# Flying Wing


http://www.nurflugel.com/Nurflugel/Northrop/n-1m/n1m_refurbished_1.jpg


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http://www.geocities.com/witewings/bwb/gallerydetail-1-6.html


http://www.bugimus.com/stealth/stealth.html

# 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

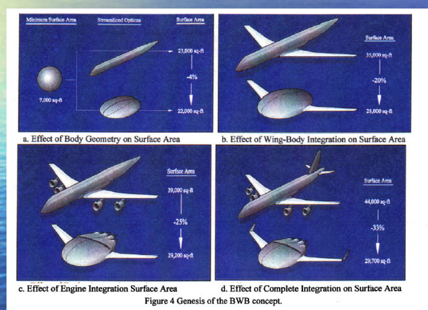
Cons:

- Low $C_{Lmax}$ requires high angle of attack at takeoff and landing
- Low $C_{Lmax}$ 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

Matt

# Drag Reduction

**Wetted Area Comparison**




Reference 4

- 33% reduction in Wetted Area
- Results in reduced drag

**Drag Comparison (XB-35 , C-5)**

- Cd min of XB-35 = 0.012
- Cd 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

Bryan/Matt


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

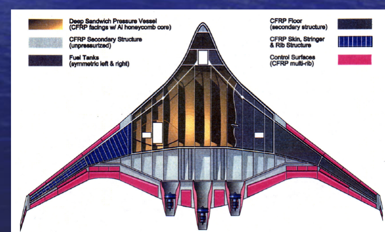
# Structures

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:

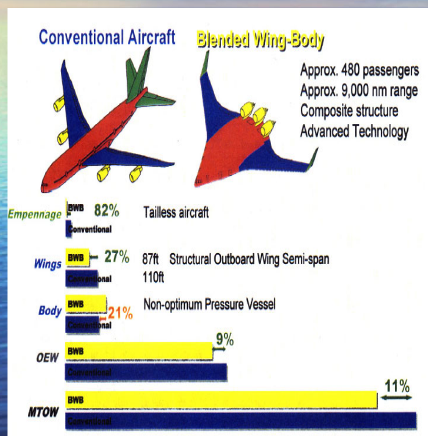
- Difficult to pressurize cabin
- Difficulty in evacuation of passengers in an emergency




Reference 4.

Mike

## Weight Comparison



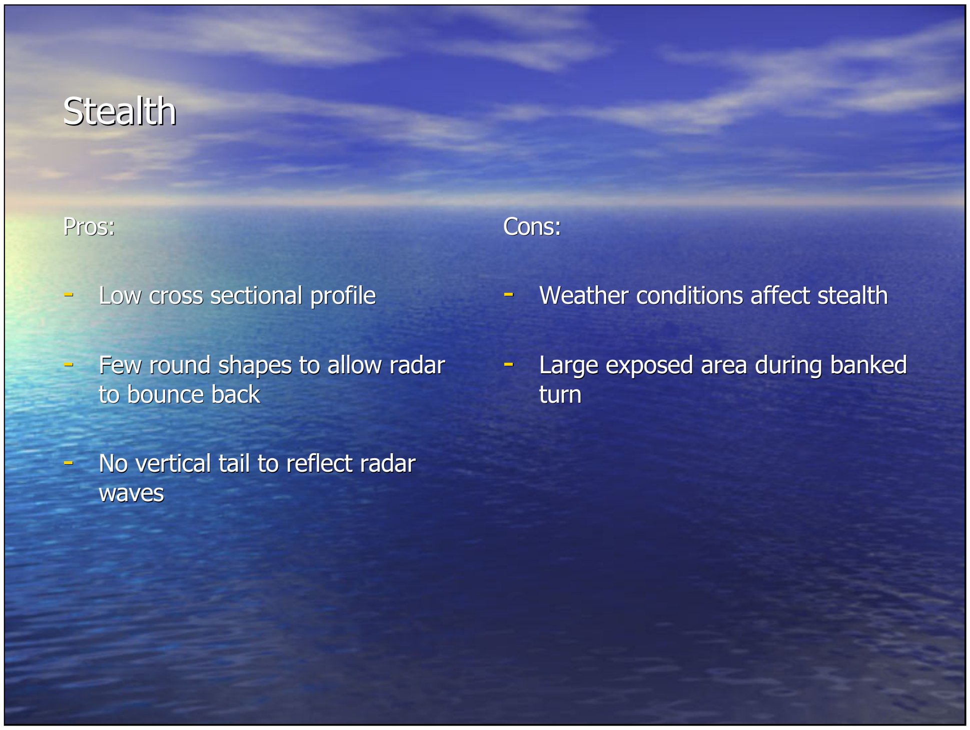

Reference 4

- 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

Bryan


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

Matt


Stealth
Pros:
- Low cross sectional profile
- Few round shapes to allow radar to bounce back
- No vertical tail to reflect radar waves
Cons:
- Weather conditions affect stealth
- Large exposed area during banked turn

Mike

## Early Flying Wings

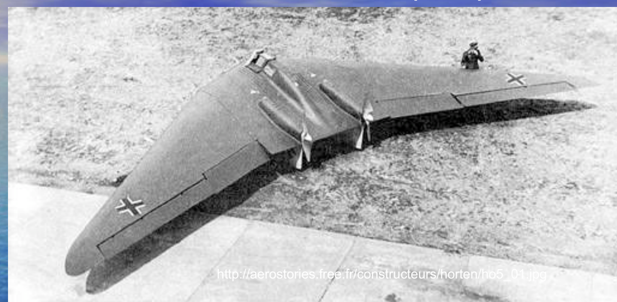
**The Tailless Biplanes of John Dunne (1912)**

- 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 [2]
- Dunne based his design on his success with tailless gliders
- Dunne's designs were inherently stable in pitch and incorporated wing washout

Matt----

## The German Contribution

**The German Ho V (1937)**




- 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)**

http://aerostories.free.fr/constructeurs/horten/ho9test.jpg

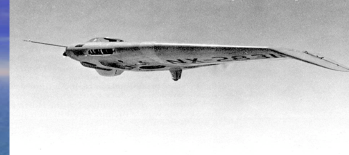
- The German Ho IX was the world’s first turbojet powered flying wing
- The Ho IX was designed as a fighter aircraft
- Only 3 were built and the war ended before any Horten designs could be used in combat

## 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

N-1M “Jeep” (1939)



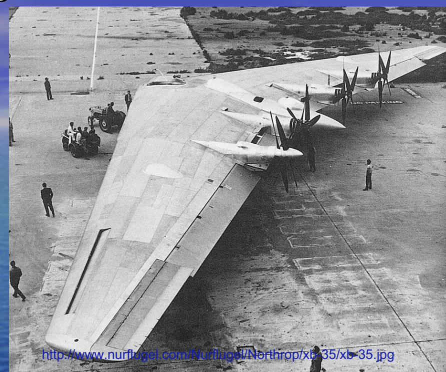
http://www.nurflugel.com/Nurflugel/Northrop/n-1m/n1m_flight.jpg

- 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

## The N-9M


- 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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- 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

http://www.nurflugel.com/Nurflugel/Northrop/yb-49/yb-49_color.jpg

- 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.


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, unrefueled
**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 delivery 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


Portable B-2 hangars constructed at Diego Garcia in the Indian Ocean


http://www.af.mil/news/factsheets/B_2_Spirit.html

# 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

# Conventional vs. BWB

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

| Model | BWB | Conventional |
|---|---|---|
| Passengers | 800 | 800 |
| Range (n.mi) | 7,000 | 7,000 |
| MTOGW (lb) | 823,000 | 970,000 |
| OEW (lb) | 412,000 | 470,000 |
| Fuel Burned (lb) | 213,000 | 294,000 |
| L/D @ Cruise | 23 | 19 |
| Thrust (total lb) | 3x61,600 | 4x63,600 |

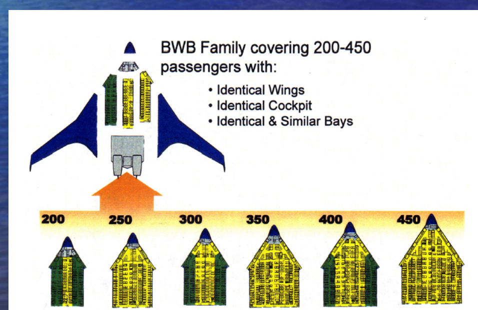
Reference 4

## Unique Opportunities for BWB

- Manufacturing part count
  - 30% 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

**Tanker/Transport**
- Simultaneous multi-point refueling
- Large offload at very long ranges
- Centerbody for cargo - all fuel in wing

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

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

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

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