The B2 – Bomber
A Closer Look at the B2 Configuration

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Brief History

• The B-2 is a revolutionary aircraft
• Unique flying wing configuration with the following design objectives
  – Serve as a multi-role bomber
  – Stealth was extremely important
  – Had to be able to fly long missions
• Development
  – Began in the 1970s
  – First off the line in November of 1988
  – First Flight was July 17, 1989
  – In 1991, B-2 design team was awarded the Collier Trophy
• B-2 in Action:
  – 1999 in Kosovo
  – 2001 in Afghanistan
  – February 22, 2008, first reported accident of B-2
  – Humidity on sensors were yielding skewed pre-flight checks
## Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>First flight</td>
<td>17-Jul-89</td>
</tr>
<tr>
<td>Classification</td>
<td>Bomber</td>
</tr>
<tr>
<td>Span</td>
<td>172 feet</td>
</tr>
<tr>
<td>Length</td>
<td>69 feet</td>
</tr>
<tr>
<td>Gross weight</td>
<td>336,500 pounds</td>
</tr>
<tr>
<td>Cruising speed</td>
<td>High subsonic</td>
</tr>
<tr>
<td>Range</td>
<td>6,000 miles plus</td>
</tr>
<tr>
<td>Ceiling</td>
<td>50,000 feet</td>
</tr>
<tr>
<td>Power</td>
<td>Four 19,000-pound-thrust F118-GE-100 engines</td>
</tr>
<tr>
<td>Accommodation</td>
<td>2 crew</td>
</tr>
<tr>
<td>Armament</td>
<td>More than 40,000-pound nuclear or conventional weapon payload</td>
</tr>
<tr>
<td>Runway Length</td>
<td>6500 feet</td>
</tr>
<tr>
<td>Cost</td>
<td>$2 billion</td>
</tr>
</tbody>
</table>

# Geometry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planform Area</td>
<td>5118.55 ft²</td>
</tr>
<tr>
<td>Mean Aerodynamic Chord</td>
<td>39.47 ft</td>
</tr>
<tr>
<td>X-Centroid</td>
<td>40.21 ft</td>
</tr>
<tr>
<td>Spanwise position of MAC</td>
<td>29.53 ft</td>
</tr>
<tr>
<td>X-Leading Edge of MAC</td>
<td>20.47 ft</td>
</tr>
<tr>
<td>Quarter Chord of MAC</td>
<td>30.34 ft</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>5.78</td>
</tr>
<tr>
<td>Average Chord</td>
<td>29.76 ft</td>
</tr>
<tr>
<td>Taper Ratio</td>
<td>0.00</td>
</tr>
<tr>
<td>LE Sweep</td>
<td>34.74 deg</td>
</tr>
</tbody>
</table>

Picture Source: [http://www.aerospaceweb.org/aircraft/bomber/b2/b2_schem_01.gif](http://www.aerospaceweb.org/aircraft/bomber/b2/b2_schem_01.gif)

Data Source: Utilized WingPlanAnal Code to generate data
CG location

CG location was calculated by looking at the side profile of the B-2.

Assuming a 15° angle between the landing gear ground contact and the cg location and assuming the cg was located forward of the landing gear, the cg was calculated to be around 33.2 feet aft of the reference datum line.

Neutral Point: 32.98 ft aft of nose
Static Margin: 0.22 ft

Reference Datum

Picture Source: http://www.aerospaceweb.org/aircraft/bomber/b2/b2_schem_01.gif
Data Source: Utilized VLMpc Code to generate neutral point data
Cdo at Various Altitudes

Data Source: Utilized FRICTION code from http://www.aoe.vt.edu/~mason/Mason_f/MRsoft.html

Note by Mason, this was run at a different altitude (Re)

M = 0.79
Spanloading Comparison


e = 0.96

Cl = 1
Twist Distribution for Minimized Drag

Optimized Spanloading

Data Source: Used spanloading data output from LAMDES program found at http://www.aoe.vt.edu/~mason/Mason_f/MRsoft.html
Section Cl for B2

Data obtained from Lift equation at Mach = 0.79 and the corresponding densities for each altitude.
Lift – to – Drag Ratio

Data Source: http://www.aoe.vt.edu/~mason/Mason_f/ConfigAeroAppD.pdf
Takeoff and Landing

- Ground effect:
  - Large area flying wing
  - Sits on cushion
  - Has to be “forced” to land
  - Not difficult (2nd easiest to the F-15)
- Stealth design led to great lifting features.
Control Surfaces

• B-2 has 4 pairs of control surfaces on the wing trailing edge.

1) Split drag rudders on outer wing
2) One elevon on outer wing
3) Two elevons on inner wing
4) Beaver tail

• Outer elevons provide primary pitch & roll control.
• 2 inner elevons considered secondary control surfaces (used at low-speed).
• Beaver-tail works constantly to alleviate gust loads.

At low speed flight, drag rudders are open.


Stability and Control of Conventional and Unconventional Aircraft Configurations: By Bernd Chudoba Page 201
[http://science.howstuffworks.com/stealth-bomber2.htm](http://science.howstuffworks.com/stealth-bomber2.htm)
Stealth

Low Observable Characteristics

- RADAR cross section (RCS)
- Infrared signature
- Appearance
- Electromagnetic Signature
- Acoustic Signature

Picture source:
http://www.is.northropgrumman.com/systems/b2spirit_assets/photos/hi/01top20_94a65408.jpg
Stealth

- The key to Stealth is know how RADAR waves are reflected off a body.
- RADAR waves reflect similar to light rays.
- A light ray will reflect off a surface the same angle at which it encountered the surface.
- To get a return a RADAR reflection requires a surface perpendicular to the incoming wave.

Reference Data:
- http://www.answers.com/topic/stealth-aircraft
Stealth

The B-2 outer profile has a variable radius/continuous curve that deflects RADAR waves at any angle (non-tangential surface). Thus, reducing it’s RCS.

It’s shape also allows for aerodynamic flow.

To further reduce it’s RCS the skin is coated with RADAR Absorbing Materials (RAM)

Reference Data:
Inside the Stealth Bomber By Bill Sweetman
(page 25-26)

http://www.answers.com/topic/stealth-aircraft

http://en.wikipedia.org/wiki/B-2_Spirit

Picture Source:
http://www.is.northropgrumman.com/systems/b2spirit_assets/photos/hi/01top20_95020910.jpg