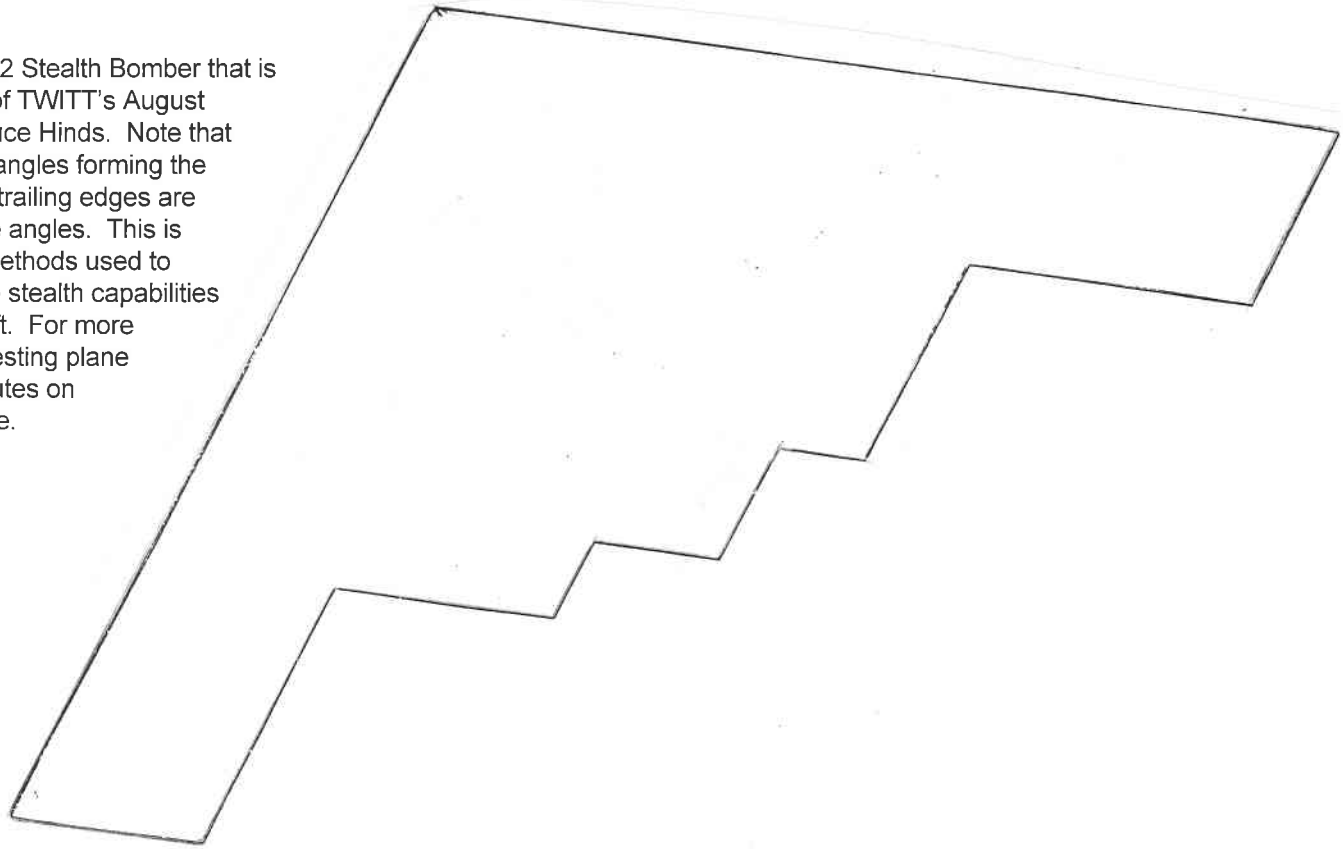
No. 122 AUGUST 1996

T.W.I.T.T. NEWSLETTER

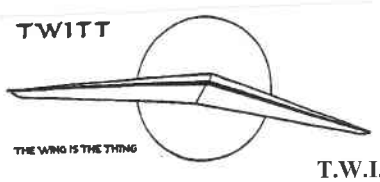


Outline of B-2 Stealth Bomber that is the subject of TWITT's August speaker, Bruce Hinds. Note that none of the angles forming the leading and trailing edges are at 90 degree angles. This is one of the methods used to help with the stealth capabilities of the aircraft. For more on this interesting plane see the minutes on page 2 inside.

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

The number to the right of your name indicates the last issue of your current subscription, e.g., **9608** means this is your last issue unless renewed.

Next TWITT meeting: Saturday, October 21, 1996, beginning at 1330 hrs at hanger A-4, Gillespie Field, El Cajon, CA (first hanger row on Joe Crosson Drive - East 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.

T.W.I.T.T. Officers:

President: Andy Kecskes (619) 589-1898
Vice Pres: Bob Chase (818) 336-5485
Secretary: Phillip Burgers (619) 563-5465
Treasurer: Bob Fronius (619) 224-1497
Editor: Andy Kecskes

The T.W.I.T.T. office is located at:
Hanger A-4, Gillespie Field, El Cajon, California.
Mailing address: P.O. Box 20430
El Cajon, CA 92021

(619) 596-2518 (10am-5:30pm, PST)
(619) 224-1497 (after 7pm, PST)
E-Mail: NBKP63A@prodigy.com

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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, east side of Gillespie).

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PRESIDENT'S CORNER

I would really like to thank everyone who came out for the August meeting. It was a super turnout as you can see from the minutes starting on page 2, and I think our speaker, Bruce Hinds, was pleasantly surprised to find such a knowledgable group of people and who had a genuine interest in not only the B-2 but flying wings in general.

I want to give a special thanks to Chris and Connie Tuffli for bringing, and serving, the cake and ice cream. I obviously hit the spot since there was very little of the cake left over for take home. We couldn't ask for better hospitality chairpersons.

I talked with Craig and Nancy Roberts after the meeting and they say the input of the library information is moving along at a good pace. Although they didn't have an exact completion date, I think they are nearing the end. Once it is all in an electronic format I will be able to sort it and put it into some type of logical order for printing. That part of the process shouldn't take too long and I should be done with all my other last minute projects by the time they are done with the input work.

I have not been able to get in touch with the individual responsible for putting together the newsletter index. I will try again and if it fails begin looking into new options for getting that project back on track. If there is anyone out there that would like to take it on, let me know and I may take you up on it once I know there is no other choice. It will take someone with a computer and either Lotus, Excel, Access, WordPerfect or Microsoft Word to do the job and make the data transportable to me for final formatting and printing.

I was glad to see that we are getting some new members, although we are loosing some of our current ones from not paying their annual membership dues. The new ones seem to be hearing about us by word of mouth which is good because it means people are talking about flying wings and gaining a greater appreciation for their capabilities. We hope to hear from our new members letting us know where their interest are putting them in touch with others moving in the same direction.

Andy

OCTOBER 21, 1996 PROGRAM

Next month's program will feature one of our own members, **CRAIG ROBERTS**, who will be telling us about his on-going flying wing project. At this point it is in the model stage with a flying version that he says is superbly stable. Of course he will be bringing the model and he anticipates video footage of the flights. We should have more details for the October newsletter. It should be fun, so make sure to mark you calendars now for that important day.

MINUTES OF THE JULY 20, 1996 MEETING

The meeting got started a little later than planned but the wait was worth it since we had 35 attendees who signed in plus at least another 5 walk-ins. That's a super turnout in anyone's book. Andy thank everyone for coming and making the meeting such a success. After the usual housekeeping items, Andy asked everyone to introduce themselves so our speaker, Bruce Hinds, could get an idea of the calibur of audience he was about to face.

It was nice to see some familiar faces like Roman Benn and Johnny Parker who are long-time glider types, Ed Lockhart who has been noticably absent of late, E.E. Larabee who is a propeller designer, Jim Logsdon who is assisting with the flight museum at Edwards AFB, and Bob Cardenas a former AF test pilot for the YB-49.

We all owe a debt of graditude to Chris and Connie Tuffli for seeing to it that we had a super anniversay cake with the TWITT logo and lots of vanilla ice cream to help wash down the very hot day in a metal hanger. They have been marvelous hospitality chairpersons. Thanks from all of us.

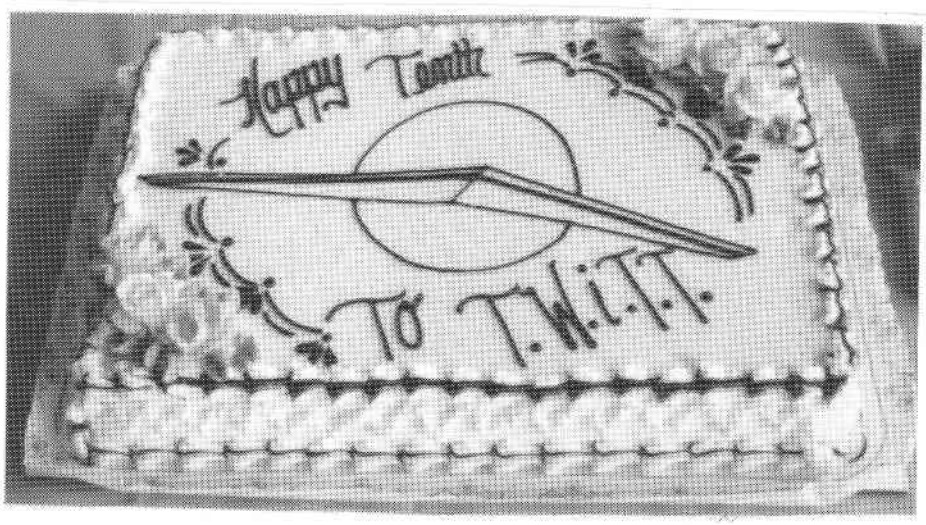
Without further ado, Andy introduced Bruce Hinds, former B-2 test pilot for Northrop who would being telling everything we ever wanted to know about the B-2 but didn't have anyone to ask.

Bruce opened by giving us an overview of his career in the Air Force as a test pilot and then how he got involved in the B-2 program in 1982. For the first year he was on the program he couldn't say he was really working for Northrop and then for the next 8 year he couldn't say he was a pilot. This was all due to the security surrounding the program since they didn't want knowledge of low radar observability to get out to other competing nations during the cold war period.

We closed the doors so Bruce could pull out his view-graphs and show us more of the details. He commented, as many have in the past, that the wing span is the same 172' of the YB-49. The length is about the same as an F-4 fighter, and the side profile is also about that of an F-4, but packaged in a 350,000# airplane vs a 48,000# fighter.

The payload is about 40,000#, has a range of 6-7,000 miles unrefueled due to the efficiency of the wing. The wing is pretty fat so the aircraft is sub-sonic, but since it is stealthy speed is not as important a factor. With inflight refueling the range can be increased to about 10,000 miles which will allow it to get to almost anywhere in the world. It carries both conventional and nuclear weapons, and the conventional aspect was in the initial development, not an after thought. It flies at high altitudes where it gets the best efficiecy from the engines and airframe configuration (flying wing).

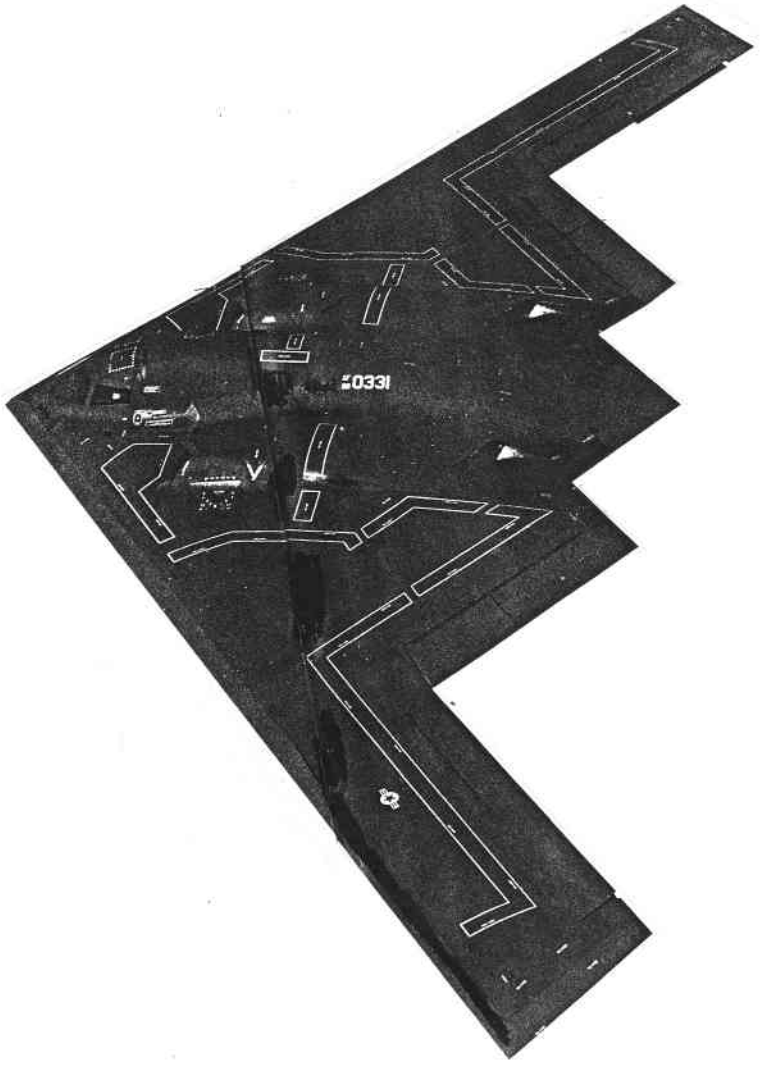
It has a quad-redundant, fly-by-wire flight control system using space shuttle type systems. The original design called for it to be flown by a single pilot with a navigator system operator. The Air Force now uses two pilots to provide some redundancy in this area as well if something should happen to the primary pilot. There is a small area where a third pilot can be carried for those longer air-refueling missions that allows room for laying down for sleeping along with a small galley and latrine facility.



The engines are General Electric F-118, low by-pass type with 19,000# of thrust each which is not a really good thrust to weight ratio. However, the wing's efficiency makes up for what would seem like an under powered condition. They are a spin-off of the F-101 engine with the by-pass ratio reduced to .8 from 2.0.

The landing gear has a 40' spread between the mains with

30' between the mains and the nose gear. This is sort of opposite of something like the DC-10. He said it makes for some interesting ground handling characteristics due to the enertia of the large amout of fuel in the wings. Also, there are no vertical surfaces to assist in keeping the plane moving in a straight line.



ABOVE: View of the upper surface while in flight. Angle of picture is causing the apparent differences in wingtip sizes. White oulined areas designate the authorized walking paths for the ground crew. Contract is not good enough to see the wide flat exhaust nozzels next to the little white dots in the aft center section. Photo extracted from Aviation Week & Space Technology, April 17, 1995, pp. 46-47.

Bruce put up a slide showing the major subcontractors of the main components. Boeing was responsible for most of the structural work, developing their composite technologies along the way. We now see some of this in airplanes like the new 777. They did the 72' outboard wing panels including the skins, ribs and stringers. The skins range in thickness from about .25" at the wing tip to about 1 - 1/12 inches at the inboard end.

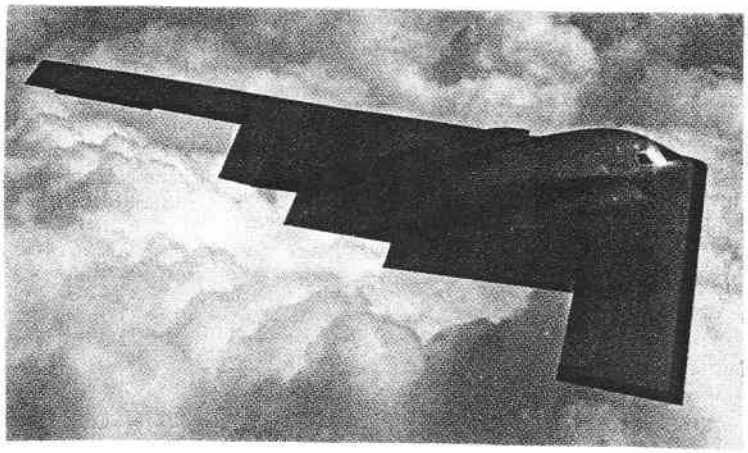
Boeing also made the aft center section that contains the bomb bays. They are 44' long by 13.5' high and 10' wide and there are 2 of them side by side. The bombs can be carried on a rotorary system or in stack packs depending on the type of ordinance and the delivery method.

Vought did the intermediate wing section which was probably the most complicated part. This section has a NASA inlet for radar cross section reduction and has a lot of secondary airflow for cooling ducts and the engine's exhaust. It contains 55% of the usable fuel, carries the two engines on each side, and has an area for the auxilary power unit. The exhaust section is much more flat than the traditional engine which allows for a lower radar signature and allows for faster cooling of the gases to prevent infrared detection. The titanium landing gear is also housed in this section.

Northrop was responsible for program integration and construction of the forward cockpit area. They also were responsible for the flight control systems, leading edges and the rest of the steathy stuff like leading edges.

Hughes constructed the radar and navigation systems. The radar can do ground mapping for bombing runs, but it can also has a terrain following capability, air to air modes as well as some other classified abilities that Bruce couldn't explain further.

One of the key elements of the development program was the capability for Northrop to establish a video and data link via satelitte with Boeing, Vought and the design center at Wright Patterson AFB on a real time, secure basis. Each party was looking at the same pictures and data and whenever a change was made everyone saw it at the same time and had the same information from which to produce their respective components.



ABOVE: Another inflight shot from Aviation Week & Space Technology, April 17,1995, p. 55.

The question was asked about how the major components were attached to each other. Bruce explained this was done through titanium fittings and

bonding. There is a load path along the forward and aft areas of the wing box. The first aircraft was built using the production tooling and was another reason for the video and data links between the various sub-contractors. It made for such perfect junctions that there are no steps or bumps in the surface which could cause any radar reflections.

Bruce then moved on to the flight control system which covers the entire trailing edge of the wing. One of the new technologies on the airplane was the sevro actuation systems. Each actuator has two hyraulic systems going to it along with a lot of computer input and monitoring systems. If one side should fail then it automatically switches to the alternate system. Each flight control has at least two actuators so there is a minimum of two hydraulic systems available to the controls at all times.

ABOVE: From left to right: Bruce Carmichael (aeronautical engineer and author), Bob Cardenas (YB-49 test pilot), Bruce Hinds (B-2 test pilot and today's speaker), Bob Fronius (one of TWITT's original founders), and Andy Kecskes (TWITT President). Photo taken by Phillip Burgers.

The main pitch control is through an inboard and outboard elevon. Yaw control is achieved through drag rudders opening in a clamshell fashion very similar to the YB-49 and other early Northrop experimental prototypes. There is also a gust load aleviation surface that goes down about 11 degrees for takeoff and acts like a body flap. Each surface is independently controlled and each hydraulic powered surface has an actuation rate of 100 degrees per second which is extremely fast for a large aircraft. This compares to about 10 degrees per second for an F-16 rudder.

The reason for such a high rate of movement is so the aircraft can fly in a terrain following mode at over 500 kts versus the lower speeds of earlier planes. The composite contruction makes the airframe very stiff there it needs to be protected from gust loads. The surfaces can react fast enough to reduce the bending moments to acceptable limits. As an example, Bruce mentioned the B-52 wing tip moves through about an 18' arc under a 2g load, whereas the B-2 only moves about 18". This is accomplished by having the gust sensors at the leading edge and then having computers react within micro-seconds to move the control surface, like the body flap being put down to move the center section up to meet the upward movement of the tips in a gust situation.

The drag rudders also move at such high rates that the aircraft is very stable in the yaw axis. To achieve the steathly characteristics the engines are also controlled by the computers to provide differential thrust so the control surfaces don't have to be moved and provide something for radar to bounce off of.

Contrary to popular belive, the aircraft is flown in a neutrally stable condition rather than with an aft CG. The more stable approach reduces the amount of control movement which also reduces the radar cross-section by keeping them in the streamlined position as much as possible.

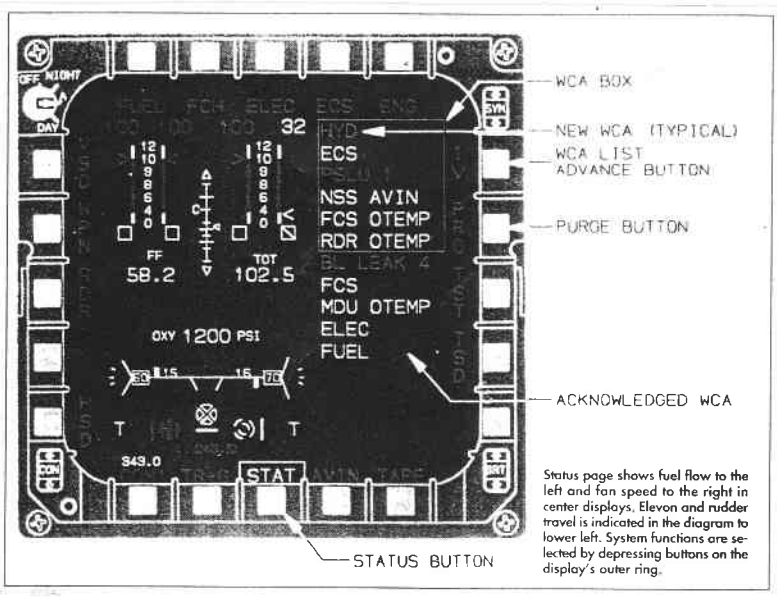
There are no pitot tubes sticking out anywhere since they too would create a radar return. The sensors are flush mounted in the leading edge which means they have an angle to airflow. Computers handle all of the conversions, but the engineers had to do a lot of testing to achieve the right correction factors for level and turning flight. These sensors are also quad-redundant like the flight control system. How well they worked was of great concern before the first flight since there were no plans to put the customary boom on the front since it would have to be at least 70' long, defeating the whole purpose. There is an attitude motion sensing system using a ring-laser gyro that would provide a backup if the pitot sensors were ever completely disabled.

The cockpit uses CRTs for displaying flight information being run by what are today old technology computers. Anything can be displayed on any screen. (See a sample screen on the next page.)

The aircraft is set up to be flown by a crew of two with the pilot in the left seat and the mission commander in the

right seat. The flight controls are duplicated on each side so they are redunant both for mission completion capability and to provide for aircrew training.

The computers are all linked together through a multiplex bus which allows the use of buttons to provide functional data with the push of a single button. There are 3 of these used for takeoff, go-to-war, and landing. The takeoff mode sets up the flight controls, turns on the radios, shows the takeoff performance data, and provides any warnings if something is wrong. The go-to-war button turns off anything that would emit a signal that could be detected, all external lights and configures the flight controls for the stealth mode. The landing button set the flight controls for approach and landing, gets the radios back on line and provides the necessary performance data.



ABOVE: Example of a display on one of the CRTs used by the crew to monitor system's operations, provide navigational and bombing data, and receive aircraft flight performance information. Photo from Aviation Week & Space Technology, April 17, 1995, p. 50.

They found that an airspeed of 140 kts was a good all around speed for takeoff and landing performance. It was optimal for full gross weight takeoffs and only used slightly more runway at lower weights. Approaching at 140 did not adversely affect the landing distance at different gross weight, 3,000' being about the normal rollout distance. Bruce joked about a pilot being able to fly the airplane by remembering 140 kts and being able to push the 3 mode buttons.

The pilots use control sticks that have about the same amount of movement as a B-1. There was some experimentation with side mounted version like the F-16 and with control wheels, but the full movement stick was the final choice.

The question was asked if the aircraft has a high angle of attack during the landing approach. Since it is a flying wing the angle is only about 7 degrees. It has an angle of attack limiter that stops the pitch movement about 3 degrees below max CL. This capability will allow it to do a 2 g turn at approach speeds which was one of the things Bruce liked to show new pilots during simulator training.

Bruce's next slide covered the various types of weapons that can be carried in the internal bomb bay. They have all been tested and approved. The question was asked about air-launch cruise missle capability and Bruce responded that it was not part of the original planning but that the bomb bay was capable of handling the typical missle's size. The point was made that you have an aircraft that is capable fo reaching the target because of stealth so why would you want to carry a stand-off weapon like cruise missles.

Bruce briefly went over how the stealth capability impacted the ability to conduct war time operations. Basically the B-2 can do the work of a large armada of more conventional aircraft that have to rely on electronic counter measures and other tactics to reach a target. He also showed a slide that demonstrated the difference in radar pentration capabilities between something like the B-52 and the B-2. He felt stealth may have had a great deal to do with the end of the cold war since the cost to the Russians of building a defensive radar system to detect a B-2 would have been prohibitive.

Bob Archer (who designs and manufactures low drag aircraft antennas) had asked where all the antennas were on the B-2. Bruce showed a slide where he pointed out all of the flush mounted ones and the radar antenna is built into the skin with a tuned radome.

The noise and infrared signatures are minimized by placing the engines on top and deep inside the wing. Once in the cruise mode at about 80% power the aircraft is very quiet so noise detectors would have a hard time finding it. The exhaust also exits on top the wing and is cooled very rapidly so by the time it leaves the trailing edge its IR signature is almost the same as the ambient air.

There was a short period of questions and answers where it came out the B-2 had a glide ratio of 23:1 which is similar to that of a Blanik but its at 140-180 kts. Because of the flying wing efficiencies it can fly on one engine at at gross weight of 180,000 pounds (that's on 19,000 # of thrust).

After a few more questions, we all thanked Bruce for coming down and giving us an excellent presentation. Andy then told everyone we would be taking a short break to enjoy the cake and ice cream and cool down a little before continuing with the day's program.

B-2 Team decal. Note that each Vee of the star forms the leading edge for a B-2 outline. Each of them can be peeled out and used as a stick-on leaving the black star and B-2 shapes to show up on a white background.

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ABOVE: Left to right: Pat Oliver, builder of the semi-scale N9M being held by Bob Cardenas and Bruce Hinds.

After a few more questions, we all thanked Bruce for coming down and giving us an excellent presentation. Andy then told everyone we would be taking a short break to enjoy the cake and ice cream and cool down a little before continuing with the day's program.

After the break Bruce showed a short video of the B-2 in flight and answered a few more questions that came out from the video footage. We again thanked Bruce for a very enlightening program.

Before continuing, Andy annouced the items that were available for raffle prizes today and that there would be 3 tickets pulled with each winner getting his choice of one of the items.

Andy then introduced Pat Oliver who came up to show the group his standoff scale version of an N9M he had made using a Klingberg wing as the basis. This is a radio controlled glider type model that Pat has now successfully flown. He says it flies fast and seems to handle very well.

Pat started with the basic model kit and began making modifications to make it look like the N9M. These included making a new set of ribs to increase the chord for a more scale look. It has 706 sq. in. of area, an aspect ratio of 9.1 and has a wing loading of 7 oz/sq ft so it will fly slowly. The airfoil is asymmetrical to about the 65% span point then changes to an inverted camber by the time it gets to the tip. This was the airfoil provided for by the original kit, he simply made new ribs for the increased chord at the root section.

It uses an electronic mixer to move the control surfaces which is one of the nice features in most of the newer radio control systems now on the market. There is one servo for each of the surfaces so only one stick is used to actuate the elevons. This eliminates the need for a sliding tray and the associated problems of friction and binding.

Pat is also working on a straight wing flying wing similar to a Mini-Bat that is based on a set of Schweizer 1-35 wings that have a lot of under camber. He plans on calling it the Tumble Bat. He indicated he would keep us up to date on how each of them develops and flys.

Andy had Pat draw the tickets for the raffle prizes with the first one going to Howie Burr who took the Swiss type army knife, the second going to Bruce Carmichael who took the combination pliers set, and the last one to Dominique Veillard who took the snap shot camera.

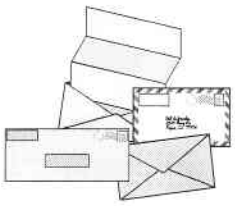
Andy then asked Bob Cardenas if he would entertain any questions about the YB-49 since he was one of the Air Force test pilots. He gave the group a hair raising tale of how not to stall a flying wing. The stall series started at 20,000' and got to such a high angle of attack that before he knew it the airplane tumbled over backwards out of control. Fortunately for him and the crew the throttles were located on the cabin roof where his hands were pinned by the g-forces. He grabbed a handful of four

levers and slammed them to full power on one side and opened the opposite drag rudders to try and force it back into level flight. They were lucky that day in that he was able to pull it out of the resulting dive at about 1,000'. He wrote up a report saying it should not be intentionally stalled and that the stall series was completed.

He clarified that he never said the aircraft was unstable, but rather it had demonstrated margin stability around all three axis' as a result of which it would develop occilations coming out of maneuvers. This was an obvious problem for a bomber trying to make a stable bomb run that requires great accuracy. At that time the autopilot system did not include things like stablility augmentation systems that could be added to the vertical fins to help with this problem.

He related that he thought that one of the reasons the YB-49 was not successful was that it was ahead of the technology for the time. The B-2 was the result of new technology that over came all the earlier problems and took the theory even further with stealth capability. He went on to talk a little bit about tactics where the B-2 would come into play and it is because of the flying wing's efficiency that it will be able to perform these missions.

Andy thanked Bob for his time and comments for the group. There being no further business Andy adjourned the meeting so everyone could enjoy more cake and ice cream and talk with Bruce and Bob on a more casual basis.



LETTERS TO THE EDITOR

July 23, 1996

TWITT:

I am writing an article about the XB-35/YB-39 for Air and Space Magazine and an internet acquaintance directed me to you.

I would be very grateful to have copies of recent newsletters, along with membership information.

Thank you so much, and long may you prosper,

Dan Ford
433 Bay Road
Durham, NH 03824
(603) 868-5850 (voice/fax) 8am-8pm EST
E-mail: dan.ford@unh.edu
danford@cris.com

(ed. - Since Dan had an e-mail address I sent him the membership information and asked if he would like to purchase those newsletters that dealt with the XB-35/YB-49 so he would have some help with his article. I also told him about the "Wing Will Fly" video which we have that has some additional comments by Bob Cardenas that didn't make it on the Discover Channel's version. If any of you out there would like to help him with some unusual or as yet unpublished information about these planes or the people who flew them, I'm sure he would appreciate it.)

July 15, 1996

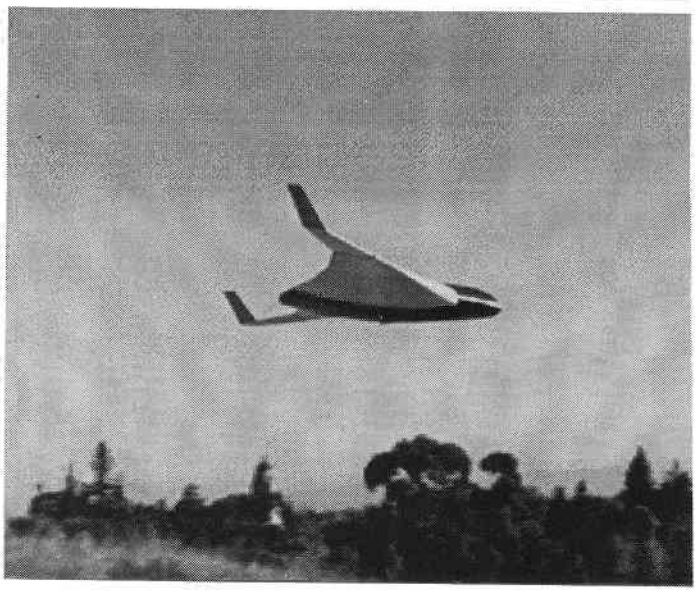
TWITT:

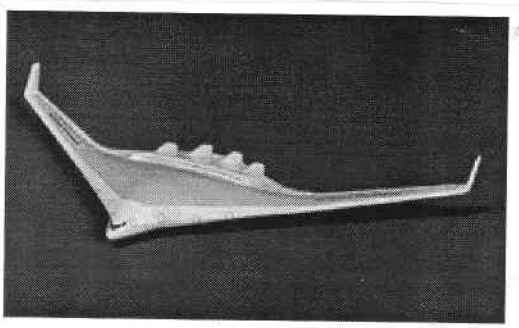
Enclosed are a couple of items to help populate the newsletter.

The first is some information on a large tailless Blended Wing-Body transport aircraft that is under study by a consortium of McDonnel Douglas, NASA, and Stanford University. For those of you that have access to the Internet, they have a home page at:

http://aero.stanford.edu/BWBProject.html

The Blended Wing Body home page includes video of a model of the aircraft in flight. (Below: Model in the landing phase and a comcept model.)





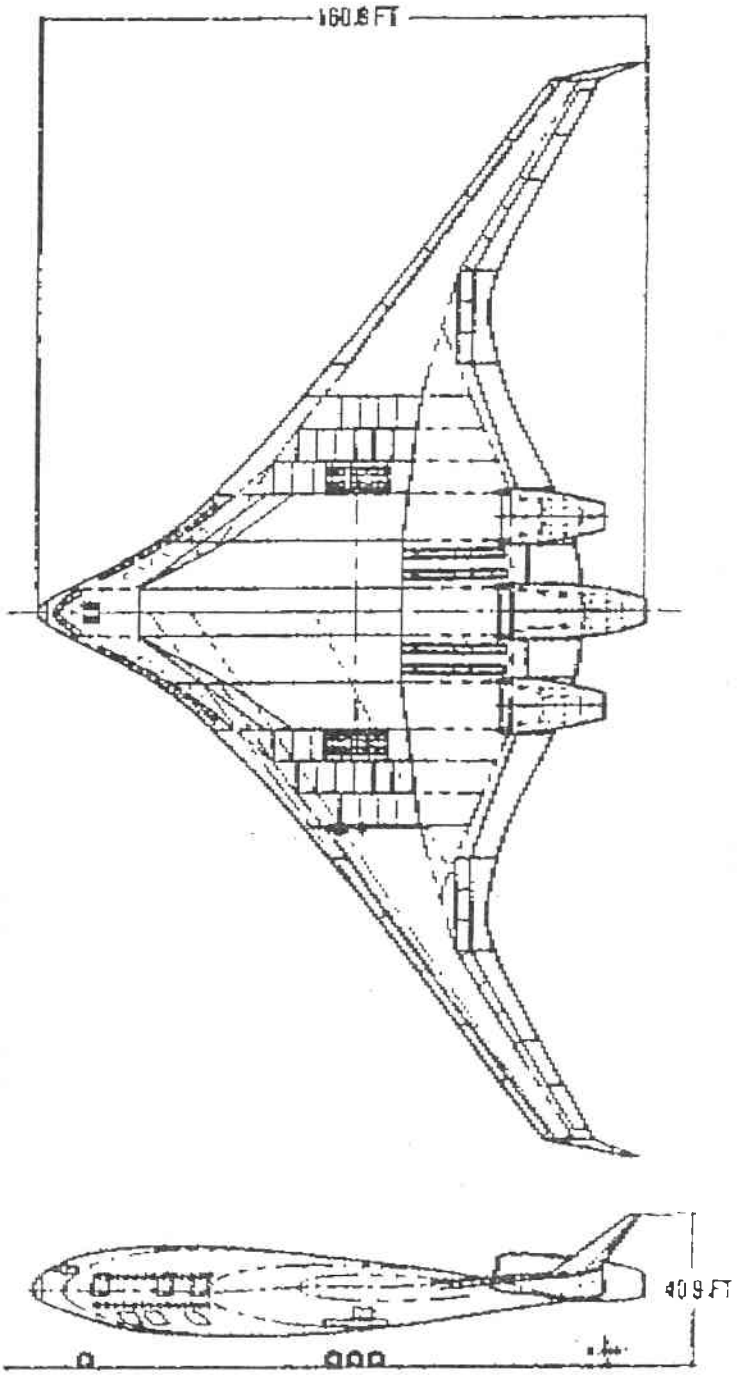
The other item is a copy of the home page for the Genesis sailplane team. Their home page can be found at:

http://www.groupgenesis.com/index.html

Enjoy,

Kevin Renshaw

(ed. - Thanks for the information on these home pages and the aircraft. We had a small picture of the BWB some time back that came out of an article sent in by Chris Tuffli, but this should be a good update on how the aerospace companies are doing with the project. I tried the Stanford page and could only get the first summary page with everything else being username and password controlled. It there someone that needs to be contacted on another net page to get these items so the information can be viewed?? Since I couldn't get in to do my own printout I used the expanded one you sent along so everyone can bet a better idea of the planform in case they wanted to perhaps try a model using this shape. By the way, the total wing span is 289'.



The Genesis Group seems to be going great guns with their almost flying wing aircraft, since they have expanded into the electronic forum to get a wider audience and perhaps some more customers. There is a lot of information out there under this page. There are plenty of pictures (which I couldn't get to print as well as the BWB ones so are not included), data tables and graphs throughout the various parts of the document. There are also 2 video sections, but I don't have the software to view them at this time.

As we are beginning to see, the age of the Internet is certainly upon us. It's great that people can be exposed to the concepts of flying wings and have some of the mystery removed which will help make them more acceptable if ever entered into commercial service. But I think we will see them as cargo type aircraft before we ever see a group of normal airline passengers board such an "alien appearing thing" to fly home for the holidays.

Some day I hope that we will have a TWITT homepage, but until I become more familiar with what all that entails, including expenses, we will have to stick with the good old tried and true methods of the paper printed message.)

7/24/96

TWITT:

It's time to renew my membership. Please find enclosed $22 to extend it for one year.

I noticed Les King's "Primer" sketch in the June newsletter and found the design layout similar to Jerry Blumenthal's "Rattler". It seems that finally someone has taken seriously Jerry's idea of combining the low aspect ratio wing center section with the high aspect ratio outer sections!

I wish Les King success in his efforts and I would like to send him, and to all of those who fight for ultralight sailplane development, a word of appreciation.

Are there in the membership other projects following this concept, being it full scale or model?

Thank you,

Artur Moreira Goncalves
Ermesinde, Portugal

(ed. - Thanks for the renewal. You are right about the similarities in layout between the Primer and Rattler. There was one member who was going to build a quarter-scale version of the Rattler, but we never received any word as to how the project worked out. Jerry passed away while working on a small concept model from which he was going to produce a set of plans. His one wish was to see one of his designs, or something like it, some day actually get airborne to prove out his theories.

We understand that Les King has flown the Primer, but as of right now do not have any firm word on how well it performed. I will try to find out more from him while at the SHA Western Workshop the last weekend in August and report back next month.)

7/8/96

TWITT:

Please sign me up with your Wing Is The Thing newsletter.

I now fly an A-10 Mitchell wing and have about 175 hours so far flying it. I also fly a Swift in the area.

Thanks,

Woody Jones
2900 N. Rochester Street
Arlington, VA 22213

(ed. - We would all like to welcome Woody to TWITT and hope that he enjoys his future issues of the newsletter.

It sounds like you are "really into" flying wings since you fly a Mitchell and a Swift. If you have some extra pictures laying around you could part with we sure would appreciate you letting our members take a look at them through the newsletter.

In 175 hours of flying a Mitchell wing you must have at least one or two good stories about the positive or negative things you have found with it. If you have a little time could you also send us a short article we could share with those members who have been thinking about getting a Mitchell but haven't been able to find anybody to ask questions of to help make the final decision?

We ask about this since one of TWITT's purposes is to help spread the word about all types of flying wing and tailless technology, but we can only do it with the help of our members. I am looking forward to hearing from you in the month's ahead.)

AVAILABLE PLANS & REFERENCE MATERIAL

Tailless Aircraft Bibliography

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4th Edition: An extensive collection of about 2600 tailless and over 750 related-interest listings. Over 15 pages of tailless design dates, listing works of over 250 creators of tailless aircraft, and the location of thousands of works and technical drawings for the Ho 229 (IX), Me 163, & Me 262.

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Consists of 268 pages filled with line drawings, tables and a corresponding English text. It is directed towards modelers, but contains information suitable for amateur full size builders. Price is $38, postage and handling included (also applies to Canada and Mexico).

You might also want to purchase his new book **Structural Dimensioning of Radioguided Aeromodels,** priced at $18.00.

On The Wing...the book, by Bill and Bunny Kuhlman

(B^2) is a compilation of their monthly column that appears in RCSD. Many of the areas have been expanded and it includes coding for several computer programs to determine twist and stability. Priced at US$28.00.

All these are available from B^2 Streamlines, P.O. Box 976, Olalla, WA 98359-0976, or (206) 857-7249 after 4pm Pacific Time. Orders shipped elsewhere will be sent surface mail unless an additional $10 is included to cover air mail postage. Washington residents must add 7.5% sales tax.

Personal Aircraft Drag Reduction, by Bruce Carmichael. This 207 page, soft cover, 8½ x 11" book starts with a chronological history of experimental verification of large theoretically predicted drag reductions on aircraft components having extensive laminar boundary layers. Practical problems which could limit attainment of these large drag reductions are discussed and methods to minimize the problems are suggested. The book is limited