X-48B Blended Wing Body Flight Control Demonstrator

Disclaimer

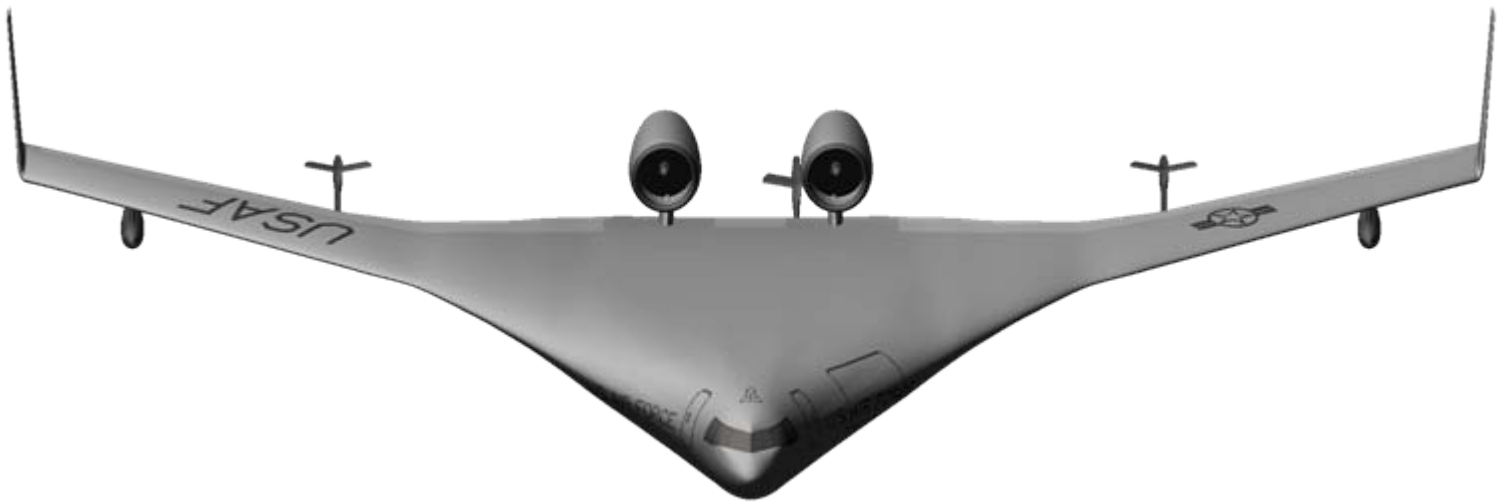
X-48B IS NOT JUST ANOTHER UAV

INSTEAD, IT IS:

A PILOT-IN-THE-LOOP TECHNOLOGY DEMONSTRATOR

Disclaimer

FOR A FULL SCALE, PILOTED VEHICLE



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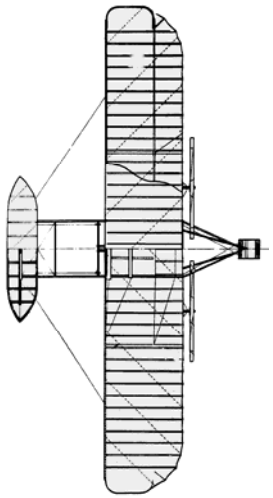
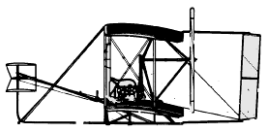
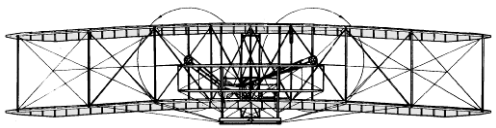
Concept Genesis







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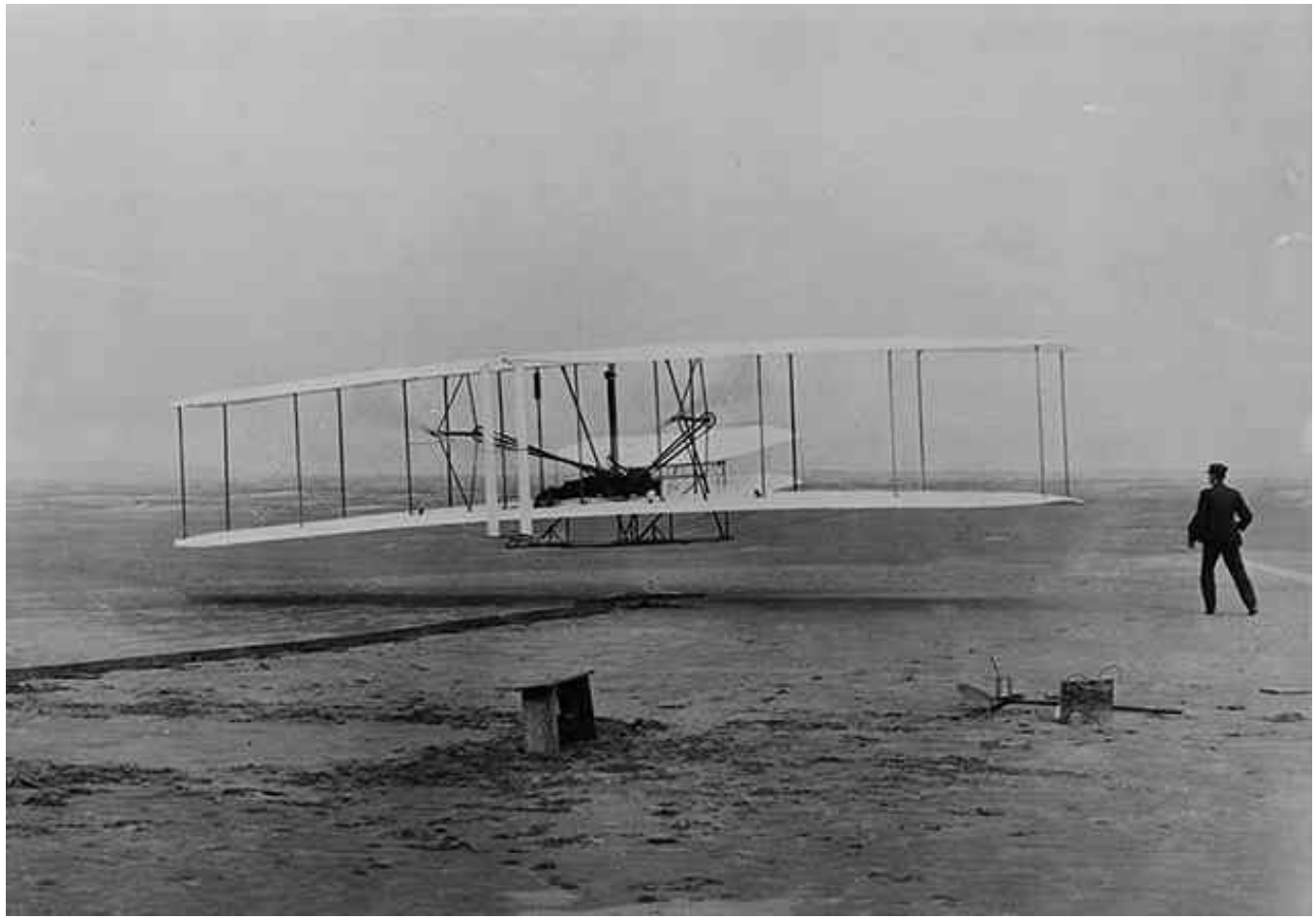
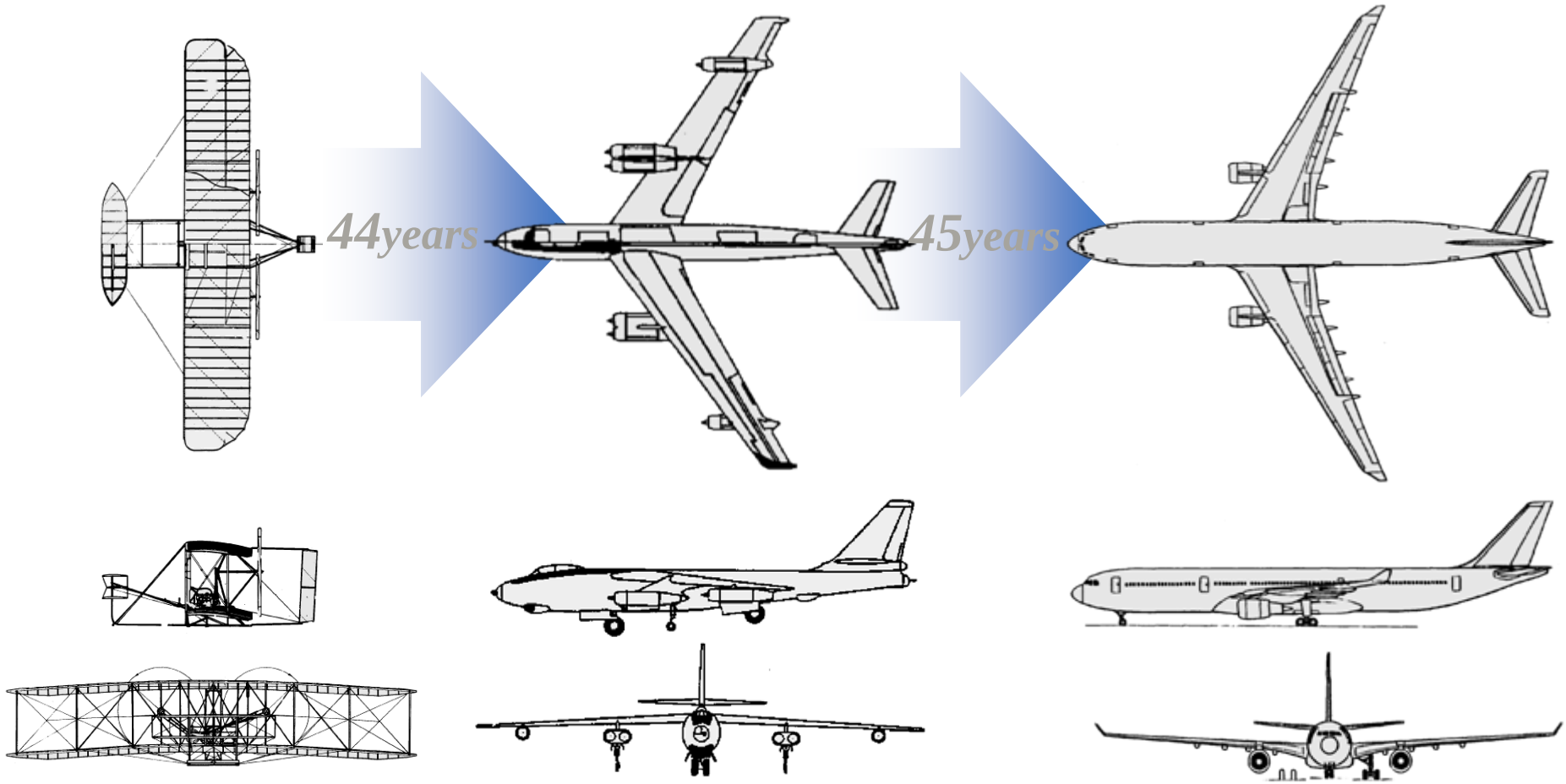
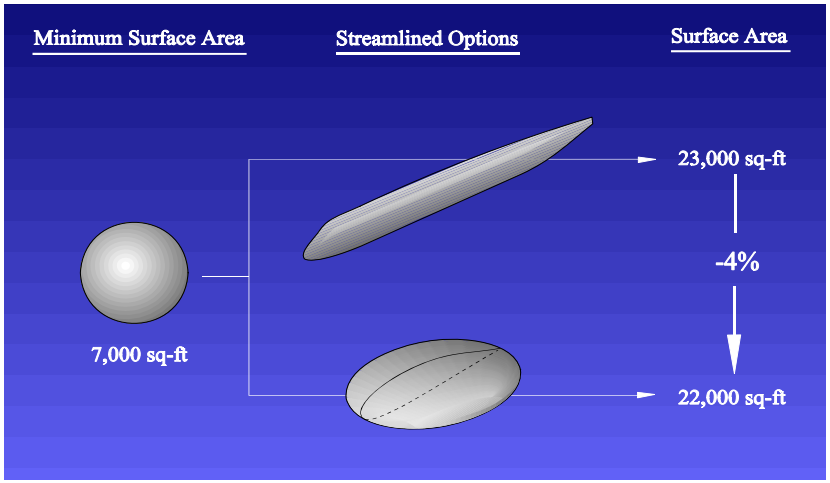


Concept Genesis

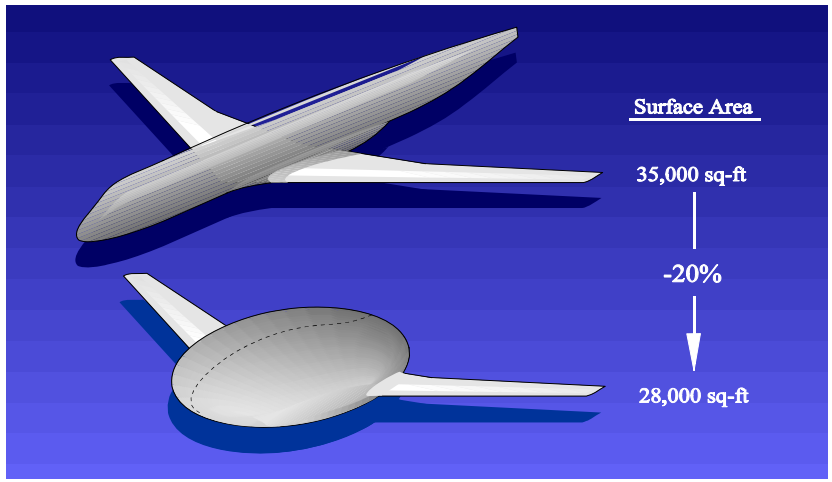


1/3 Less Wetted Area than Conventional

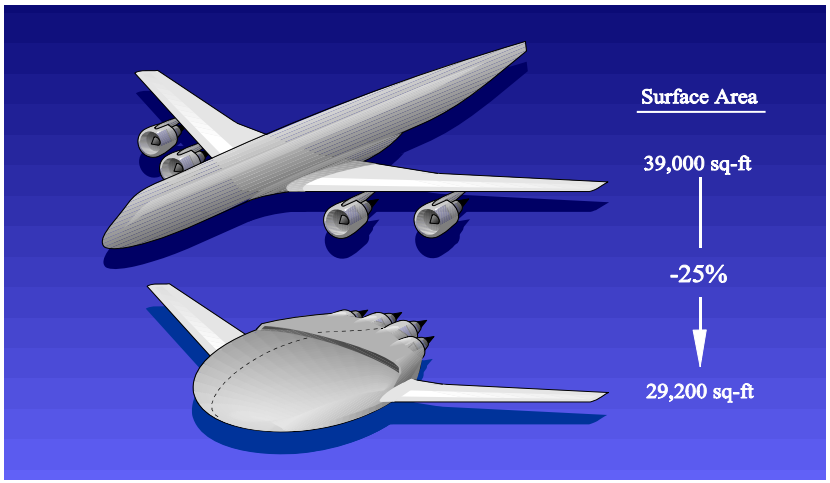
Effect of Body Type



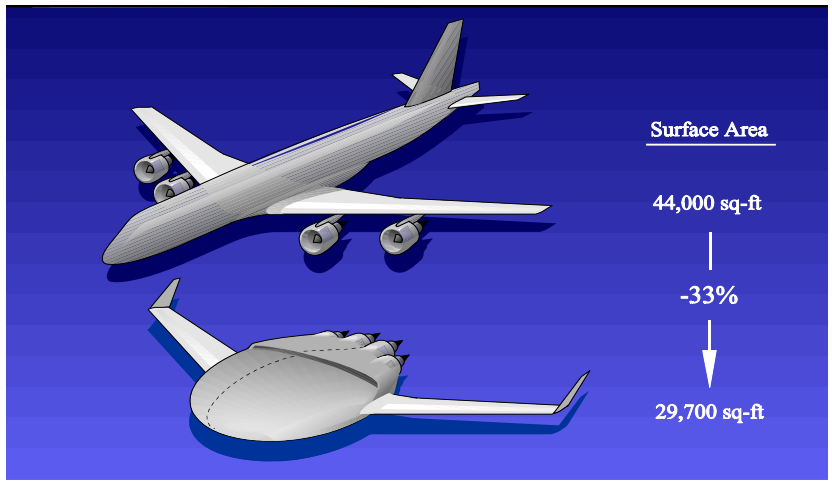
Effect of Wing/Body Integration



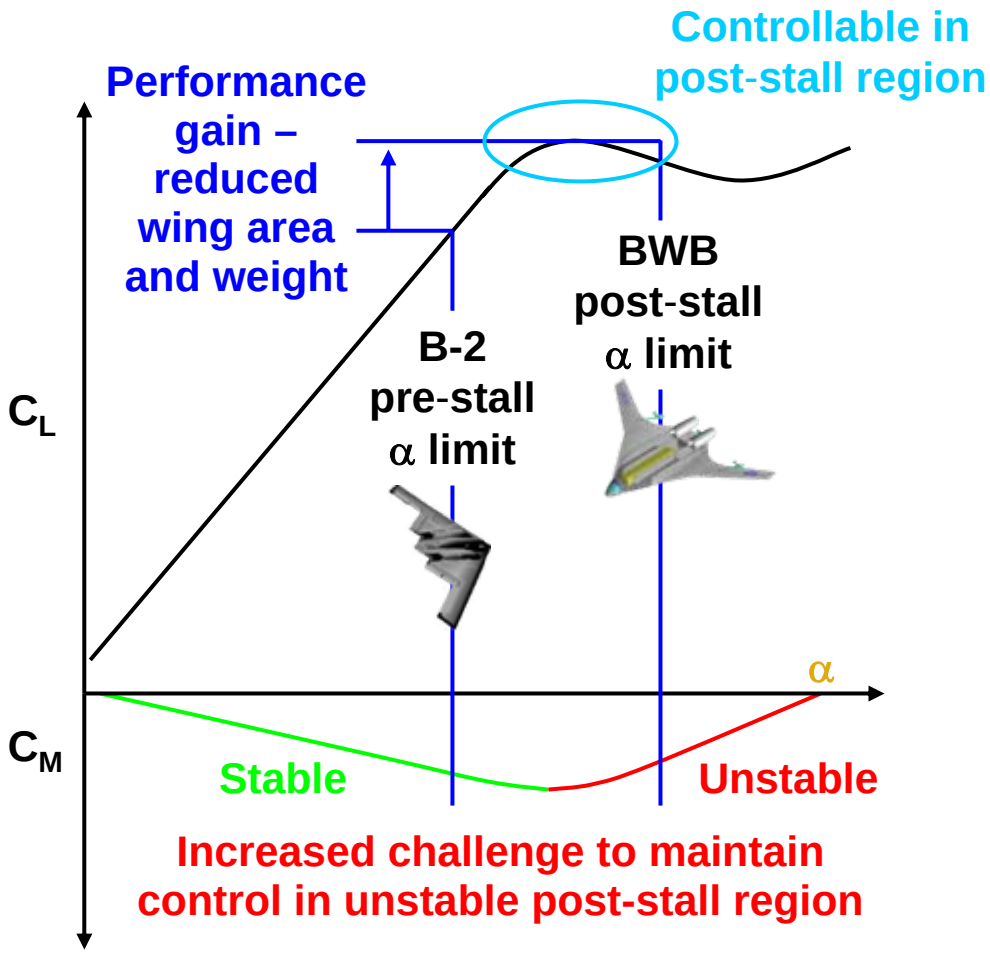
Effect of Engine Installation



Effect of Controls Integration

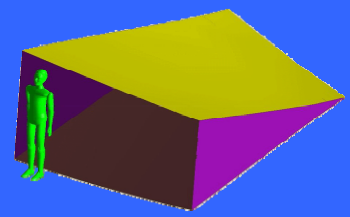


Critical Flight Control Technology



High-rate large control surfaces create large secondary power demands

BWB Elevon #1



Need to Prove that the BWB is as Robust as a C-17

Flying Wing Spin & Tumble Departures

Then...

- **Flying wing dynamics dominated by minimal aerodynamic pitch and yaw damping**
- **Post-stall, this could lead to unrecoverable spin and tumble modes**

Northrop XB-35 in 20 Foot Spin Tunnel
NASA Langley Research Center 10/11/1943 Image # EL-2000-00235

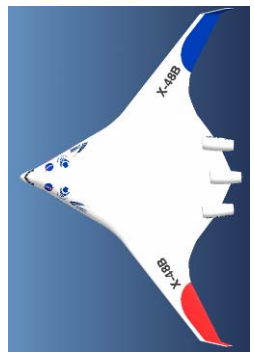
Air Flow

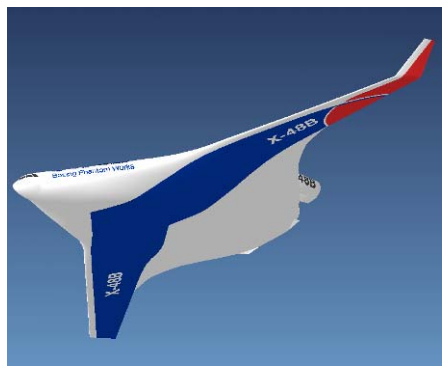
Now

- **Spin testing shows that the BWB potentially has unrecoverable spin and tumble modes**
- **Need to prove that an advanced flight control system will prevent entry into departure regions**

X-48B BWB Low Speed Vehicle

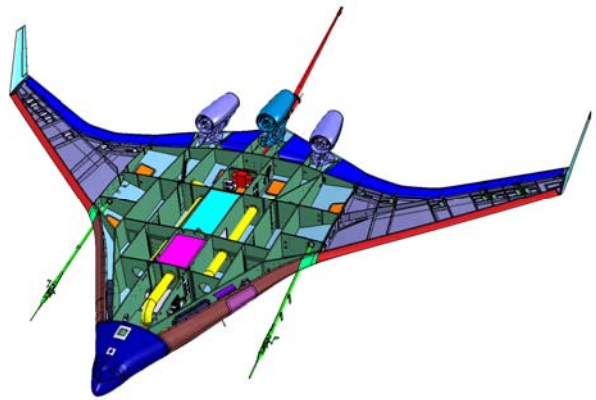
- **Flight testing provides:**
  - **Flight Control System risk reduction**
  - **Required to convince customers that BWB configuration is as safe as a conventional airplane**
- **Investigate:**
  - **Stall Characteristics**
  - **Departure Onset Boundaries**
  - **Asymmetric Thrust Control**
  - **Flight Control Algorithms**
  - **Envelope Protection Schemes**
  - **Dynamic Ground Effects**
  - **Control Surface Hinge Moments**

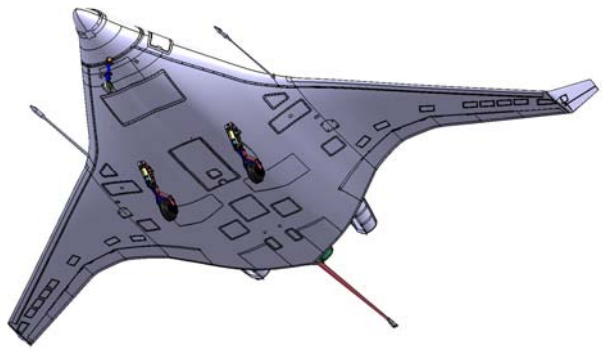




X-48B BWB Low Speed Vehicle

- **Two X-48B Aircraft and Ground Control Station (GCS)**
  - **Research Partnership of Boeing, NASA, and AFRL**
  - **Design and fabrication contracted to Cranfield Aerospace**
- **Air Vehicle Highlights:**
  - **Dynamically Scaled**
  - **Uninhabited Air Vehicle**
    - **Flown by Pilot from Ground Station**
  - **Powered by 3 Small Turbojets**
    - **Ground Start only**
  - **Conventional takeoff and landing**
    - **Non-retractable Tricycle Gear**
    - **Slats are Fixed for either Extended or Retracted Configuration**
  - **Recovery System**
    - **Drogue, Parachute, and Air Bags**

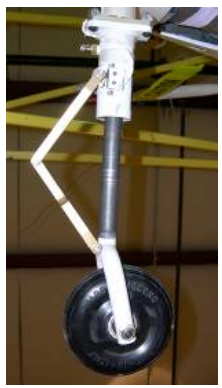




8.5% Dynamically Scaled X-48B BWB

- **Design Approach**
  - **Use low cost (COTS) equipment where possible**
    - **Engines - JetCat P200**
    - **Landing Gear - mountain bike shocks & brakes**
  - **Use normal industry practice for electronic equipment**
  - **Use aircraft spec equipment where necessary**
    - **Radios, IMU, Actuators, Flight Termination System (FTS) parts**
  - **Save weight to meet dynamic scaling requirements**

JetCat P200 Engines



Nose & Main Landing Gear

X-48B 30x60 Wind Tunnel Test

- ***NASA / AFRL contributed test time in ODU Langley Full-Scale Tunnel***
- ***Wind tunnel test completed April / May 2006***
- ***250 hours of testing with flight control hardware active***
- ***Data used by Boeing for X-48B simulation and flight control software***

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Validation Testing

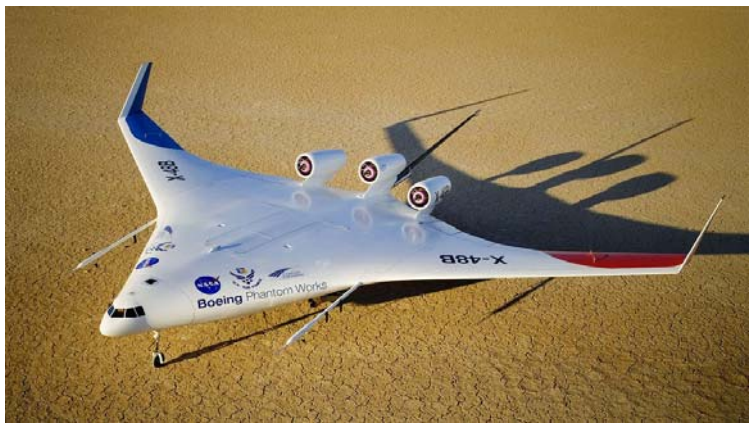
Landing Gear Drop Tests

Wing Load Test

Drogue Boom Load Test

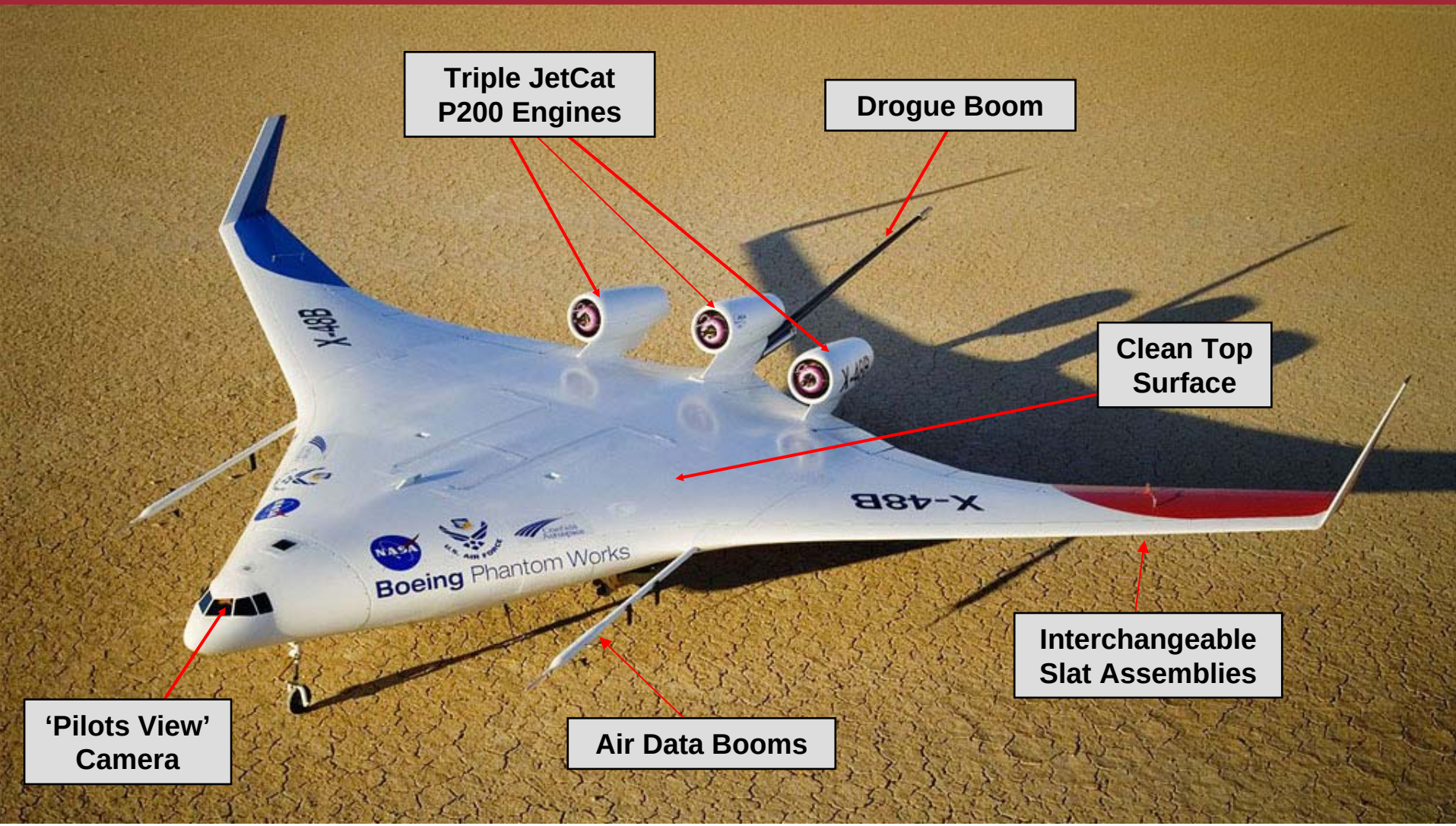
8.5% Dynamically Scaled X-48B BWB

- **Vehicle Characteristics**
  - **Wing Span** **20.4 ft**
  - **Wing Area** **100.5 ft2**
  - **Maximum Weight** **523 lbs**
  - **Static Thrust** **162 lbs**
  - **Maximum Airspeed** **118 kts**
  - **Maximum Altitude** **10,000 ft MSL**
  - **Load Factor Limits** **+4.5 g's to -3.0 g's**
  - **Flight Duration** **30 minutes + 5 minute reserve**

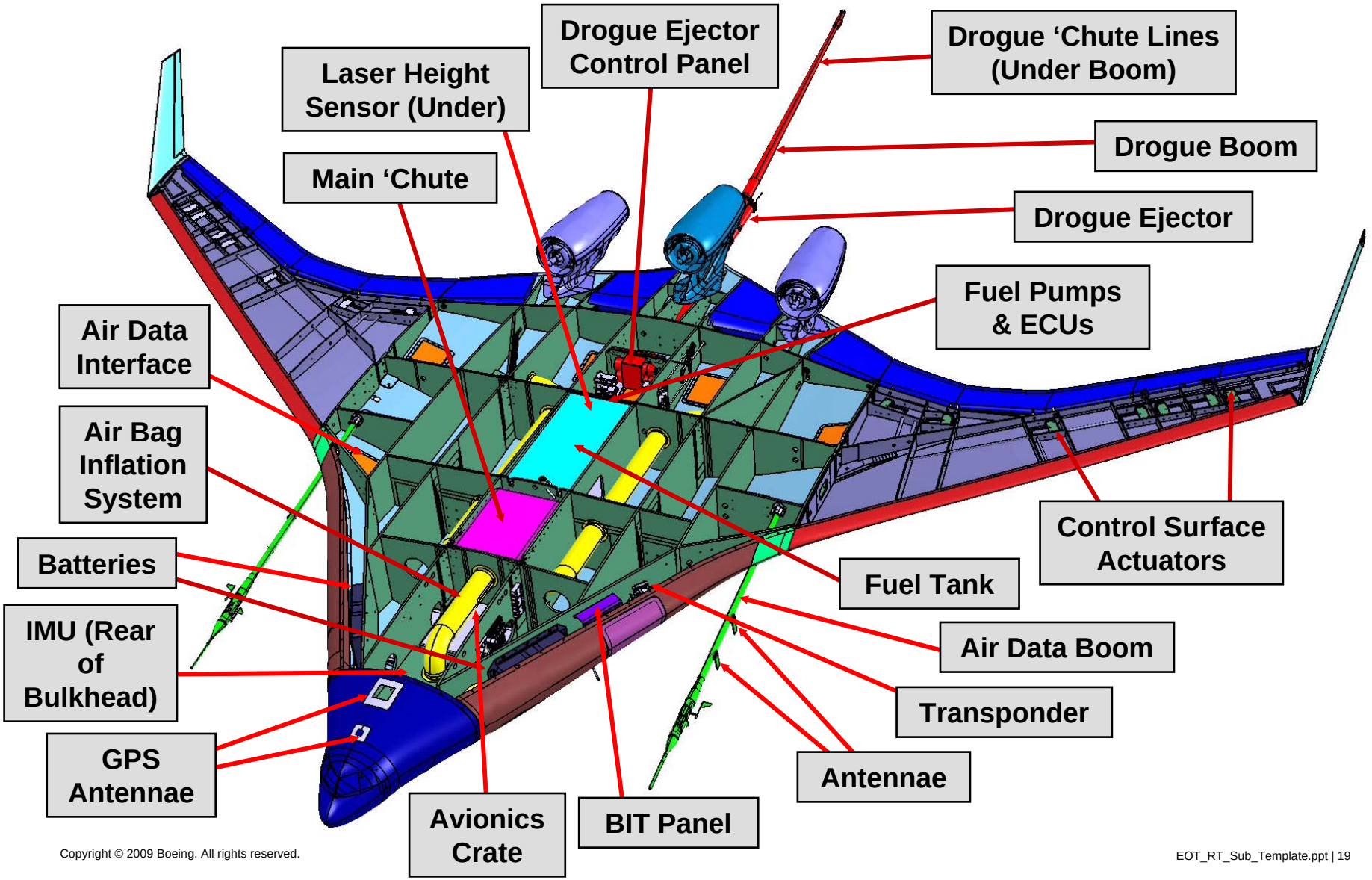


8.5% Dynamically Scaled X-48B BWB

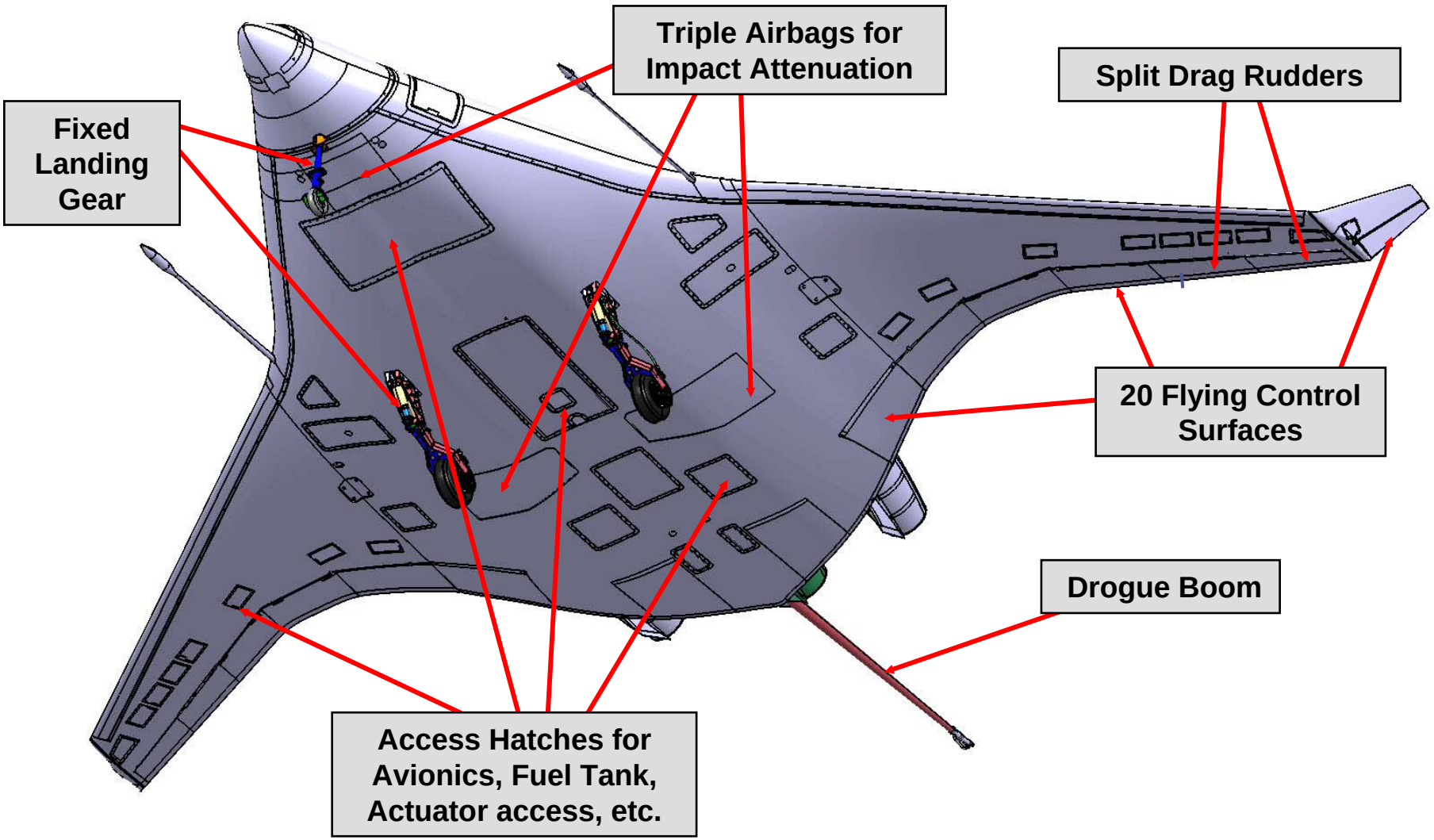
X-48B Configuration – Top View



X-48B Configuration – Internal View

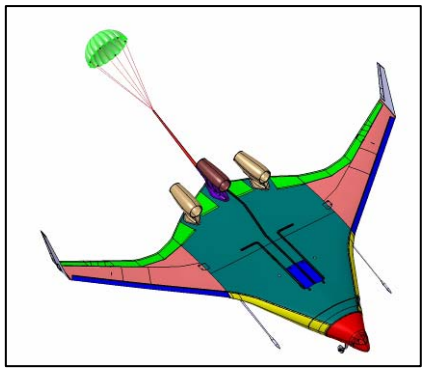


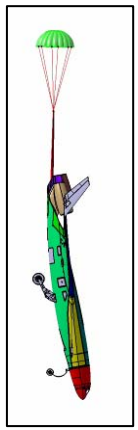
X-48B Configuration – Underside View



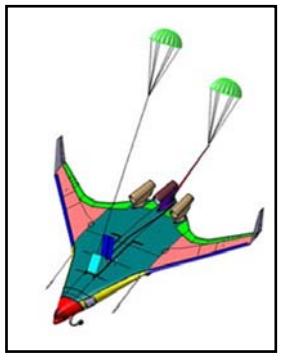
Recovery System

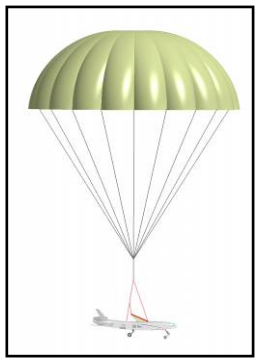
Drogue



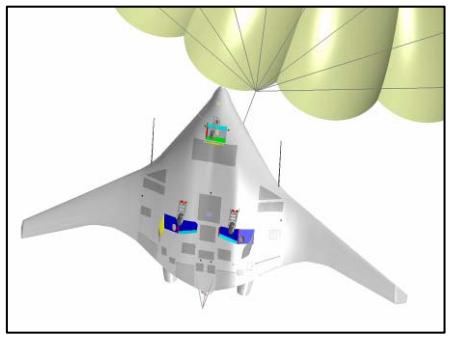


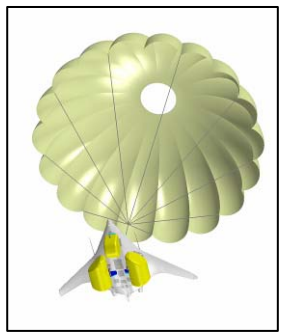
Main





Airbags





GCS – Trailer

GCS – Trailer

GCS – Pilot Station

Lakebed Operations

Lakebed Operations

Lakebed Operations

First Flight Video

X-48B Flight Test Summary

- **Fifty Flights completed (as of 2 April 2009)**
  - **32 Flights w/ Slats Extended**
  - **18 Flights w/ Slats Retracted**
    - **8 Multi Mission Operations**
- **Test Highlights:**
  - **Test Maneuvers**
    - **Real-Time Stability Margins – Envelope Expansion**
    - **Automated Parameter Identifications (PID) – Freq Sweeps/Doublets**
    - **Steady Heading Sideslips - Simulate Cross-winds**
    - **Lazy-8s and Wind-up Turns**
    - **Airspeed Calibrations (Triangle method)**
    - **Approach to Stalls**
    - **Stalls & Deep Stall Recoveries**
    - **Engine Out Maneuvering**
    - **Trim in Ground Effect**

  - **Operations from Hard Surface Runway vs. Lakebed Runway**
    - **Edwards AFB North Base 6/24 – 3,000 Feet (Eastern End)**

X-48B Initial Flight Test Results

- **Extremely Maneuverable in Roll**
- **Aircraft Very Closely Matches GCS for Up/Away Flight (and Landing)**
  - **Pitch / Yaw Limiters different in Simulator than Airplane**
  - **Potential Air Data Calibration issue – under investigation**

- **Flight Control Design is Very Robust**
  - **Some Control Law deficiencies were masked during Slat Ext flights**
    - **Beta Vane Switching (Average to Single) / Takeoff Pitch Authority**
- **Overall, the Aircraft Flies Extremely Well**
  - **Despite no peripheral cues (2-D only) / no seat-of-the-pants**

X-48B Lessons Learned

- **COTS Design approach**
  - **Initial Equipment Cost Low, But Integration Cost may be High**
  - **Original planned Engine Design not COTS – large impact to Flight Duration**
- **Waypoint Nav Design / Software V&V testing**
  - **Test Limits - Windshear, Gusts / Weather Balloon Data**
- **Flight Simulator invaluable for Successful Tests**
  - **Very good match for flight – Excellent flight rehearsal / pilot training tool**
- **Braking PIO potential High**
  - **No Decel Feedback to Pilot / Brake Spring or Ground Models inaccuracies**
- **Robust Flight Control System can Mask some Control Law Deficiencies**

Lessons Re-Learned

X-48B What's Next for the Future

- **Current Funding to complete a total of ~65 Flights**
  - **Follow-on Testing planned to continue thru FY2010**
- **Next Phases – Slats Ext first, then Slats Ret**
- **Phase 3/4 :**
  - **Stalls / High Alpha / Engine Out Assym**
- **Phase 5/6:**
  - **Departure Resistance - Limiter Assaults / High Beta**
- **Potential new Engine Design**
  - **More Efficient = More Duration**

X-48B Blended Wing Body -- Legalese

- **Slide 1: NASA Photo**
- **Slide 2: NASA Photo / Boeing Photo**
- **Slide 3: Boeing Photo**
- **Slide 6: Boeing Photo**
- **Slide 7: NASA Video**
- **Slide 11: Boeing Photo**
- **Slide 12: Boeing Photos**
- **Slide 13: Boeing Photo**
- **Slide 14: Boeing Photo**
- **Slide 17: Cranfield Photo**
- **Slide 18: Boeing Photo**
- **Slide 19: Boeing Photo**

- **Slide 20: Boeing Photo / NASA Photo**
- **Slide 21: NASA Video**
- **Slide 22: NASA Photo**
- **Slide 23: NASA Photo**
- **Slide 24: NASA Photo**
- **Slide 25: NASA Video**
- **Slide 26: Boeing Photo**

Questions?


X-48B
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Boeing Phantom Works
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NASA
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