Flying Wing

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http://www.bugimus.com/stealth/stealth.html
http://www.nurflugel.com/Nurflugel/Northrop/n-1m/n1m_refurbished_1.jpg
What is a flying wing?

Flying Wing:

“….A type of airplane in which all of the functions of a satisfactory flying machine are disposed and accommodated within the outline of the airfoil itself.”

- Jack Northrop
Aerodynamics

Pros:
- Reduced minimum drag due to elimination of empennage assembly
- Elimination of wing-tail vortex and shock interactions
- Greater efficiency from elimination of non-lift producing surfaces
- Elliptic span loading is easily achieved through wing camber and twist
- Lower trim drag using unstable configuration

Cons:
- Low $C_{\text{max}}$ requires high angle of attack at takeoff and landing
- Low $C_{\text{max}}$ requires lower wing loading if takeoff conditions govern W/S
- Significant increase in induced drag when washout is used for stability
- Thick wing sections create high drag at transonic speeds
Drag Reduction

Drag Comparison (XB-35, C-5)

- $C_d$ min of XB-35 = 0.012
- $C_d$ min of C-5 = 0.023
- Flying at same speed, all-wing design can fly 13-33% farther with 11-25% less power
- At optimal speed for all-wing design, flying wing will fly 7-19% faster and 14-41% farther

Reference: 4

- 33% reduction in Wetted Area
- Results in reduced drag
Stability and Control

Pros:
- Can get a higher CLmax from relaxed static stability

Cons:
- Decreased weather-cock stability makes precision flying difficult
- Larger/more control surfaces needed for pitch control due to smaller moment arm
- Coupling of lateral-directional controls complicates control
- Control coupling causes non-conventional spin recovery
- Induced tumble difficult to recover, but not encountered in normal flight

Bryan
Structures

Pros:
- Can put a spar through the entire width of the plane
- Simpler to build as a single unit
- Better internal weight distribution
- Higher thickness to chord ratio to fit passengers and cargo
- Bending moment on the order of conventional value
- Fewer 90° joints require fewer structural members
- Lighter than conventional fuselage aircraft

Cons:
- Difficult to pressurize cabin
- Difficulty in evacuation of passengers in an emergency

Reference 4.

Mike
Weight Comparison

- Comparison of Conventional and Blended Wing Body design for the same mission of 800 passengers
- Blended wing lighter in wing, empennage, and empty weight.
- Conventional lighter in only Body
- End result: Blended wing 11% lighter in Mean Take off weight

Reference 4

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Propulsion

Pros:
- Reduced weight plus increased aero-efficiency results in lower power required
- Eliminate concerns of jet-tail surface interaction
- Eliminate engine nacelle/wing interactions at cruise

Cons:
- Pitch stability affected by thrust moment
- Early designs suffered from insufficient engine cooling
- Propeller strike on rotation
<table>
<thead>
<tr>
<th>Pros:</th>
<th>Cons:</th>
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<tbody>
<tr>
<td>Low cross sectional profile</td>
<td>Weather conditions affect stealth</td>
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<tr>
<td>Few round shapes to allow radar to bounce back</td>
<td>Large exposed area during banked turn</td>
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<tr>
<td>No vertical tail to reflect radar waves</td>
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Mike
The design and flight of tailless aircraft is as old as human flight itself.
• This tailless bi-plane was designed by the Englishman John Dunne in 1912.
• This is the first successful tailless aircraft with back swept wings.
• Dunne based his design on his success with tailless gliders.
• Dunne’s designs were inherently stable in pitch and incorporated wing washout.
• The German brothers Walter and Reimen Horten contributed significantly to the development of the flying wing configuration as we know it today.
• The Horten brothers worked on flying wings from 1931 until 1944.
• Their Ho series aircraft utilized three sets of trailing edge control surfaces:
  - inboard flaps, elevons, and tip mounted drag rudders.
The German Contribution

The Turbojet Powered Ho IX (1944)

- The German Ho IX was the world’s first turbojet powered flying wing
- The Ho IX was designed as a fighter aircraft
- Only 3 were built and the war ended before any Horten designs could be used in combat
The Jack Northrop Designs

• No single person has done more to further the design of the “all-wing” aircraft than Jack Northrop
• Jack Northrop started out as a designer and engineer for Donald Douglas in 1923
• Northrop was convinced that the efficiency of aircraft could be substantially increased by the reduction of drag realized by the flying wing design
• In 1939 Northrop formed his own company, Northrop Aircraft, Inc. This allowed Northrop the freedom to develop his flying wing design
• Northrop designed and built flying wing aircraft from 1929 until 1950
• Although the military never adopted any of the original Northrop designs for service, Northrop was vindicated when his design won the stealth bomber competition in 1981
The N-1M

The Northrop Model 1 Mockup was built from 1930-1940

- The 38’ span aircraft was built as a proof of concept for the all-wing configuration
- Sweep, dihedral, tip configuration, CG location, and control surface configuration could all be varied while on the ground
- The N-1M proved the feasibility of the flying wing concept and was used to refine the overall design
- The N-1M was controlled by elevons and drag rudders on the wing tips
- Hidden in the airfoil, the original N-1M engines suffered from over-heating
- Drooped wingtips were originally used for stability were found to be unnecessary
Based on the success of the N-1M, the Air Force asked Northrop to investigate the development of a flying wing bomber.

- The N-9M was built as a scale mockup of the proposed bomber, the XB-35.
- The N-9M has a span of 60 ft and a takeoff weight of 7000 lbs.
- Control of the N-9M was accomplished through elevons, trim tabs, and drag rudders.
- 4 craft were built and successfully flown with the first produced in 1942.
The XB-35 was built as a long range bomber originally designed to attack Germany from North America in the event of the fall of Britain.

- 15 XB-35s were built, with the first complete in June of 1946.
- The craft had a span of 172 ft and could carry a bomb load of 32 1,600 lb bombs.
- Maximum overloaded takeoff weight was 209,000 lbs.
The YB-49

- Two of the original XB-35s were converted to turbojet power and designated YB-49s.
- 8 turbojet engines of 3750 lbs thrust each were installed in the airplane.
- Vertical fins were added to restore weathercock stability lost with the removal of the propeller shaft housing.
- The YB-49 project ended in 1950. The flying wing concept would not resurface until the stealth bomber program in 1980.
B-2 Spirit

http://rightflyer.com/B-2-Gallery.html

Mike
Specifications (1):

Primary function: Multi-role heavy bomber
Prime Contractor: Northrop Grumman Corp
Contractor Team: Boeing Military Airplanes Co., General Electric Aircraft Engine Group and Hughes Training Inc., Link Division
Power Plant: Four General Electric F-118-GE-100 engines
Thrust: 17,300 pounds each engine
Length: 69 feet (20.9 meters)
Height: 17 feet (5.1 meters)
Wingspan: 172 feet (52.12 meters)
Speed: High subsonic
Ceiling: 50,000 feet (15,152 meters)
Takeoff Weight (Typical): 336,500 pounds (152,635 kilograms)
Range: Intercontinental, unfueled
Armament: Conventional or nuclear weapons
Payload: 40,000 pounds (18,144 kilograms)
Crew: Two pilots
Date Deployed: December 1993
Inventory: Active force: 21 (1 test); ANG: 0; Reserve: 0
Reasons for Existence:
- First designed to penetrate Soviet radar and deliver nuclear bombs to the Soviet Union
- After the fall of the USSR, it was converted for conventional warfare to carry JDAMs
- Also was to serve as a replacement for the B-52 bomber

Advantages:
- Low visual (at night) and radar visibility
- Able to fly 6,000 nm without refueling and 10,000 nm with one refuel
- Can hold up to 40,000 lb worth of munitions
- Can deliver munitions anywhere in the world in 24 hours
- Does not require fighter escorts due to low visibility and high survivability

Disadvantages:
- Stealth capability affected by bad weather
- Very costly, $2.2 Billion per plane
- High maintenance, requiring 25 man hours for preparation before each mission
- Requires special protective hangars and thus is hard to base anywhere but home base at Whiteman Airforce Base, MO
As it stands now:

- It is an effective way to deliver a lot of munitions in a short amount of time
- Is stealthy in the right conditions
- Only 5 are in operation at one time, with the remainder of the total inventory of 21 in refurbishment
- Is a “silver bullet” that is used in small quantities in which its unique qualities give it a leverage over enemy forces that otherwise have an advantage
- New portable hangars are being developed to be used in other parts of the world
Boeing Blended-Wing-Body (BWB)

- Conventional Transports have been refined almost to their limit
- New direction to leap forward in transport performance
- Goals:
  - Reduce Drag, and thereby lower fuel consumption
  - Increase passenger compliment
  - Create a family of BWB a/c

http://www.boeing.com/phantom/bwb.html
Conventional vs. BWB

- Compared conventional and BWB for same mission
  - Passengers: 800
  - Range: 7000 nmi

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<thead>
<tr>
<th>Model</th>
<th>BWB</th>
<th>Conventional</th>
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<tbody>
<tr>
<td>Passengers</td>
<td>800</td>
<td>800</td>
</tr>
<tr>
<td>Range (n.mi)</td>
<td>7,000</td>
<td>7,000</td>
</tr>
<tr>
<td>MTOWG (lb)</td>
<td>823,000</td>
<td>970,000</td>
</tr>
<tr>
<td>OEW (lb)</td>
<td>412,000</td>
<td>476,000</td>
</tr>
<tr>
<td>Fuel Burned (lb)</td>
<td>213,000</td>
<td>294,000</td>
</tr>
<tr>
<td>L/D @ Cruise</td>
<td>23</td>
<td>19</td>
</tr>
<tr>
<td>Thrust (total lb)</td>
<td>3x61,600</td>
<td>4x63,600</td>
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Reference 4
Unique Opportunities for BWB

- **Manufacturing part count**
  - 20% reduction in number of parts compared to conventional transports
  - Results from
    - elimination of 90° joints with horizontal plains
    - No track driven flaps, only simple hinged surfaces
    - No Spoilers
  - Also results in lower manufacturing cost
Unique Opportunities for BWB (Cont.)

- Growth:
  - Stretching aircraft laterally instead of longitudinally
  - Results in:
    - Wing area and span increasing proportional to passenger increase
    - Planes ranging from 200-450 people in same family

Reference 4
Military Contracts

- Proposed use as
  - In-flight refueling tankers
  - Bombers
  - Heavy cargo transports

http://www.boeing.com/phantom/bwb.html
References