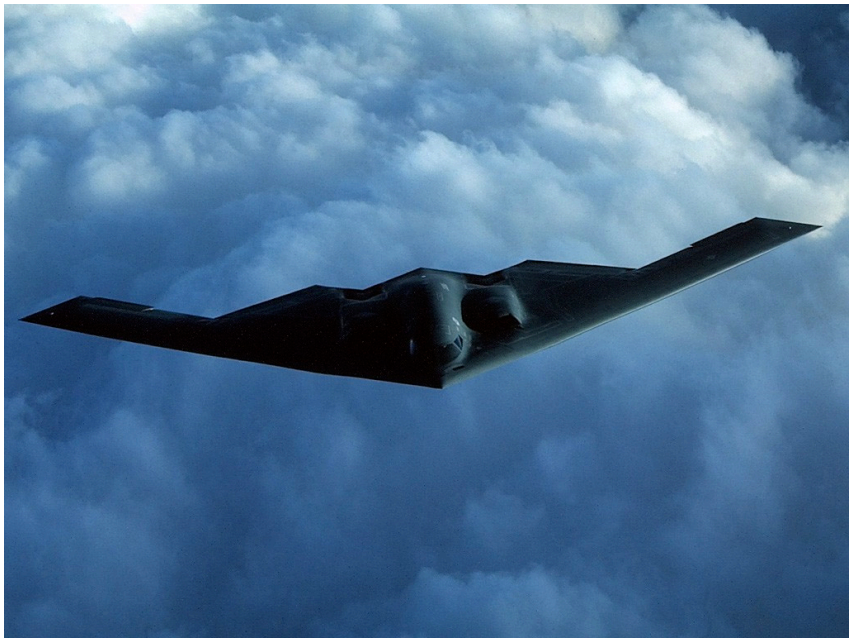
The B2 – Bomber

A Closer Look at the B2 Configuration



David Cross, Joel Faber, and Raul Telles

AOE 4124 – Team Project

April 1, 2009

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

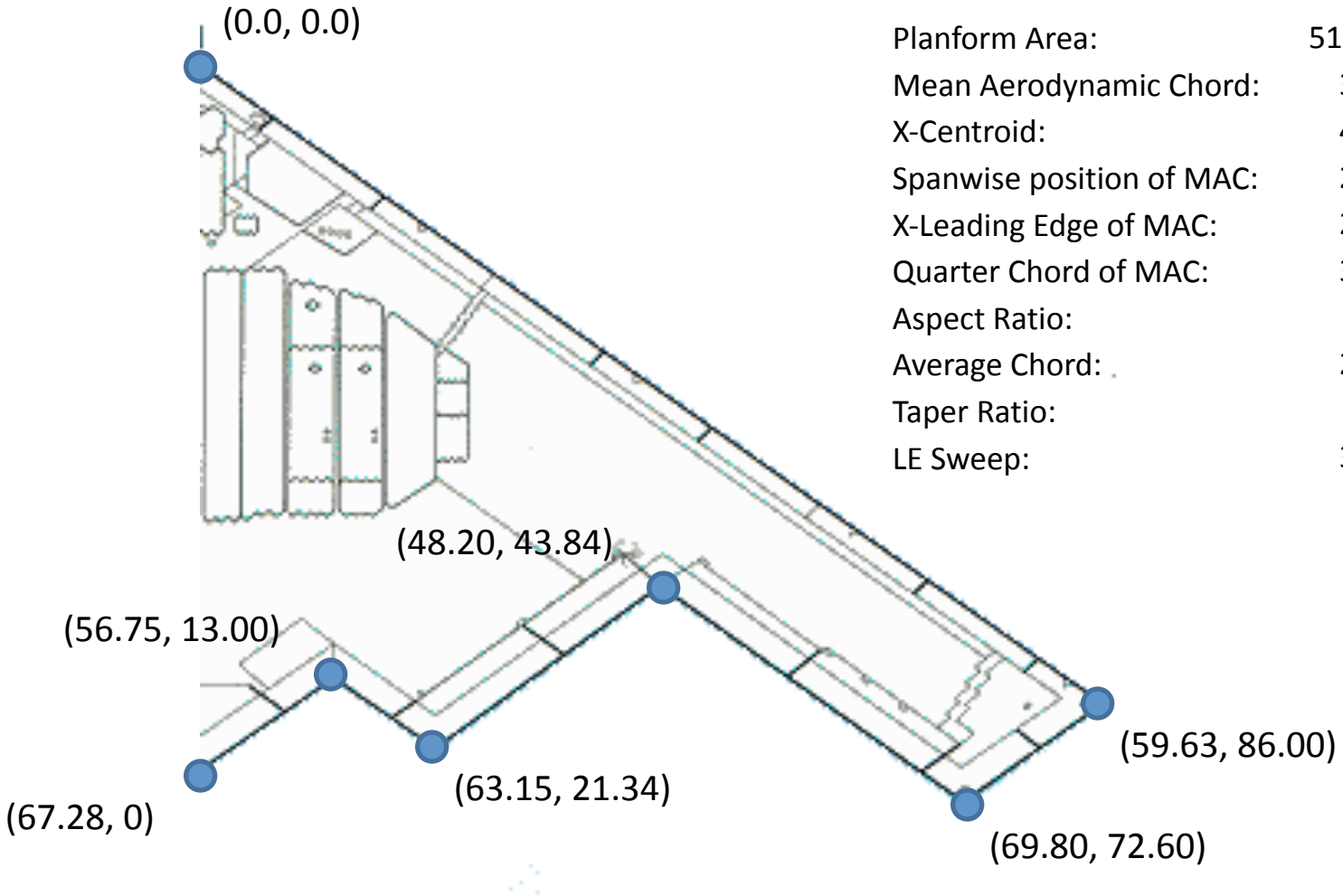
Jane's Military Aircraft Recognition Guide, 2007

Specifications

First flight:	17-Jul-89
Classification:	Bomber
Span:	172 feet
Length:	69 feet
Gross weight:	336,500 pounds
Cruising speed:	High subsonic
Range:	6,000 miles plus
Ceiling:	50,000 feet
Power:	Four 19,000-pound-thust F118-GE-100 engines
Accommodation:	2 crew
Armament:	More than 40,000-pound nuclear or conventional weapon payload
Runway Length:	6500 feet
Cost:	$2 billion

Jane's Military Aircraft Recognition Guide, 2007

Geometry



Planform Area:	5118.55	ft^2
Mean Aerodynamic Chord:	39.47	ft
X-Centroid:	40.21	ft
Spanwise position of MAC:	29.53	ft
X-Leading Edge of MAC:	20.47	ft
Quarter Chord of MAC:	30.34	ft
Aspect Ratio:	5.78	
Average Chord:	29.76	ft
Taper Ratio:	0.00	
LE Sweep:	34.74	deg

Picture Source: http://www.aerospaceweb.org/aircraft/bomber/b2/b2_schem_01.gif
Data Source: Utilized WingPlanAnal Code to generate data

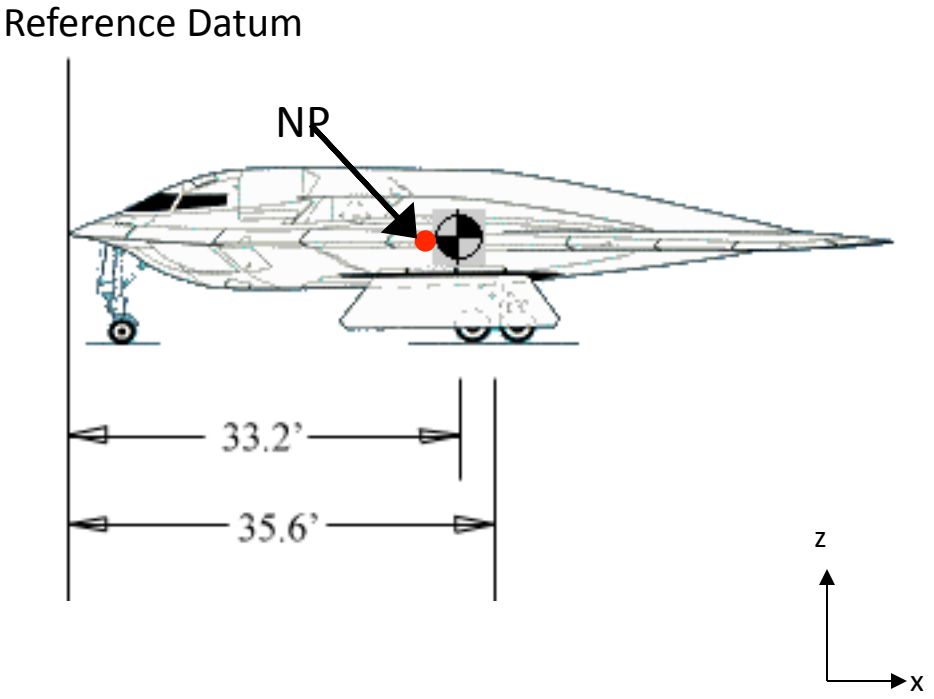
CG location

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.

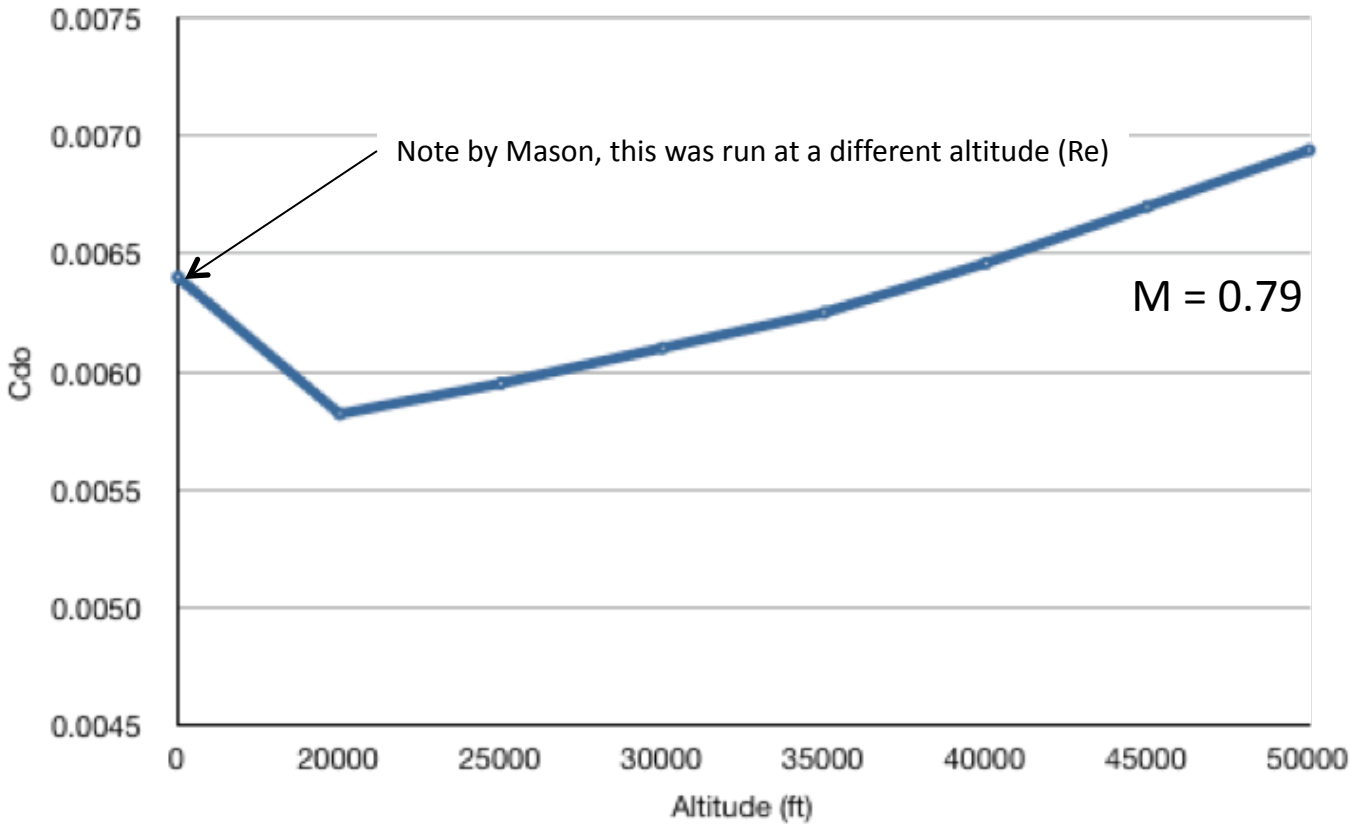
Neutral Point: 32.98 ft aft of nose

Static Margin: 0.22 ft



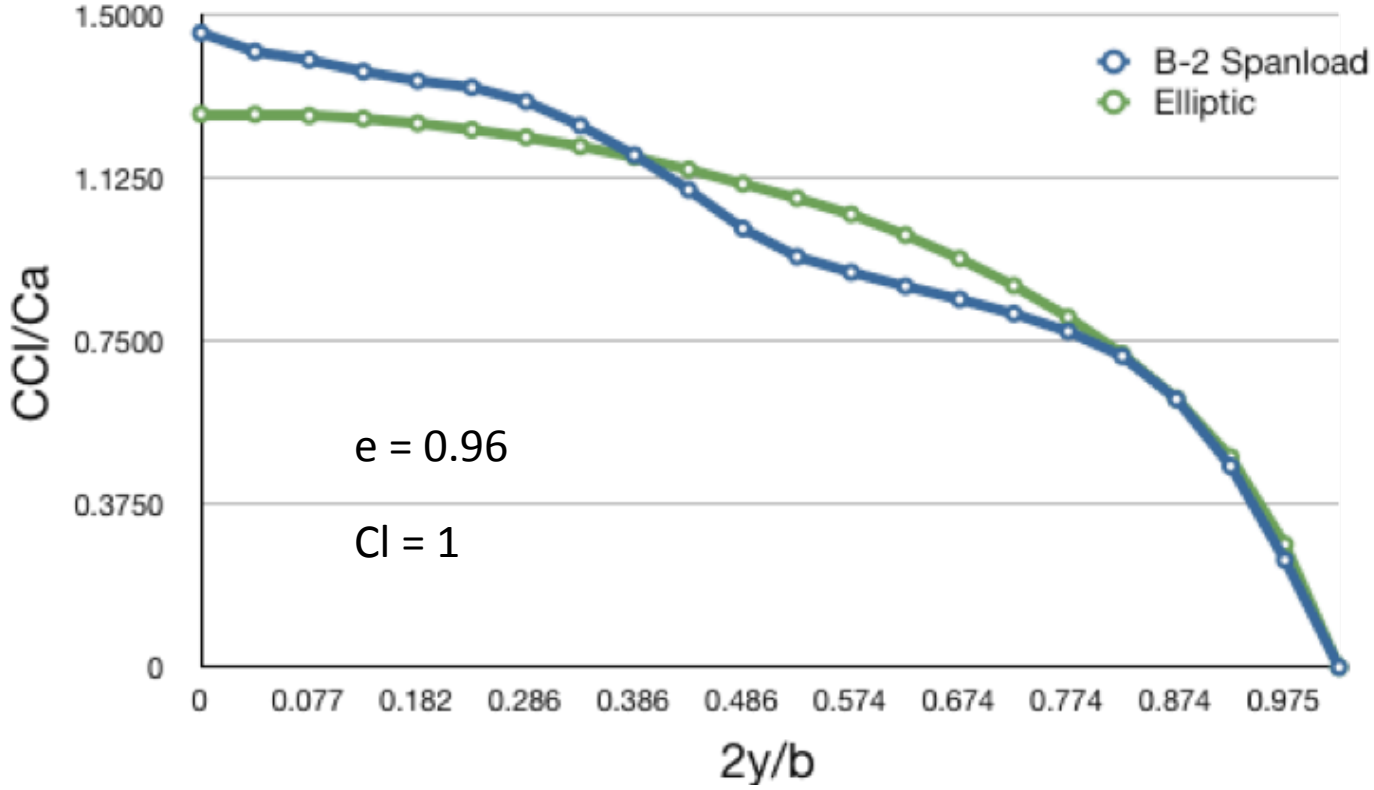
Picture Source: http://www.aerospaceweb.org/aircraft/bomber/b2/b2_schem_01.gif
Data Source: Utilized VLMpc Code to generate neutral point data

Cdo at Various Altitudes



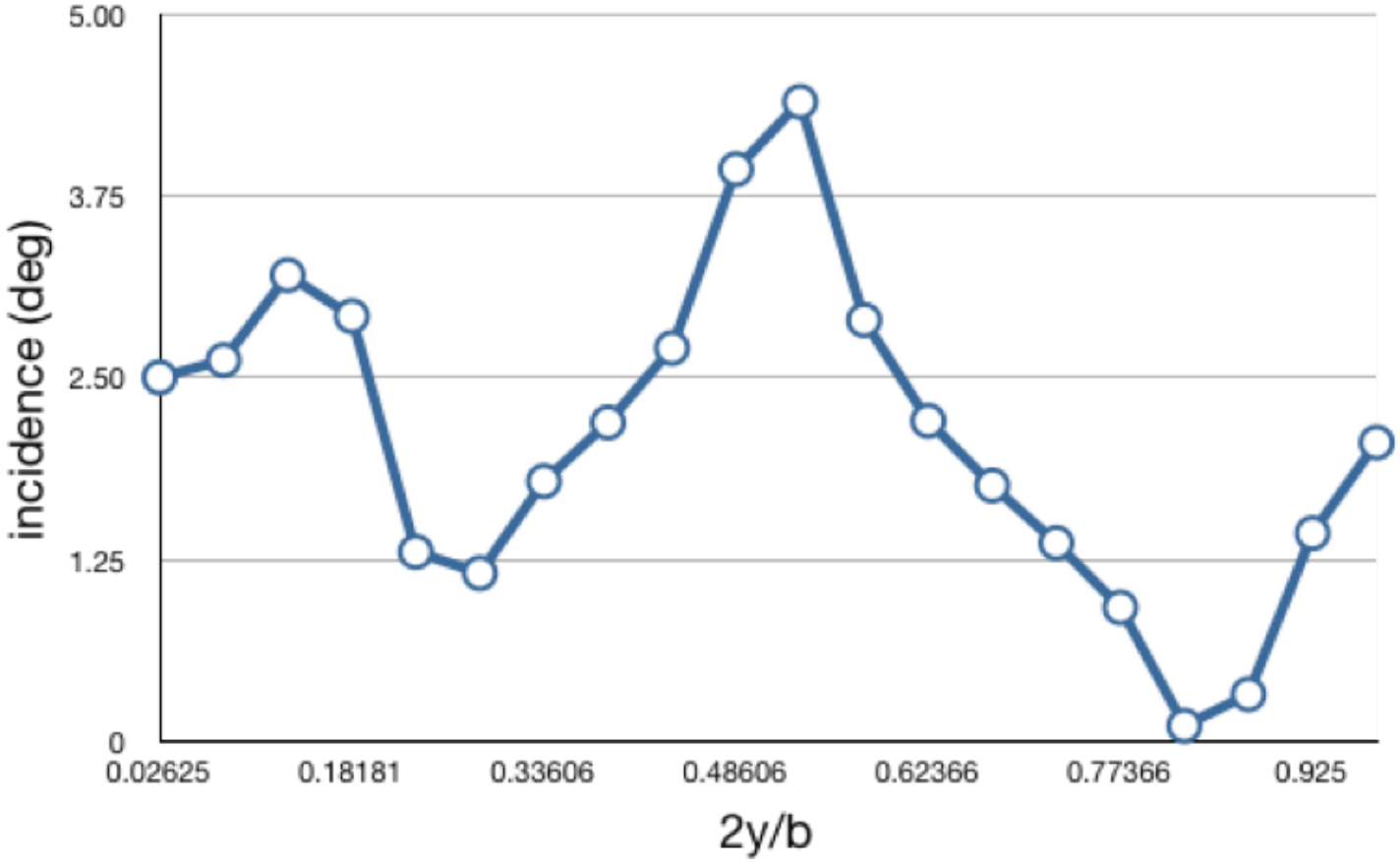
Data Source: Utilized FRICTION code from http://www.aoe.vt.edu/~mason/Mason_f/MRsoft.html

Spanloading Comparison



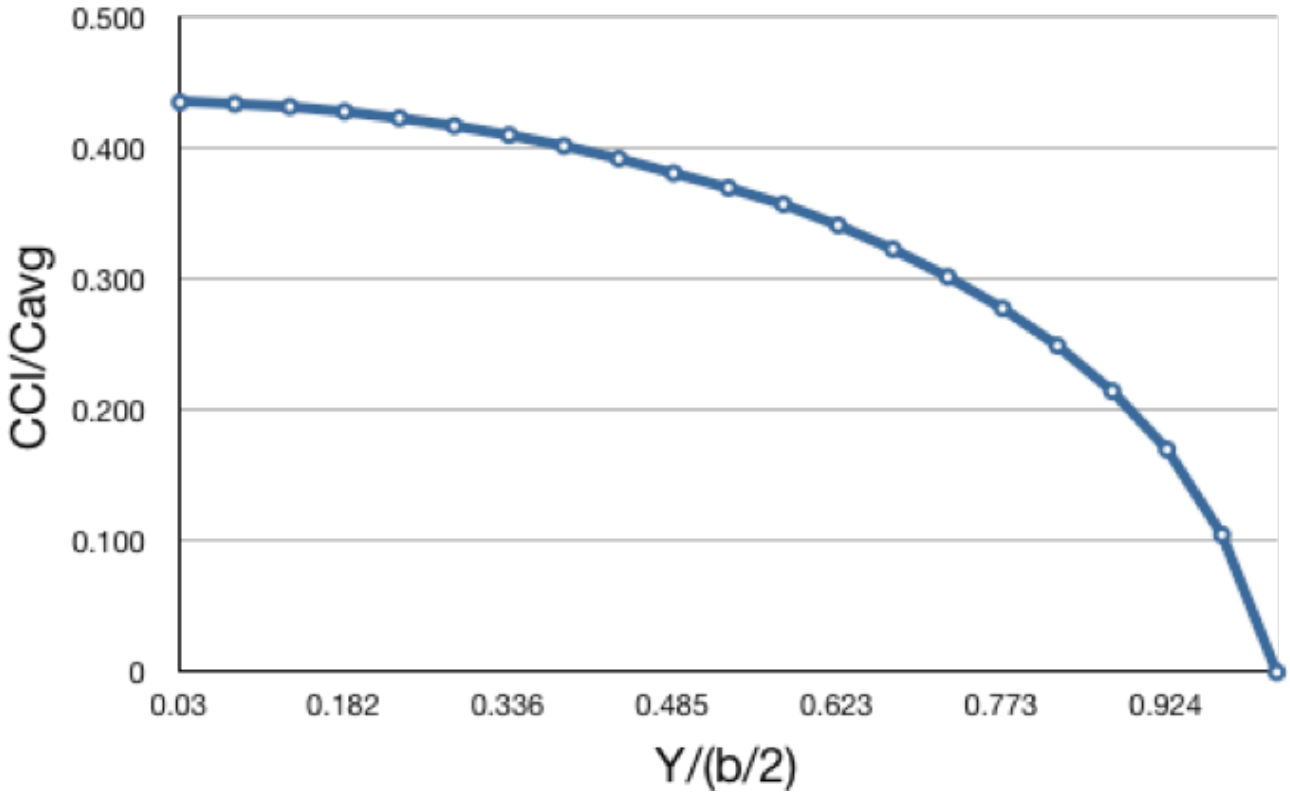
Data Source: Utilized LIDRAG Code from http://www.aoe.vt.edu/~mason/Mason_f/MRsoft.html

Twist Distribution for Minimized Drag



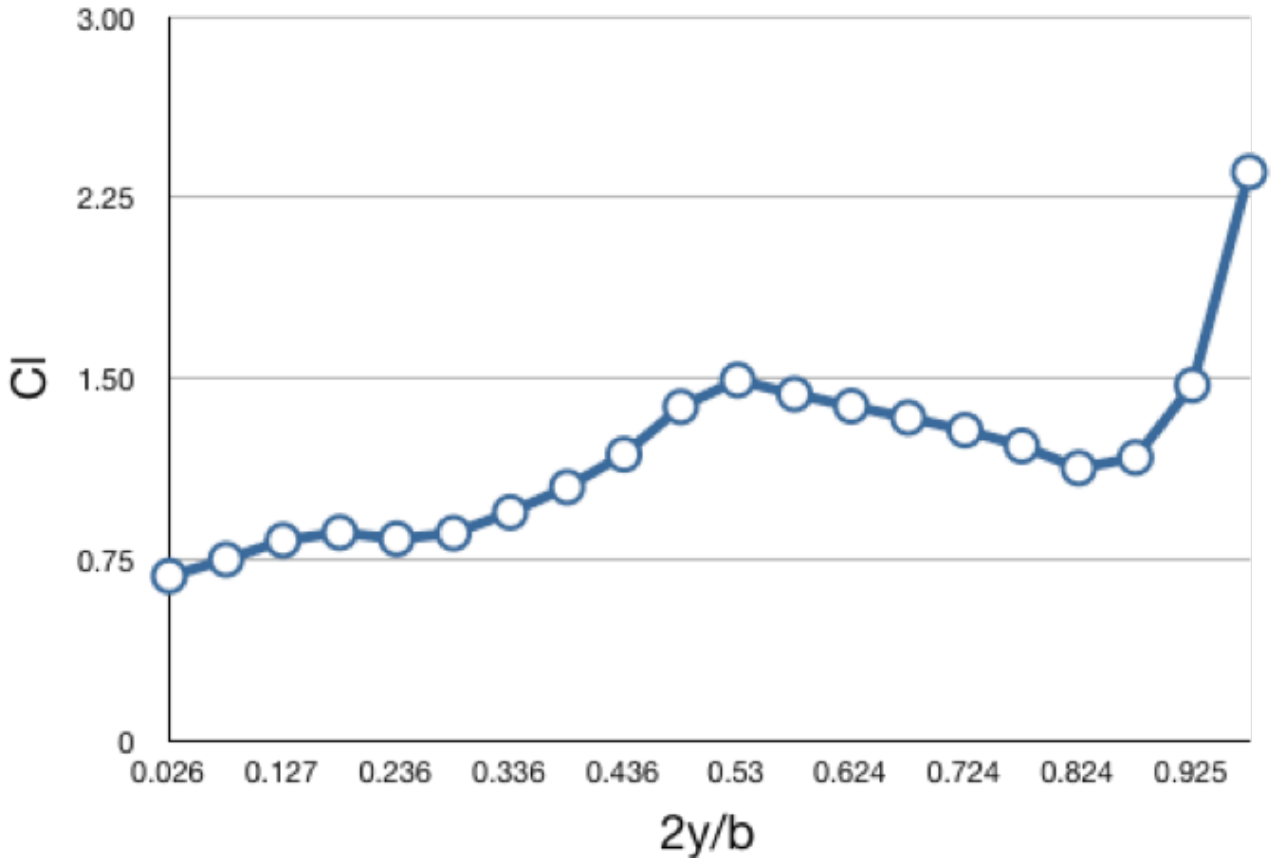
Data Source: Utilized LAMDES Code from
http://www.aoe.vt.edu/~mason/Mason_f/MRsoft.html

Optimized Spanloading



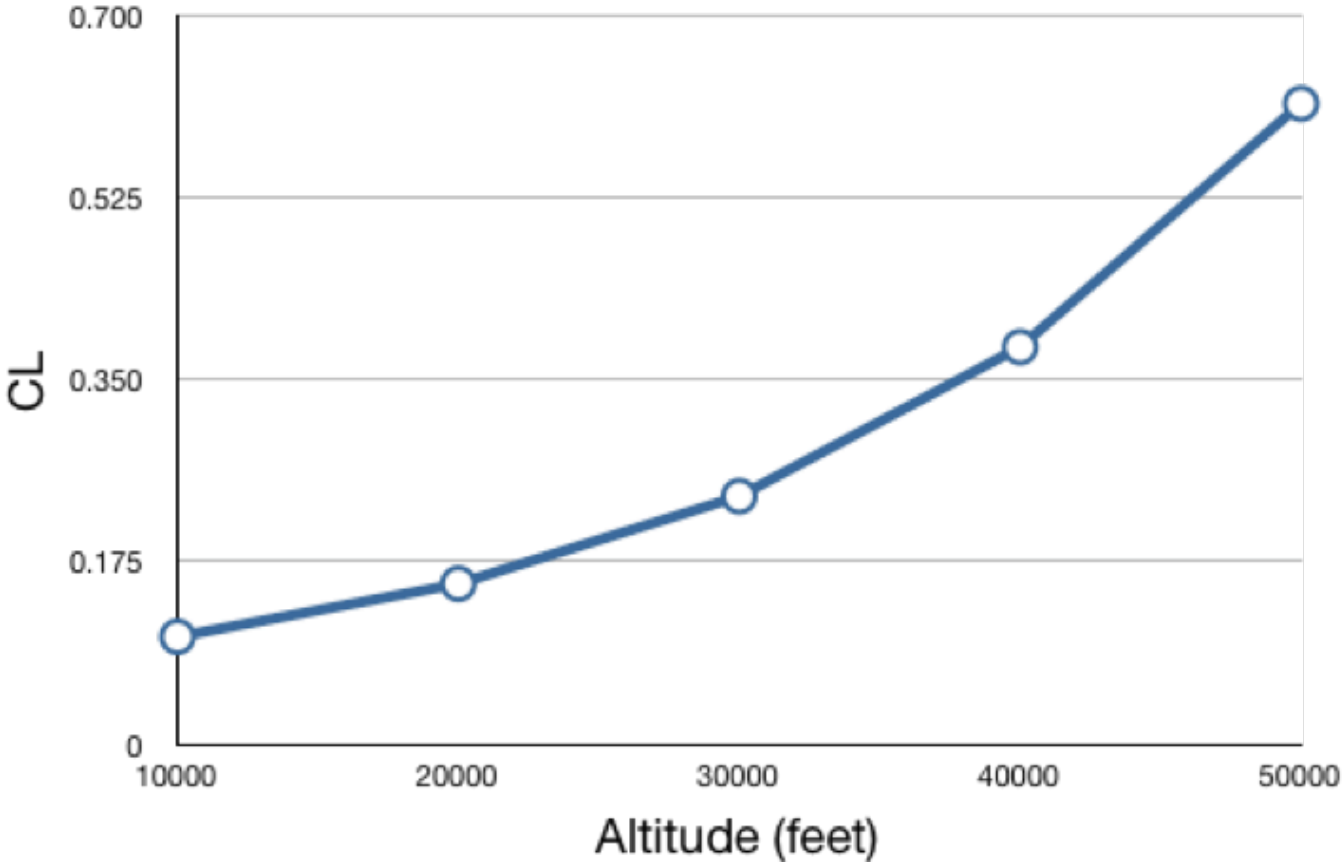
Data Source: Used spanloading data output from LAMDES program found at http://www.aoe.vt.edu/~mason/Mason_f/MRsoft.html

Section Cl for B2



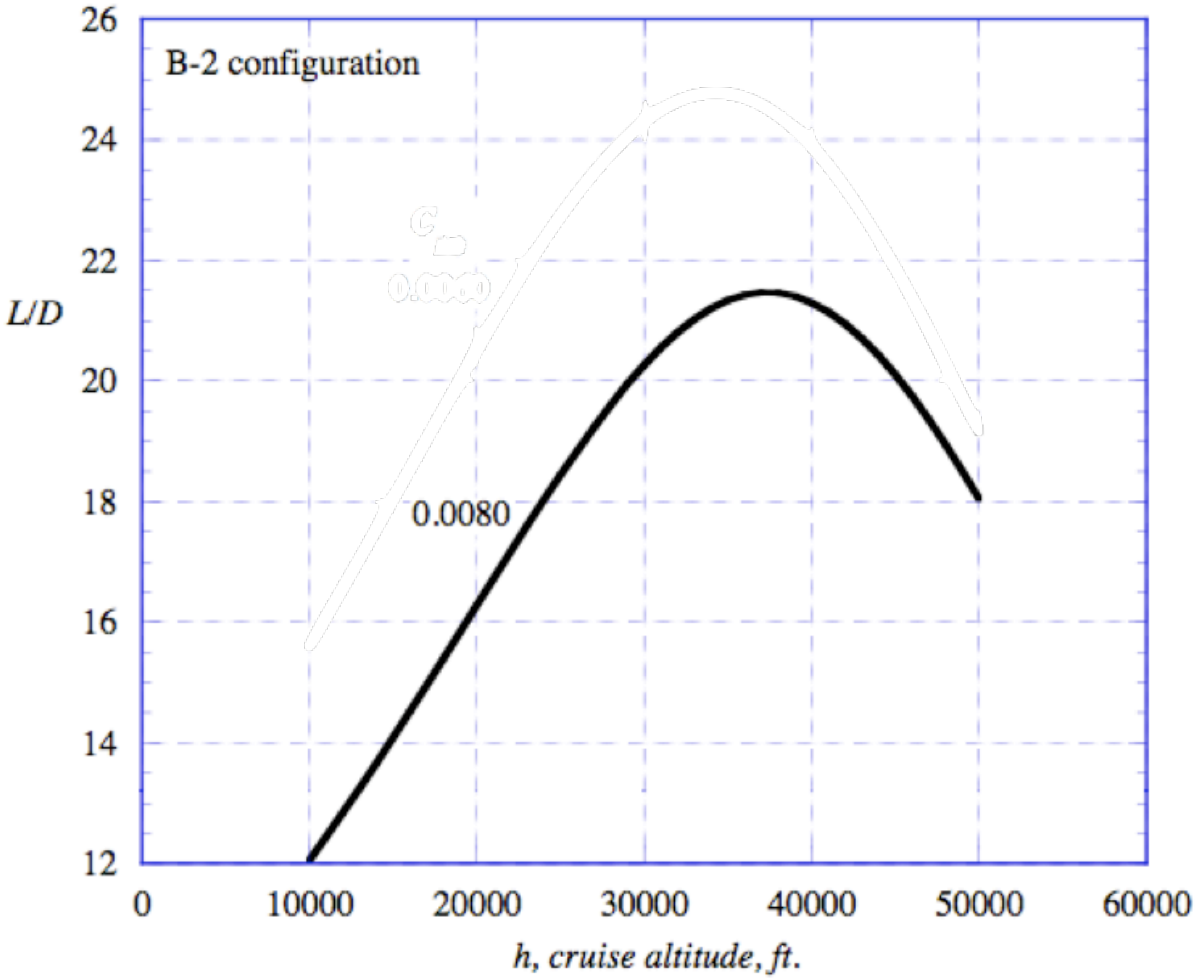
Data Source: Utilized VLMpc Code out put for section CL's from http://www.aoe.vt.edu/~mason/Mason_f/MRsoft.html

C_L at Various Altitudes



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

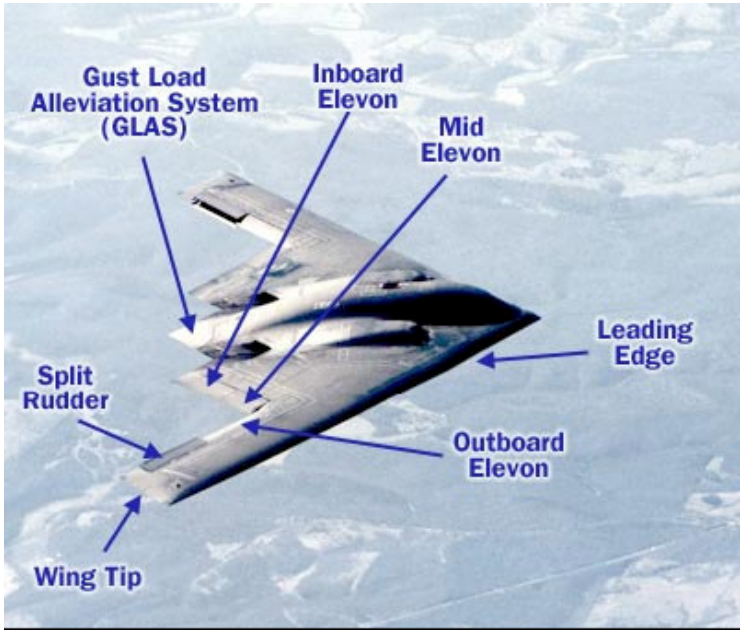
- Ground effect:
  - Large area flying wing
  - Sits on cushion
  - Has to be “forced” to land
  - Not difficult (2nd easiest to the F-15)
- Stealth design led to great lifting features.

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.

Picture Source: http://people.clarkson.edu/~pmarzocc/AE430/AE-430-5.pdf
http://people.clarkson.edu/~pmarzocc/AE430/AE-430-5.pdf
Stability and Control of Conventional and Unconventional Aircraft Configurations: By Bernd Chudoba Page 201
http://science.howstuffworks.com/stealth-bomber2.htm

Stealth

Low Observable Characteristics

-RADAR cross section (RCS)

-Infrared signature

-Appearance

-Electromagnetic Signature

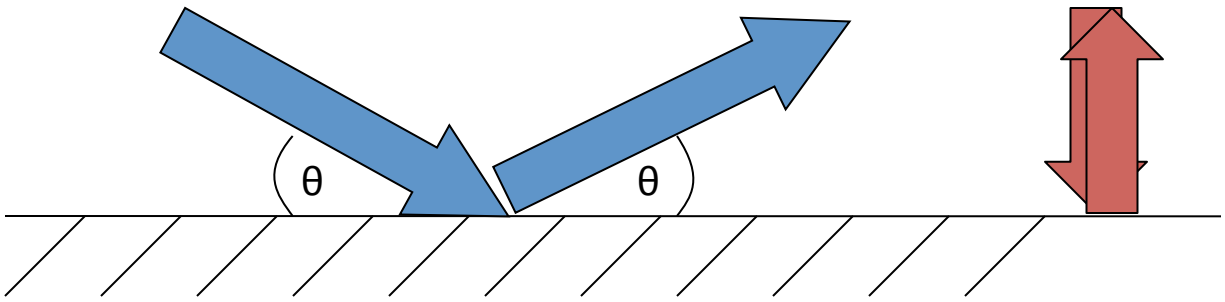
-Acoustic Signature

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.aoe.vt.edu/~mason/Mason_f/ConfigAeroStealth.pdf

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

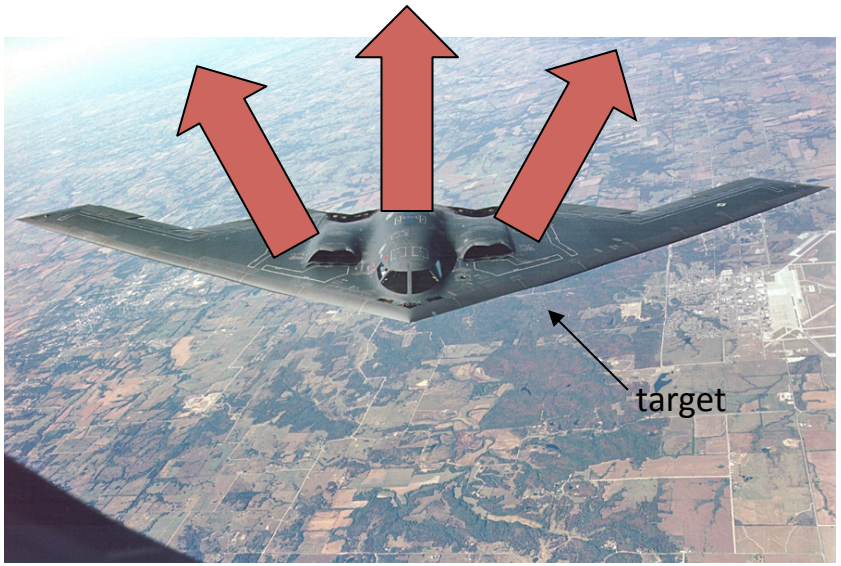
http://en.wikipedia.org/wiki/B-2_Spirit

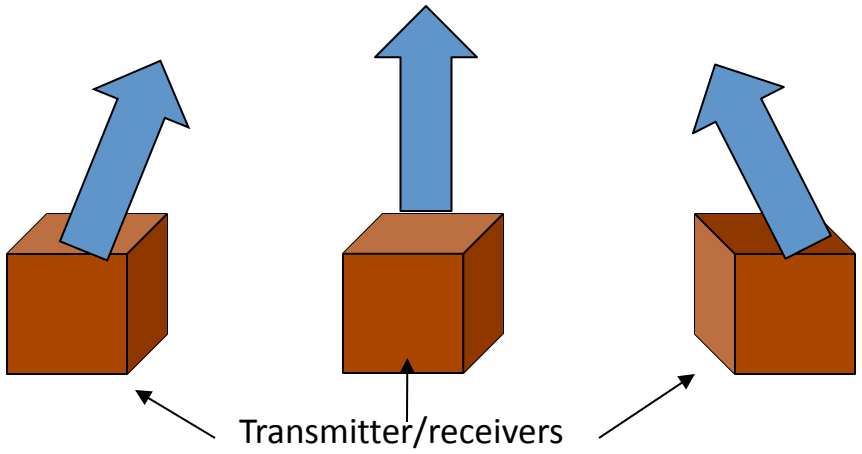
Stealth

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)

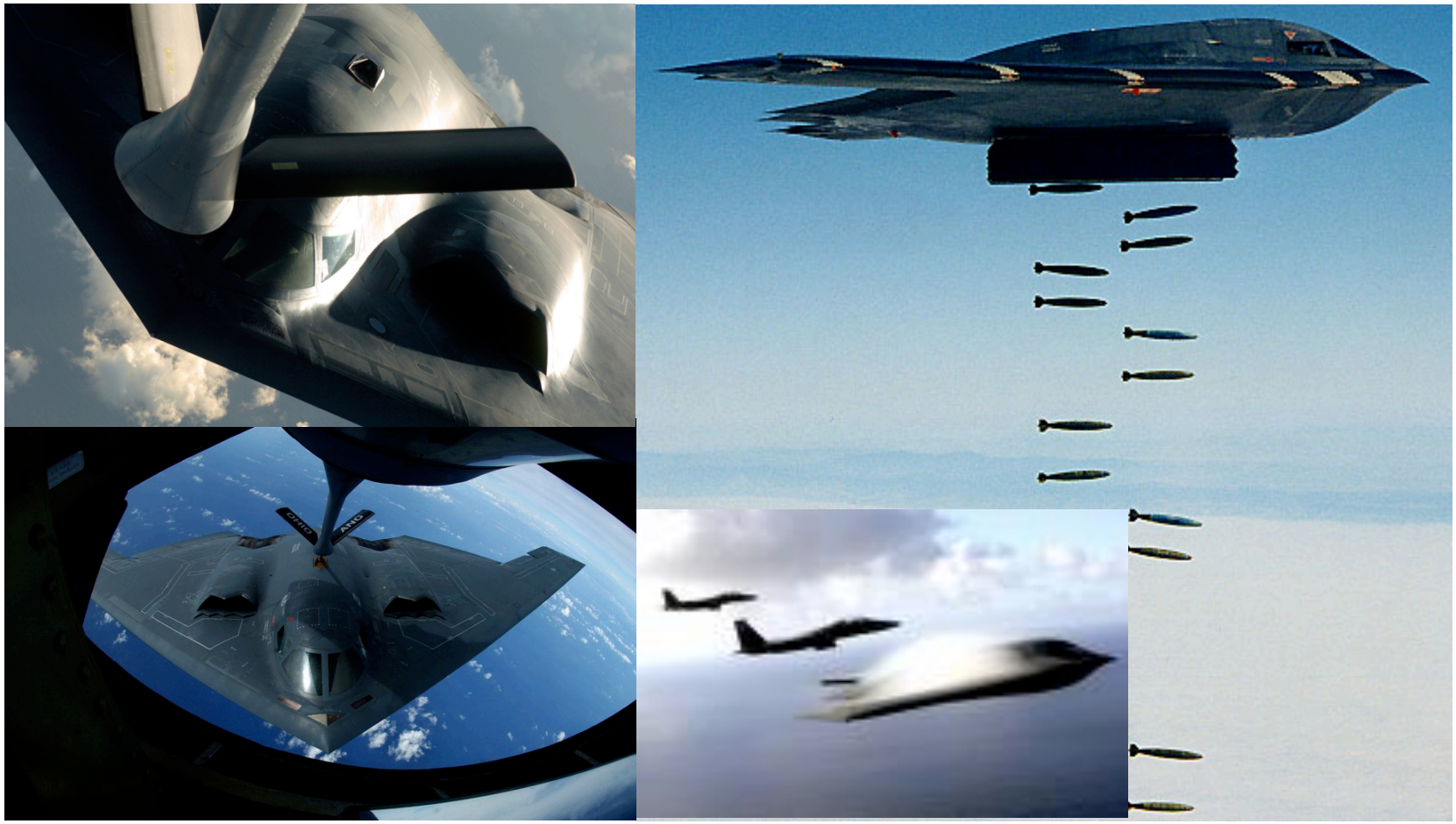
http://www.answers.com/topic/stealth-aircraft

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

Picture Source:

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

QUESTIONS???



Picture source: Google Images Search “B2”