Are Blended Wing Body Airplanes a Viable Option for Boeing?

(photo courtesy of: http://www.boeing.com/news/feature/paris01/Products/bwboverrainer1.jpg)

Submitted to: Paul M. Kellermann

Submitted by: Nicholas *****

31 October 2002

## Introduction

For 80 years the mainstream trend in aircraft design has been to build a tubular fuselage attached to a main lift-producing wing as well as vertical and horizontal tails. Both Boeing and Airbus continue to design and manufacture the conventional tube-and-wing airplane. As Pae (2001a, p. 1) points out, in the 1920's Jack Northrop pioneered the blended wing body airplane, but the idea never really caught on for commercial transportation. The blended wing body (BWB) aircraft is unlike other airplane designs in that it does not have a separate central fuselage, but rather the entire surface of the airplane produces lift. It is best exemplified by the Air Force's B-2 stealth bomber.

Up until now the aerodynamic, structural, and stability concerns of an all-flying wing could not be overcome. But in the past five years a company has decided to challenge the paradigm in commercial aircraft. Is this a smart move? Why should a well-established commercial aircraft company invest in something so radical? What follows is an analysis of some of the problems and benefits that go along with a blended wing body design.

## Drawbacks

*Stability*

Traditionally an all-flying wing aircraft, such as the B-2, had to follow certain restrictions in design. Because of the lack of a horizontal stabilizer the wing must have a reflexed airfoil, with the trailing edge pointed slightly up in order to get the appropriate pitching moment about the wing. This reflexing of the airfoil causes a decrease in the performance of the wing. It also has a huge drawback in its inability to support trailing edge flaps for low-speed landings.

More stability problems come about in the absence of a vertical tail. The vertical stabilizer is the key component in lateral-directional control. Without the vertical tail nothing keeps the airplane aligned symmetrically with its own flight path. This greatly decreases the efficiency of the wings and can be quite disheartening to a pilot, as well as the passengers, when they look out the window and see that the plane is flying sideways.

With the use of microcomputers in aircraft and the advent of fly-by-wire control systems, many of the problems of an all flying wing can be solved. Fly-by-wire controls take real-time data on the aircraft position, velocity, and heading and convert that into proper control surface movements in order to keep the aircraft stable and in control. This allows for an airfoil shape that is not reflexed, as well as the implementation of trailing edge flaps. For lateral control small vertical fins can be placed at the back of the plane near the center. But a more efficient way of obtaining vertical stability would be to add vertical tip extensions called winglets. The winglets would not only add lateral directional stability, but also have been shown to decrease drag on the wings. The result is an airplane just as stable as conventional design with more effective use of the stabilizing bodies.

*Pressure vessel*

At the extreme altitudes (35,000 to 45,000 feet) that commercial aircraft operate the static air pressure is very low. Because of these extremely low pressures, the cockpit and cabin need to be pressurized. This pressure difference between the inside and outside of the airplane can cause huge stresses, and the most effective structure in dealing with these pressure stresses is the circular tube. However, the nature of the blended wing body aircraft does not allow for a circular pressure vessel, therefore extra structural material is needed to safely absorb the increased stresses.

The problem of a higher stressed pressure vessel can be solved in two ways. First, the designers could simply add conventional structural material such as steel, and increase the weight of the center body. This is undesirable for the obvious reason that an increase in weight automatically decreases the efficiency of the airplane. Another solution, one that is being studied heavily by Boeing, is to use composite materials and a new structural design. According to Vitali et al. (2002, p. 158) the design would consist of a "hat-stiffened laminated composite panel for an upper cover panel of a typical passenger bay." This would keep weight down while maintaining the structural integrity required for commercial transports.

*Passenger comfort*

The main concern with the blended wing body aircraft is passenger comfort. The wider passenger section would allow for more room, but there would be a limited number of window seats. This has been a major sticking point for airlines worried that passengers would feel claustrophobic without easy access to an outside view, even if it is just clouds they'd be looking at.

Passenger comfort is of primary concern, and could be the only arguable reason not to send the BWB into production. Obviously, no matter how great a plane is, if no one will buy tickets to fly on in, it's worthless. Because of this, Boeing has done extensive research on whether or not the traveling public would accept fewer window seats on airplanes. So far, reports show that passengers wouldn't mind. Especially with Boeing offering consoles on the backs of each seat equipped with its Connexion high-speed internet access, feature films, and the option to view outside of the airplane via a camera placed on the body. Hibbert (1999, p. 20) also foresees other forms of entertainment such as casinos, bars and shops being placed in the enlarged passenger sections. All in all the perceived drawbacks of a blended wing body aircraft can be easily remedied with a little innovation and a few reasonable design changes.

## Advantages

*More Efficient*

Because of the nature of the design of blended wing body aircraft, they are more efficient. With a conventional tube-and-wing design the main lifting body is the wing. The fuselage adds nominal lift, but fulfills its major purpose as a passenger and/or cargo container. Therefore the tubular fuselage adds a huge amount of drag area, without contributing to the lift in any significant manner. Even more drag, referred to as interference drag, is caused at the wing-to-fuselage junction. This drag comes from the fact that the flow over the wing does not match the flow over the fuselage, so energy is lost in the form of drag in order to blend these two flows.

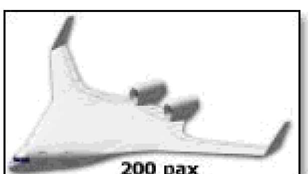
Because the BWB aircraft body is "blended" into the wing surface, interference drag can be eliminated. Another benefit of the blended wing is its lack of excessive drag area. As mentioned earlier, the fuselage section of the conventional aircraft produces nominal lift while adding to the drag. However, the BWB uses all of its drag area to produce lift. Add the lack of interference drag to the fact that the entire surface of the airplane produces lift, and what you get is a highly efficient transporter that would emit less noise and pollution (Pae 2001a, p. A.1).

*More capacity*

The increased lifting area greatly improves the performance of this aircraft in yet another way. The high-lift wing will be able to carry more weight even farther than the aircraft of today. This translates into more passengers, more cargo, or extra fuel for extended range flight. One model could carry up to 500 passengers 8500 nautical miles at speeds up to Mach 0.85 (Phillips 2001, p. 27). This extended range would allow flights from New York City to almost anywhere in the world. Erwin (2000, p.25) concludes that this "could have significant implications for military tanker and cargo platforms, allowing for heavier payloads to travel longer distances."

*Modular Design*

The blended wing body would also implement a highly efficient modular design, that would decrease manufacturing time and costs (*Blended Wing Body*). The modular design allows for multiple models of aircraft to be made out of common central parts. This would make the BWB an extremely versatile airplane. Current concepts (shown in Figures 1-6) have a commercial transport family of aircraft with varying sizes and capacities, as well as military transports, gunships, bombers, surveillance vehicles, and refueling tankers. (photos and captions courtesy of Boeing Phantom Works web site: http://www.boeing.com/phantom/bwb.html)

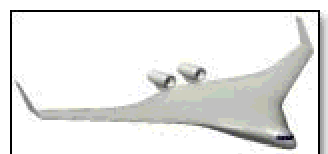



**Long-Range Commercial Family**
- 200 pax
- 250 pax
- 300 pax
- 350 pax
- 400 pax
- 450 pax
- 550 pax

Figure 1

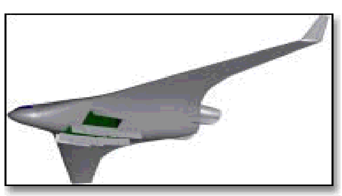
**Global Range Transport**
- Large volume
- Global range

Figure 2



**Gunship**
- Wide cabin for enclosed side-facing weapons
- Pressurized cabin
- Long endurance

Figure 3



**Bomber**
- Large payload
- Global range
- Long endurance

Figure 4

**$C^2$ISR (Intelligence, Surveillance, Reconnaissance)**
- Long endurance
- Large office-like interior
- Extensive array options

Figure 5

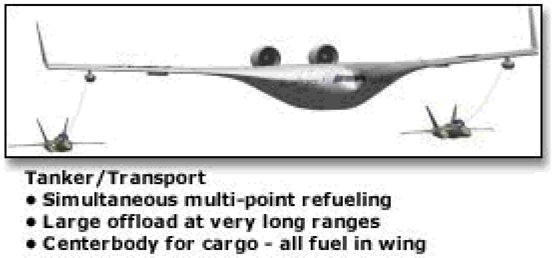



Figure 6

## Conclusion

Right now Boeing is reeling from the huge blow the airline industry took on September 11, 2001. Even before that date commercial airline traffic was declining, and now it is in a state of distress. This is not unusual, in fact Boeing has come to accept the cyclical nature of the commercial aircraft industry. But now Boeing has a formidable competitor in Airbus, that has taken over almost fifty percent of the market share. Boeing has not introduced a new airplane model in 20 years, and now more than ever they need something new and radical to take back their position as the number one aircraft company in the world.

The Blended Wing Body airplane would fit perfectly into that role. If it was put into production now it would be at least 5 years until the first model would roll out, giving the industry plenty of time to recover from its current downturn. The BWB would use 20%-30% less fuel and would be the best aircraft on the market by far. McDonnell Douglas (*McDonnell Douglas Press Releases 97-158* ) demonstrated that the BWB "concept allows a significant reduction in drag, lowers aircraft structural weight, enhances lift characteristics and allows an aircraft to operate more efficiently and at lower costs than a conventional design with a separate wing and fuselage." It has also been shown that it could be used by the military for a number of purposes, making it the most versatile airplane model in the world, and propelling Boeing far ahead of Airbus to dominate the aircraft industry for the next 30 years. The returns would be enormous, and Boeing and its investors would be missing out on a great opportunity if they decided against production of this amazing aircraft.

## Works Cited

*Blended Wing Body* [online], (2002), Boeing Phantom Works, Available: http://www.boeing.com/phantom/bwb.html (Accessed 21 Oct. 2002)

Erwin, S. (2000), "Blended wing body jet safer and more efficient, claims Boeing", National Defense, vol. 85, no. 563, pg. 25

Hibbert, L. (1999), "Reshaping the future of flight", Professional Engineering, vol. 12, no. 19, pg. 20

*McDonnell Douglas Press Releases 97-158* [online], (1997), "Blended-wing-body sub-scale aircraft demonstrates flight characteristics of new design", Available: http://www.boeing.com/news/releases/mdc/97-158.html (Accessed 21 Oct. 2002)

Pae, P. (2001a), "Boeing developing wing-body aircraft; Aerospace: The stingray-shaped plane, still at least a decade away, would be a first in commercial jet", *Los Angeles Times*, 9 February, pg. A.1

Pae, P. (2001b), "The wing's the thing / Boeing pushes design envelope / Radical superjumbo would carry up to 800 passengers", *Houston Chronicle*, 10 February, pg.1

Phillips, E. (2001), "Boeing Takes over FCS work from NASA Dryden", Aviation Week and Space Technology, vol. 155, no. 7, pg. 27

Vitali, R. & Park, O. & Haftka, R. & Sankar, B. & Rose, C. (2002), "Structural Optimization of a hat-stiffened panel using response surfaces", Journal of Aircraft, vol. 39, no. 1, pp. 158-166