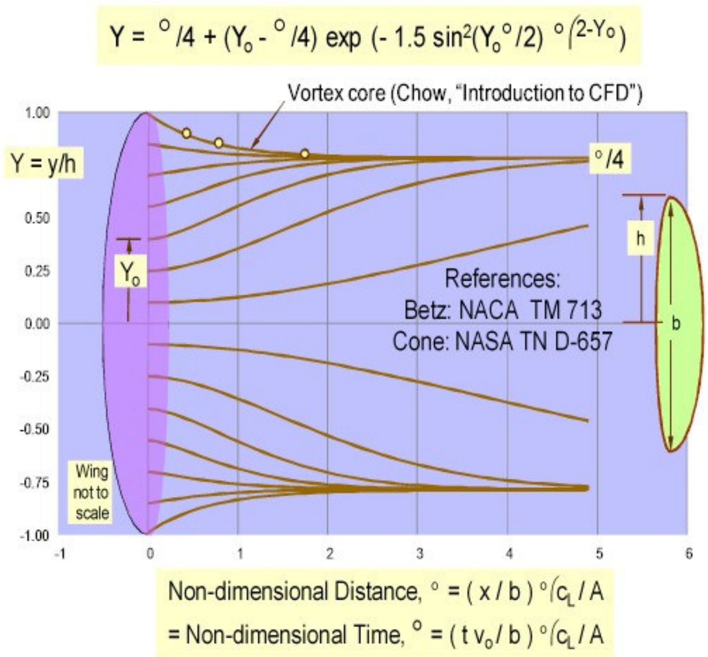


Figure 2.0-1 Elliptical Wing Vortex Drag ~ Theory and Data

In this section take advantage of the classic work of Betz, Kaden, and Cone to provide an approximate characterization of the rate at which the wake of a wing rolls up. Here, our primary application is a top-level investigation of ground effect, where we ask: "In the formation flight of pelicans, is the wake from the lead bird essentially rolled up by the time it reaches the second bird?" To most expeditiously answer this question we limit ourselves to the appearance of the wake in the plan view. Based on the referenced papers, we propose the two-dimensional mathematical model of Figure 2.0-1 to approximate the shape of the "wake planform."

Notice that the wake ultimately rolls up, in accordance with the theory of Betz, into a horseshoe vortex having a vortex-to-wing span ratio of (□/4). Note also that both the non-dimensional distance and non-dimensional time are proportional to the lift coefficient and inversely proportional to the aspect ratio, whereby the wake rolls up relatively fast for a low-aspect-ratio wing at high lift.

Now, to apply our model to the study of the formation flight of pelicans, we show various wings and their wakes, all drawn to scale, in Figure 2.0-2. If we assume that pelicans in formation are spaced longitudinally within one or two wingspans, we conclude from our analysis that those pelicans immediately following the lead pelican will experience very little wake-rollup effect. Figure 2.0-3 shows pelicans in free-air formation.

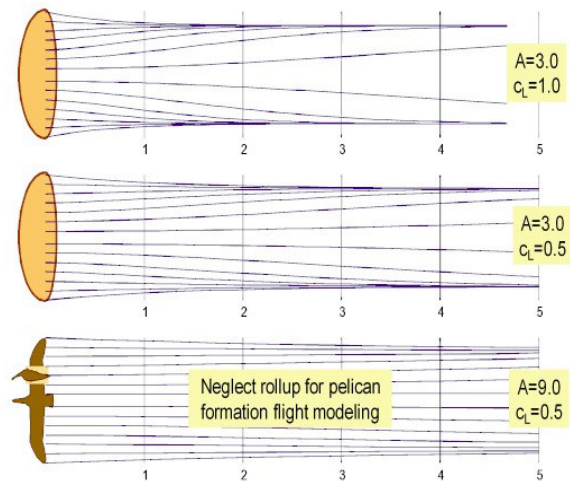


Figure 2.0-2 Wake Planform Studies

Figure 2.0-3 Pelicans in Formation

3.0 GROUND EFFECT

We are indebted to Albert Betz for his *method of images,* whereby an aircraft in ground effect can be imagined to have an inverted twin beneath the ground

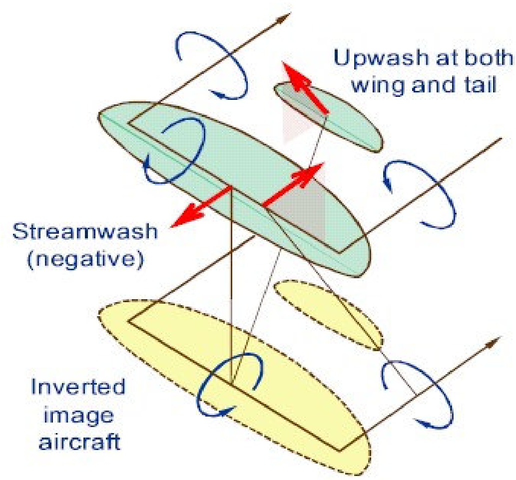


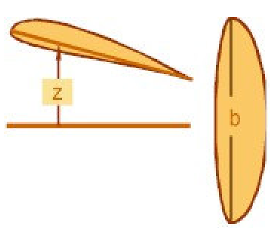
Figure 3.0-1 Vortex Interaction in Ground Effect

(or water), with all bound and trailing vortices rotating opposite to their counterparts above the ground. As a result of the mutual interaction of all the vortices, the image aircraft induces both *upwash* and *streamwash* (the latter negative) upon its upper twin, resulting in increased lift, reduced airspeed, and a negative increment in pitching moment (nose-down effect). These phenomena are illustrated in Figure 3.0-1 using a horseshoe vortex representation.

The classic analysis of induced drag in ground effect was carried out by C. Wieselsberger (NACA TM 77) with the aid of his assistant, K. Pohlhausen, and the suggestion of Ludwig Prandtl to assume that the loading remains elliptical as ground proximity increases (we show later herein that the wing tips are progressively unloaded, but Prandtl's assumption introduces only a minor error). As happens often in scientific papers, the paper author delegated the actual computation to an assistant.

Herein, we re-invent the calculations lost to Mr. Pohlhausen's notebook, while following the top-level outline of the referenced paper. We study an isolated elliptical wing, integrating from wingtip-to-wingtip the upwash due to the mirror image. Before conducting the analysis, we can expect lift to increase and drag to decrease as the wing approaches the ground. But at this point we ask: "Does aspect ratio influence the reduction of induced drag for a given lift coefficient?"

Although the details of the method are found in the Appendix for the benefit of the interested reader, we point out here the highlights of the method and its results. First, the analysis normalizes the local upwash velocity as a ratio (□=u/v_o) to freestream velocity. This upwash angle is further normalized as a ratio with the free-air downwash angle (□$_o$) which, for elliptical loading, is given by [c_L/(□A)]. When the normalized upwash is integrated (Appendix) and then plotted versus the non-dimensional spanwise coordinate (Y=y/h) we obtain the family of curves shown in Figure 3.0-2.



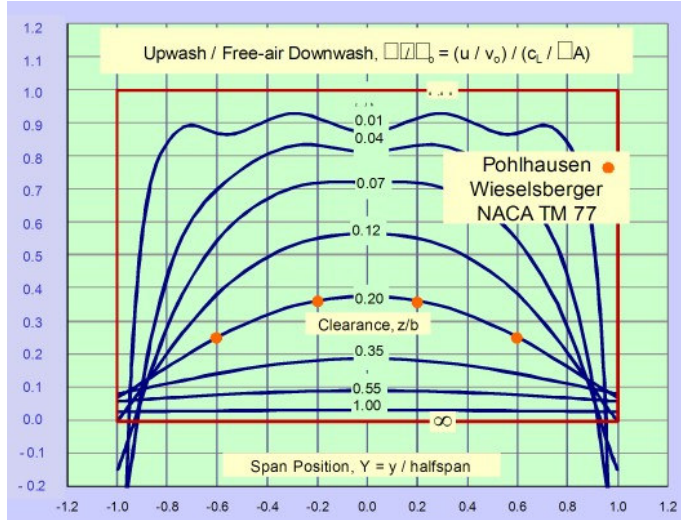


Figure 3.0-2 Integrated Normalized Upwash in Ground Effect

Here, an interesting characteristic is a "bounding box" with a lower limit representing free air (no upwash) and an upper limit representing lifting-line contact with the ground and total cancellation of free-air downwash, with induced drag vanishing in the limit. The curves in between represent various non-dimensional elevations (z/b) expressed in "wingspans." These calculations, performed with the aid of a computer, agree well with the apparently laborious hand calculations carried out by Pohlhausen. We point out that our sign convention differs from that of Pohlhausen by treating both upwash and downwash as positive in their respective directions.

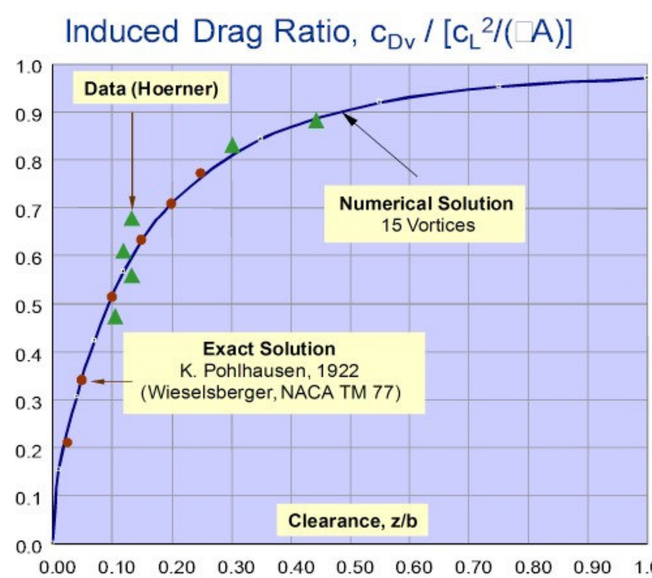
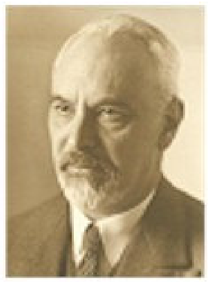


Figure 3.0-3 Induced Drag Ratio in Ground Effect

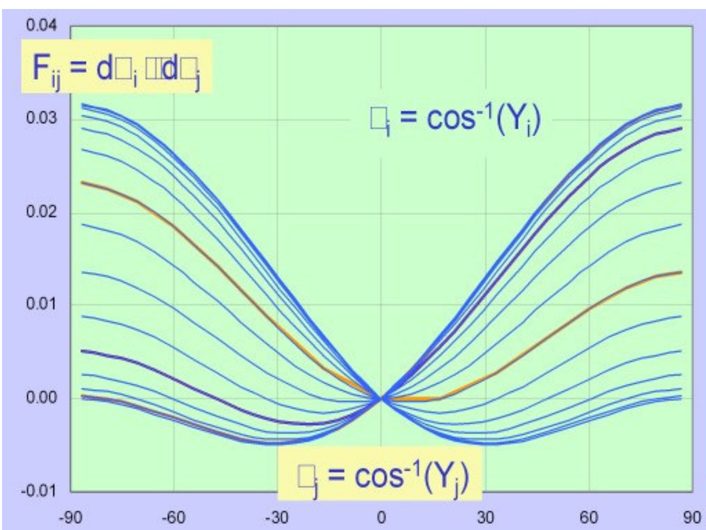
Key results of the analysis include (a) wingtips are unloaded as [z/b] decreases and (b) the induced drag reduction is independent of aspect ratio. This last result is made more clear by Figure 3.0-3 (previous page), showing the effect of ground proximity on induced drag. Our numerical method agrees not only with the calculations of Wieselsberger and Pohlhausen, but also with test data representing both elliptical and rectangular wings. Albert Betz's *method of images*, and Prandtl's *elliptically-loaded wing* concept have once again been validated.

Albert Betz



Ludwig Prandtl

APPENDIX Numerical Integration of Upwash in Ground Effect



Upwash Integrand versus Span Position in Terms of the Glauert Coordinate (□)

(ed. – See the next page for the last illustrative graphic.)

(ed. – This seemed like a very appropriate letter that Al Bowers posted on the Nurflugel bulletin board, considering Jason's article on a Mars lander.)

On the eve of the 40th anniversary of the first Moon landing, I thought it might be of interest to share some information. NASA has a special web site with all the transcripts, photos, and movies from Apollo. The men who went there, Armstrong, Aldrin, Conrad, Bean, Scott, Irwin, Duke, Young, Shepard, Mitchell, Cernan and Schmitt, all deserve our deepest respect and admiration (note: of the six commanders who landed on the Moon, five of them were Naval Aviators from the US Navy, and had landed on aircraft carriers,; all of them said a night carrier landing was harder than landing on the Moon ;-).

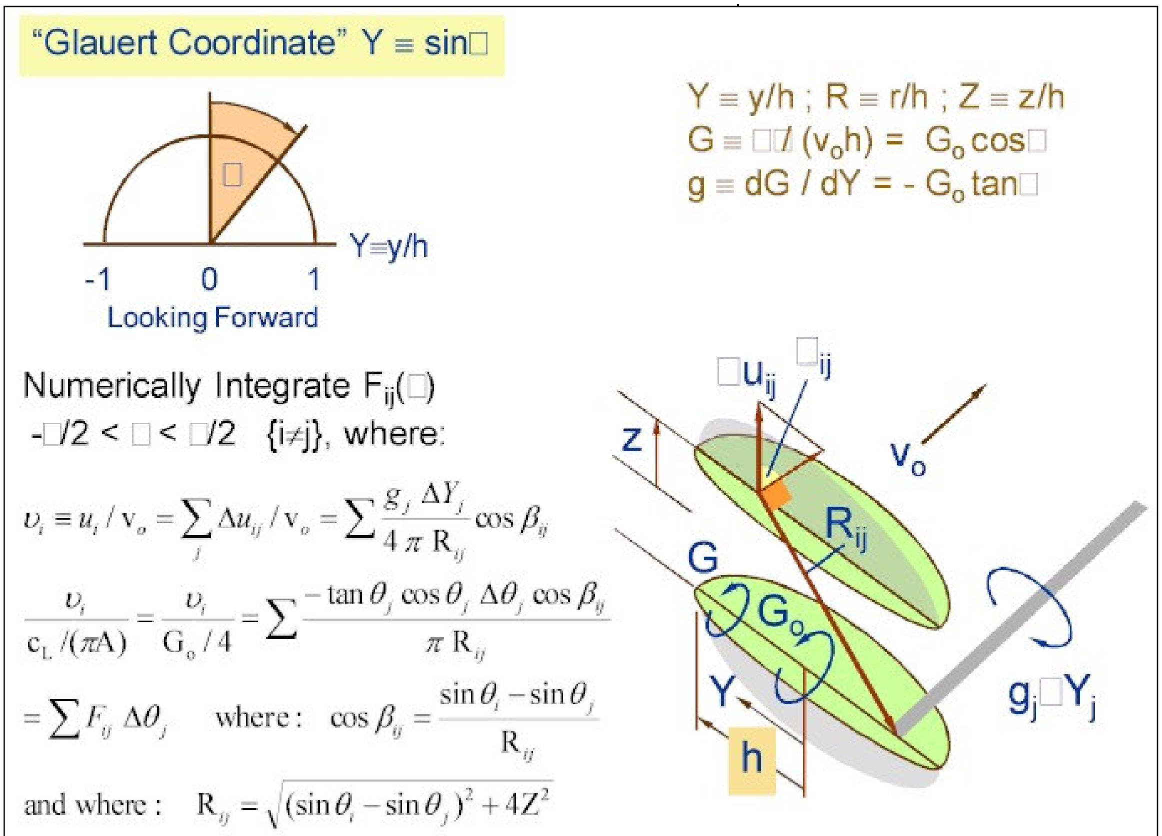
This is the link:

http://www.hq.nasa.gov/office/pao/History/alsj/frame.html

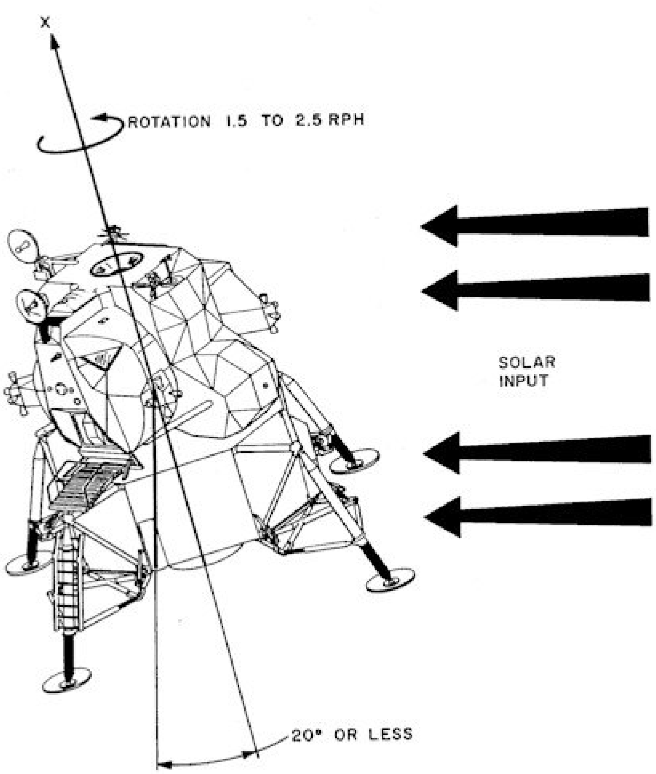
Some of the most interesting bits, for me, have come from the Apollo 12 landing movie, and the Apollo 17 landing movie. In particular, the commentary from Pete Conrad and Al Bean (Apollo 12) during their landing is very different than that from Apollo 11. We have all seen the footage from Apollo 11 many times, but the Apollo 12 landing is very different. Both Conrad and Bean were very verbose about what was happening. And the Apollo 17 landing with Cernan and Schmitt is also somewhat colorful due to the landing at Taurus-Littrow in a valley deeper than the US Grand Canyon (about 6000 ft deep, or 1800m).

To understand both landings, you have to understand the approach used by the Lunar Modules. With the descent engine pointed out through the floor, the primary part of the burn to landing was to decrease the delta_v to match the angular rate of the Moon from the low lunar orbit. So the LM was at about a 70 degree pitch down to about 3000 ft (900m) altitude above the surface of the Moon. At this point the LM would "pitch-over" to about 20 degrees off vertical to begin the terminal descent to the lunar surface. It would not be until pitch-over that the crews could see where they were going! In general, all Mission Commanders took over manual control after the pitch-over to complete the terminal descent to the surface. Further, each crew worked out the responsibilities, but all of them selected that the Mission Commander was "eyeballs-out" to visually watch the terrain they were landing on, and the Lunar Module pilot was "eyeballs-in" watching all the LM systems and call out the fuel, the altitude, and descent rate for the Commander (e.g. "9%, 240 and 20 ft/sec" is 9% fuel remaining, 240 feet altitude, and 20 ft/sec descent rate).

It would not be until pitch-over that Conrad & Bean could see the Surveyor III spacecraft that they were to land beside. The Surveyor III was their "aim-point". After traveling about 240,000 miles (approx 390,000 km) they landed about 150 ft (~45m) from the Surveyor



III. Their astonishment at seeing they were about to land so close is very evident in their voices at pitch-over.



Translunar Flight (Illustration from the Apollo 11 section of the web site.)

In the case of Apollo 17, Cernan and Schmitt were dropping into Taurus-Littrow, and the pitch-over wasn't until they were already down INSIDE the valley! Cernan was a very "cool customer" but even he had some comments about the peaks he was coming down between. Also, Apollo 17 was the only decent footage of the ascent stage of the LM leaving the Moon.

The footage is awe-inspiring. It is something that ALL of us in aerospace should be proud of.

And it is just TOTALLY cool footage...

Al

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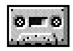

(ed. – These videos are also now available on DVD, at the buyer's choice.)

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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.
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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 in the Smithsonian IMAX film. This was an Aerovironment project led by Dr. Paul MacCready.
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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".
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I will have to go back and find out where this picture came from and whether I have used it before. This is a super example of how far the R/C modeling world has come over the years in terms of scale and quality.