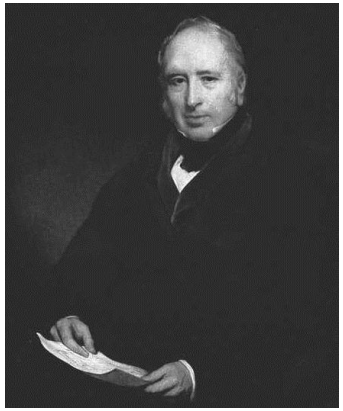
History of Aircraft Design
or
"Why do aircraft look the way they do"?

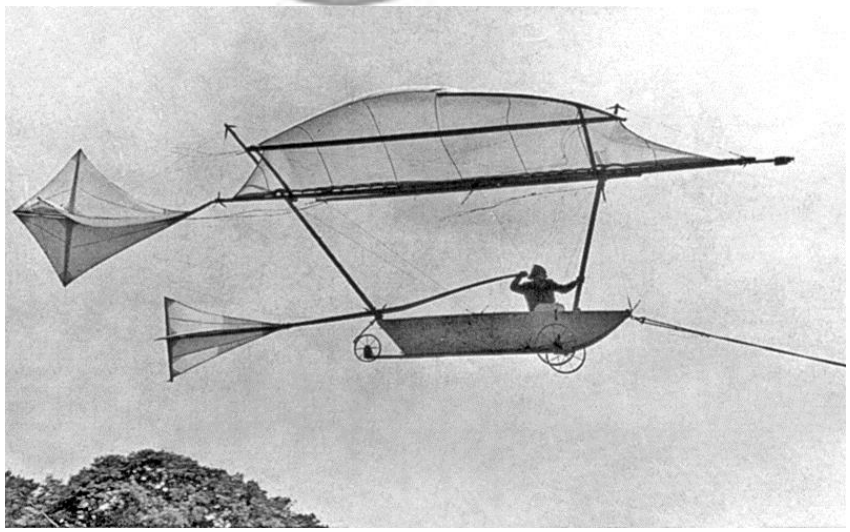
Wright Flyer

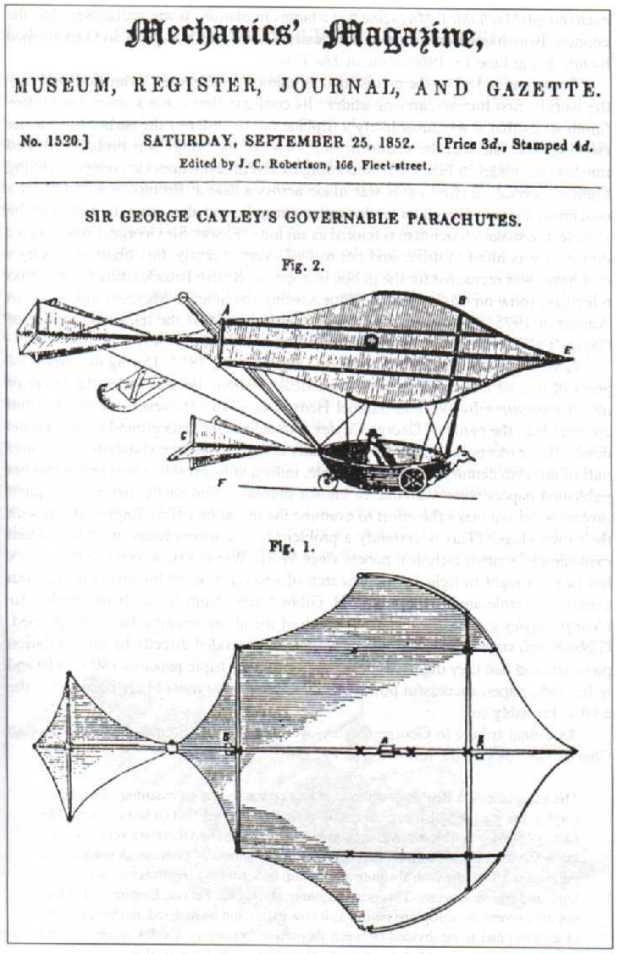
Space Ship 1 under White Knight

Mr N A (Sandy) Mitchell MSc CEng FRAeS

Sir George Cayley







Mechanics' Magazine,

MUSEUM, REGISTER, JOURNAL, AND GAZETTE.

No. 1520.] SATURDAY, SEPTEMBER 25, 1852. [Price 3d., Stamped 4d.

Edited by J. C. Robertson, 166, Fleet-street.

SIR GEORGE CAYLEY'S GOVERNABLE PARACHUTES.

Fig. 2.

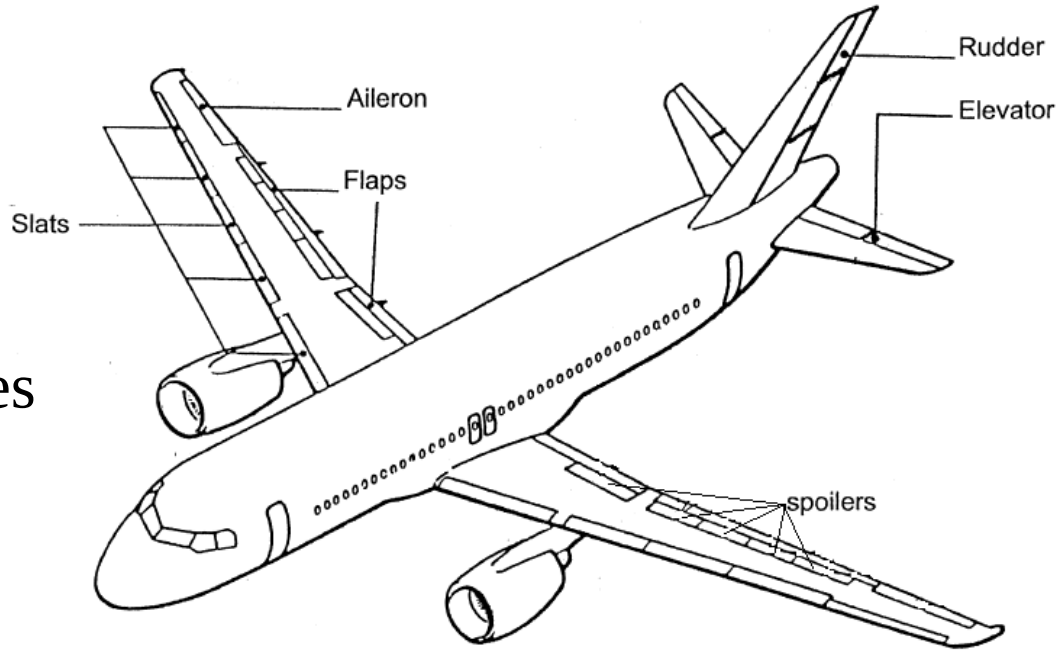
Fig. 1.

Replica Glider flown in 1973

Control

Primary control surfaces
- Elevator
- Aileron
- Rudder

Secondary control surfaces
- Flaps
- Slats
- Spoilers



Alternative primary control surfaces
- *Ruddervator, Elevon, Flaperon, Taileron, Canard*

Longitudinal Stability

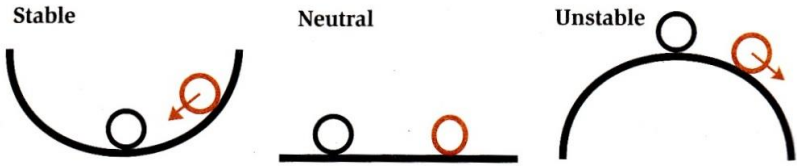
Consider a simple aircraft.

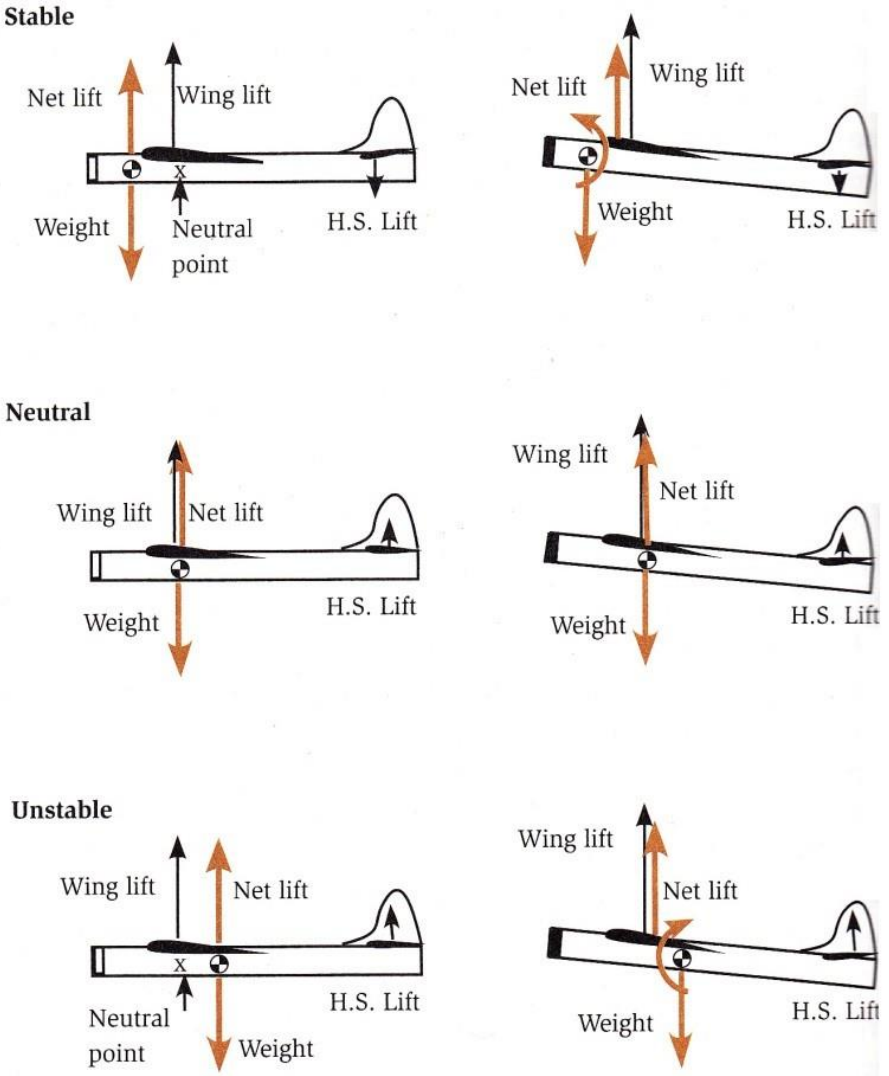
Stable: Increase in incidence produces a restoring moment

Neutral Point: Location of C of G for neutral stability

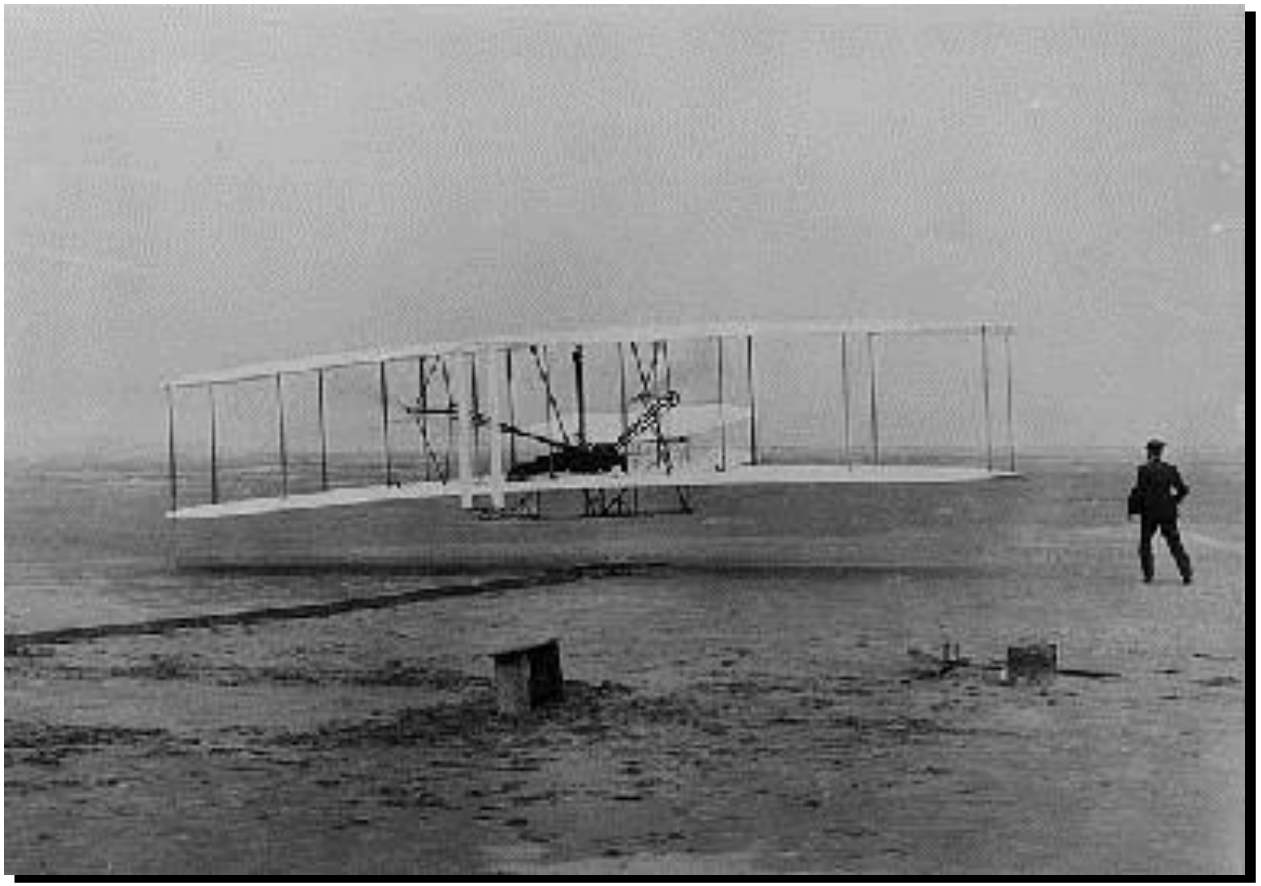
Neutral: Increase in incidence produces no moment

Unstable: Increase in incidence produces moment which further increases incidence





Wright Brothers



- Manned
- Powered
- Controlled
- Unstable!

First Flight 17th December 1903

Bristol Fighter

Civil Derivatives of Military Aircraft
Piston Engines WW1

Handley Page Vimy

Handley Page Airliner

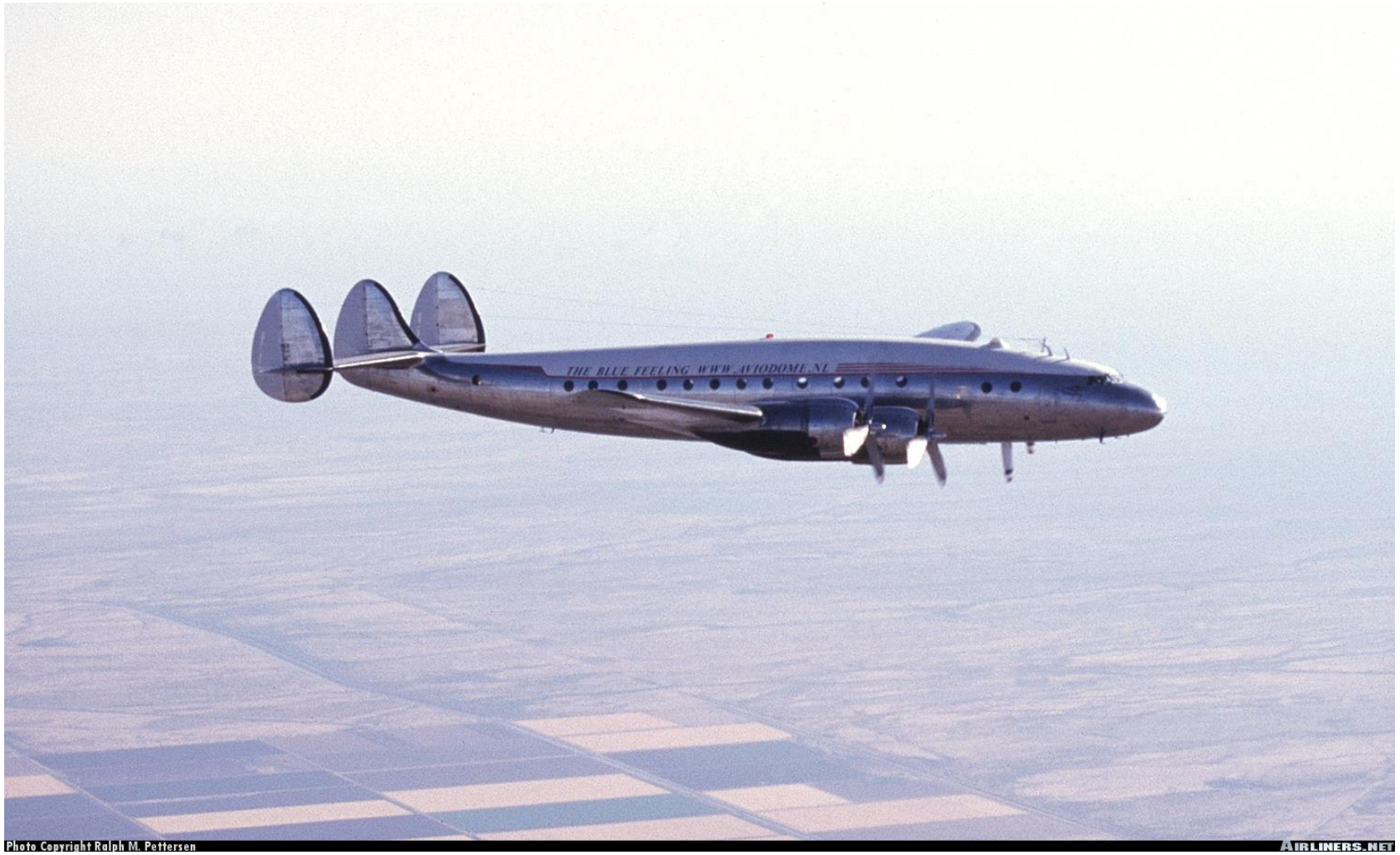
Classic Commercial Transport
Douglas DC3 Dakota

Civil Derivatives of Military Aircraft
Piston Engines in the 1940's

Boeing B29 Superfortress

Boeing B377 Stratocruiser

LOCKHEED CONSTELLATION



The evolution of the B47 and B707 ~ 1

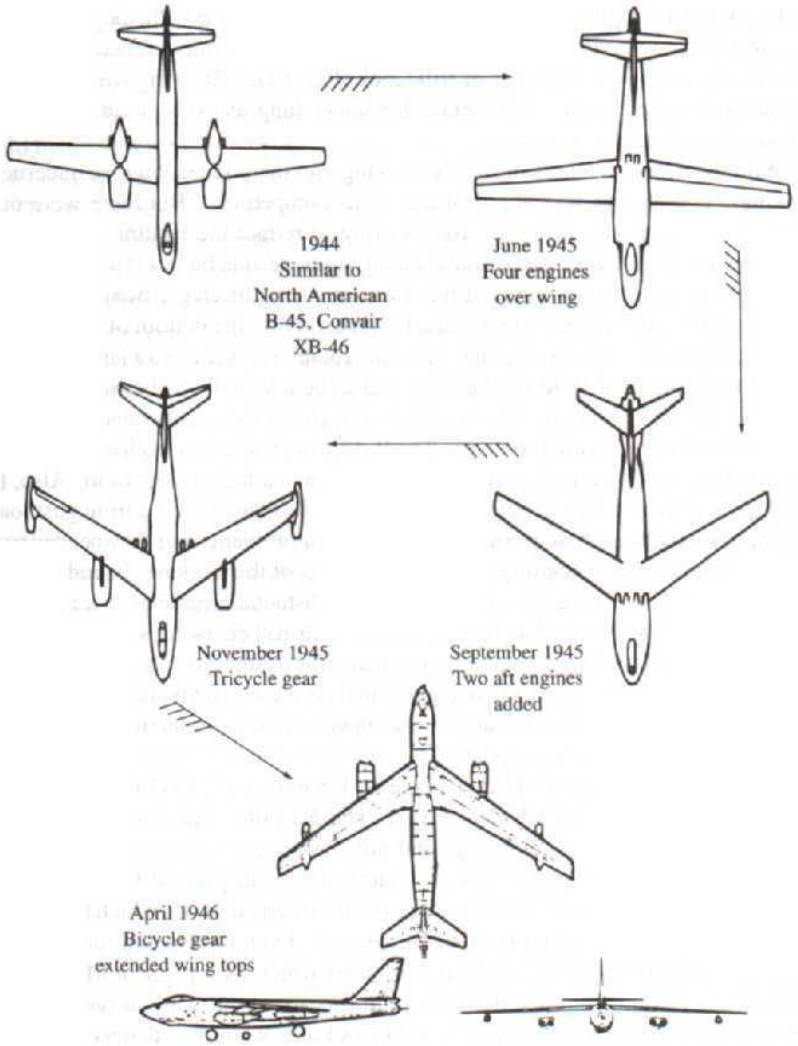
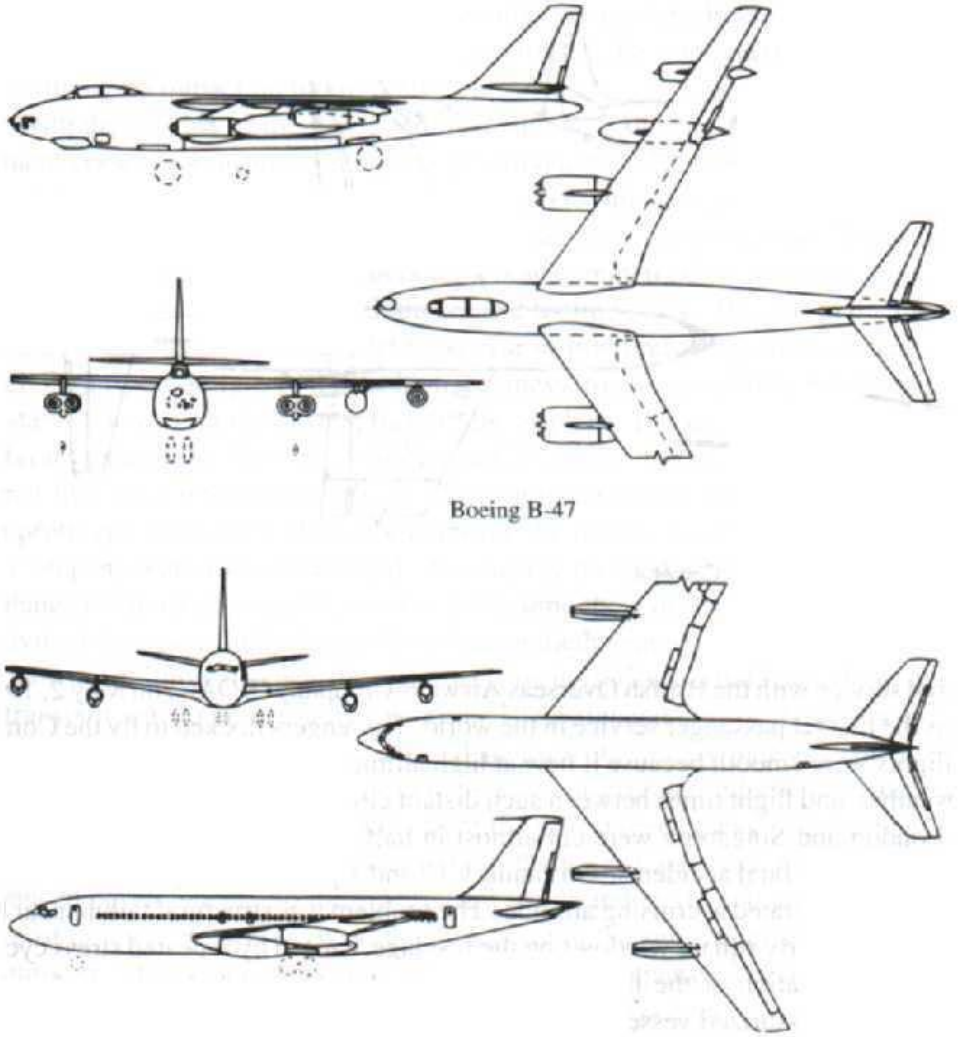


Figure 9.2 The design evolution of the Boeing B-47.



The evolution of the B47 and B707 ~ 2

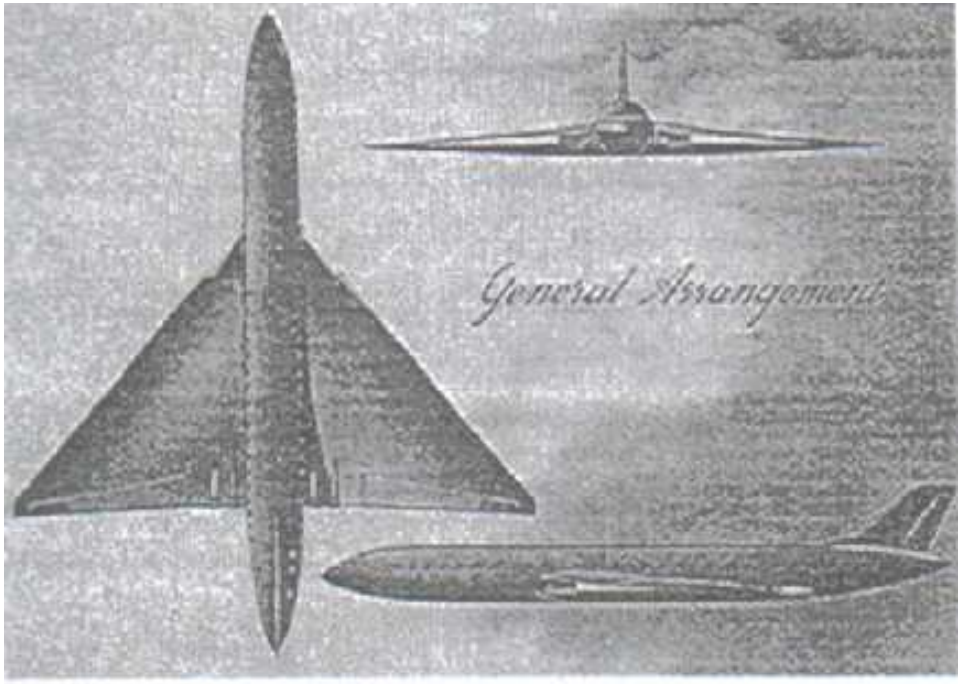
Boeing B47 Stratojet

Boeing B707

The de Havilland Comet

Civil Projects based upon V Bombers

Avro Vulcan ~ V Bomber



The Avro Atlantic – a 1952 Project

The 1950's Turbo-prop Powered Airliners

Long-haul ~ Brittania

Short-haul ~ Viscount

Rear Engined Configurations

VC10
Powerplant ~ RR Conway the first low by-pass ratio engine

Embraer EMB 145

Short/Medium Range Rear Engined Configurations
1960's Vintage

Boeing 727

de Havilland Trident

BAC 1-11

Douglas DC9

Breguet Range Equation

$$dR = \frac{V}{w_f} dW_{fuel}$$

speed

fuel flow

$$R = V(L/D)\eta_{prop} \frac{H}{g} Log_e\{W_{Take-off}/(W_{Payload} + W_{empty})\}$$

fuel calorific value

Aerodynamic Efficiency

lift to drag

overall power plant efficiency

$$W_{TO} = W_E + W_P + W_F$$

The development of high by-pass ratio turbofans

Lockheed C5A

GE TF39

The first wide-body Jets

Douglas DC10

Boeing 747

Lockheed 1011

Boeing 737

Boeing 737-200 powered by low by-pass ratio JT8D

Boeing 737-300 powered by high by-pass ratio CFM 56

Feederliners and Business Jets *(less than 100 passnegers)*

Hs146

Bomdadier Global Express

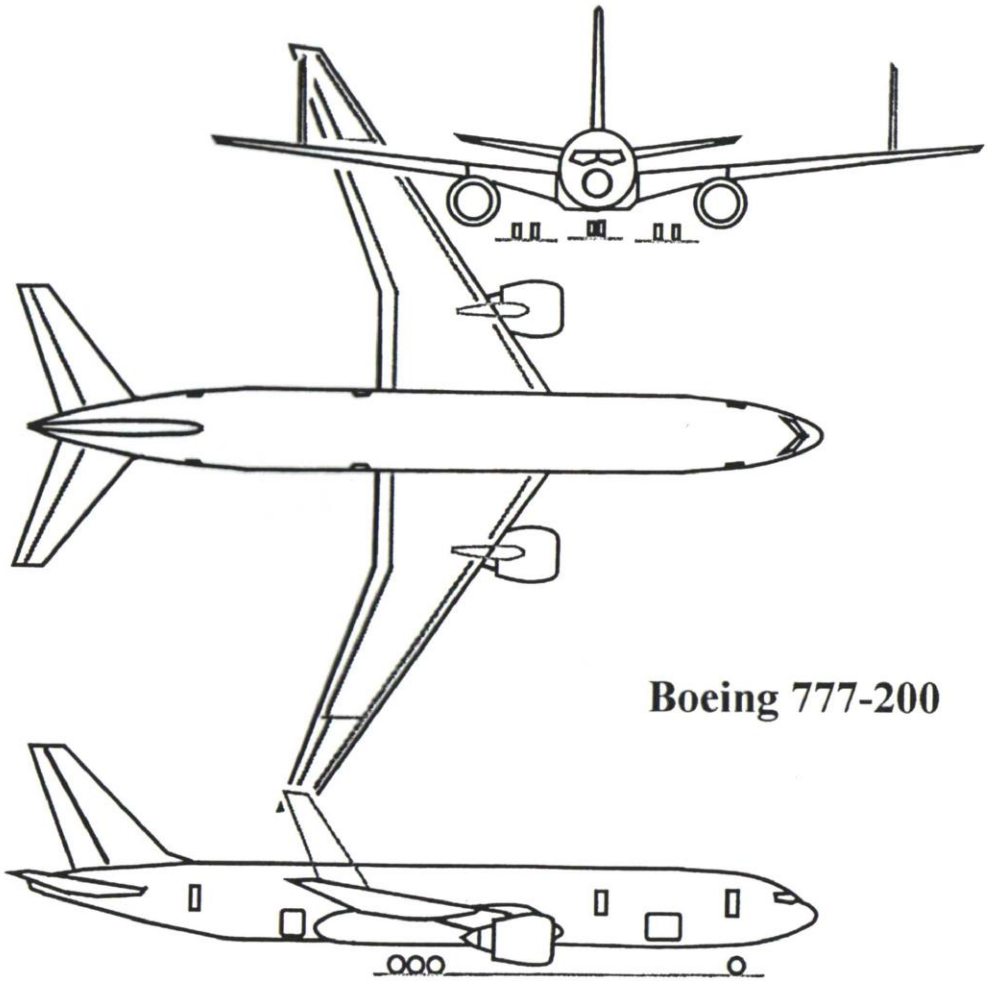
Embraer 145

Embraer 170/175

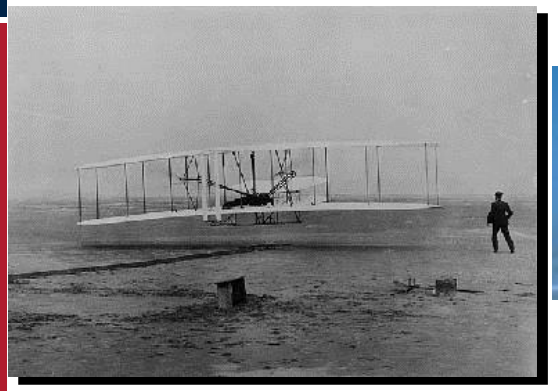
Airbus Advert

Subsonic Commercial Transport Aircraft

The Conventional Configuration



The emergence of the dominant configuration



- Highly evolved
- Strictly limited scope for improvement
- Commercial forces alone unlikely to break the mould
- Environmental considerations are the most likely drivers for change

Reference: J E Green "Civil Aviation - The Environmental Challenge" IMECHE October 2004

A NASA View

Quote* from Dennis Bushnell, Chief Scientist NASA Langley on subsonic transport systems:

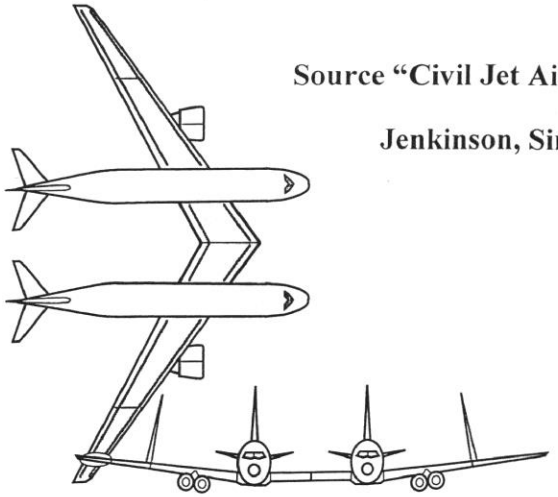
- ***"Most of the improvements over the past 40 years have been as a result of propulsion technology, primarily higher by-pass ratios and turbine inlet temperatures, nearly tripling seat miles per gallon. Advanced configuration concepts have, in general not been investigated in depth nor implemented"***

*1998 Wilbur & Orville Wright Lecture - Aerospace Journal January 1998.

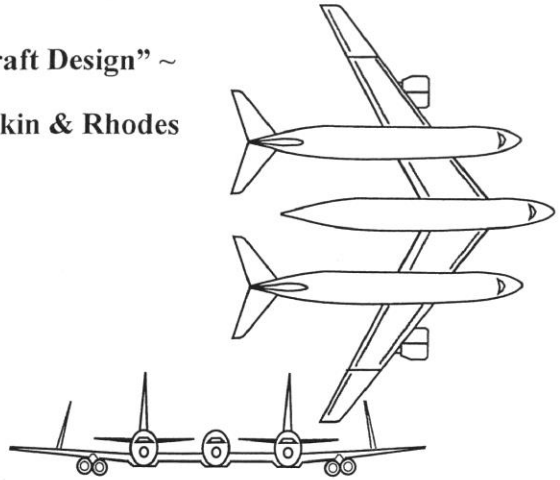
Novel Configurations 1

Source "Civil Jet Aircraft Design" ~

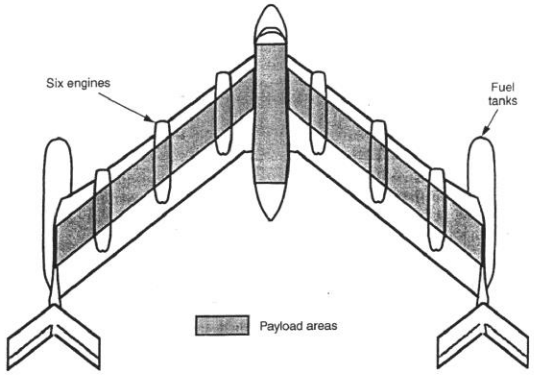
Jenkinson, Simpkin & Rhodes



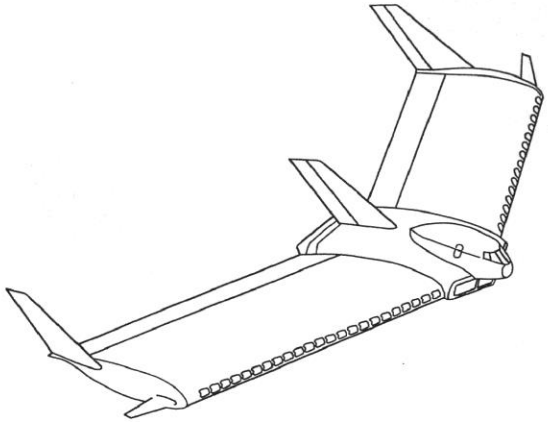
Twin Fuselage



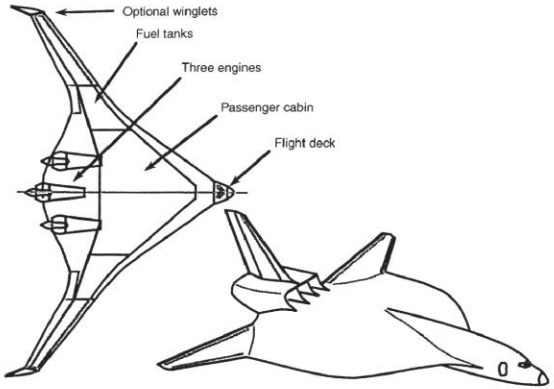
Triple Fuselage



Span-Loader



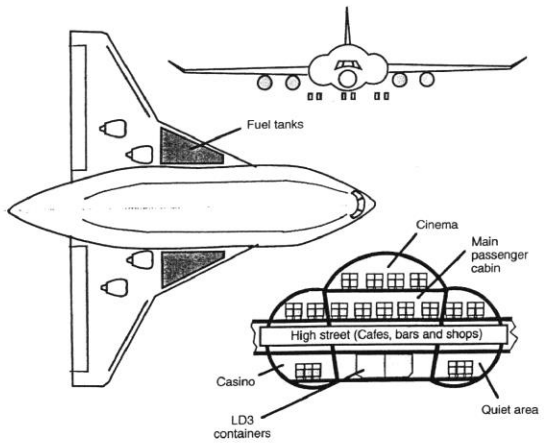
Boeing's Passenger Span-Loader



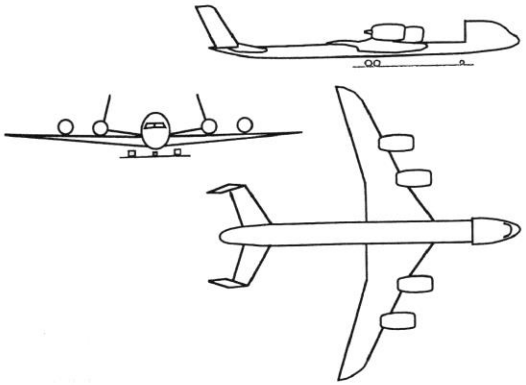
Flying Wing

Subsonic Commercial Transport Aircraft 2

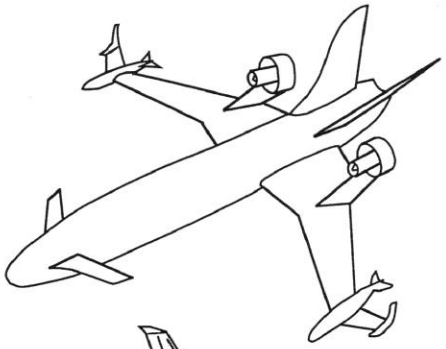
Novel Configurations 2



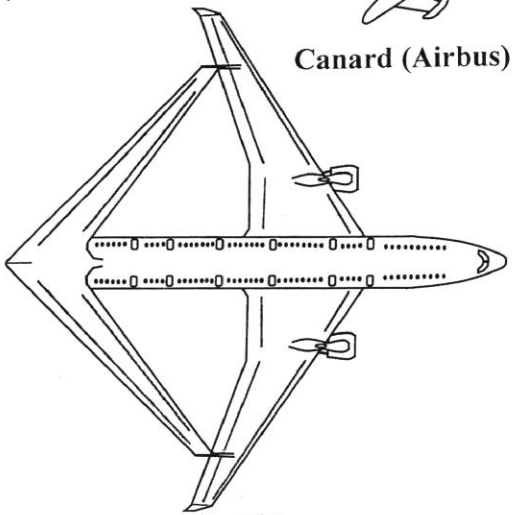
Mega-Jet



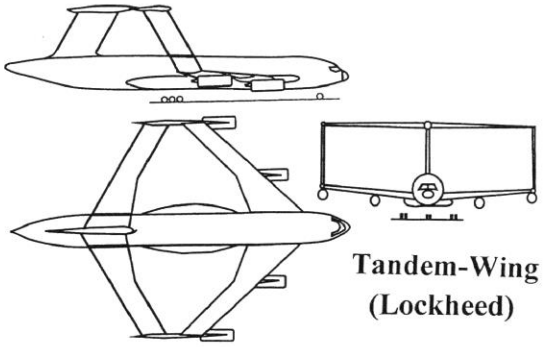
The Flatbed Layout
Source "Civil Jet Aircraft Design" ~ Jenkinson, Simpkin & Rhodes



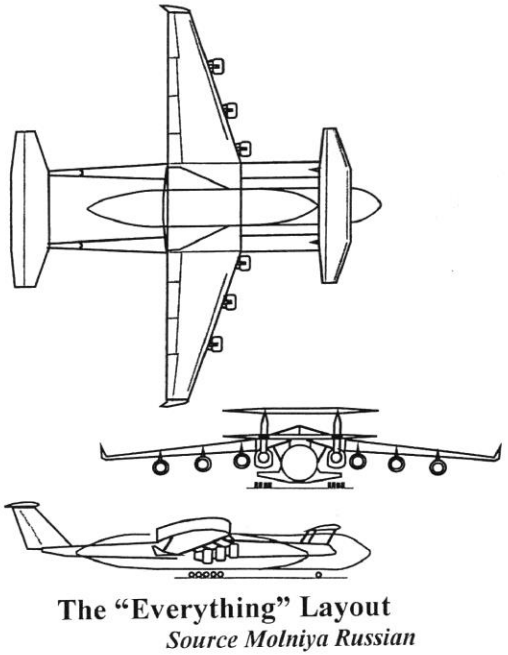
Canard (Airbus)



The Joined-Wing Layout



Tandem-Wing (Lockheed)



The "Everything" Layout
Source Molniya Russian

Overall configuration challenge

Reference: ***Airbus – where are we going next (evolution or revolution)? Neil Scott VP Engineering Airbus UK 21st October 2013***

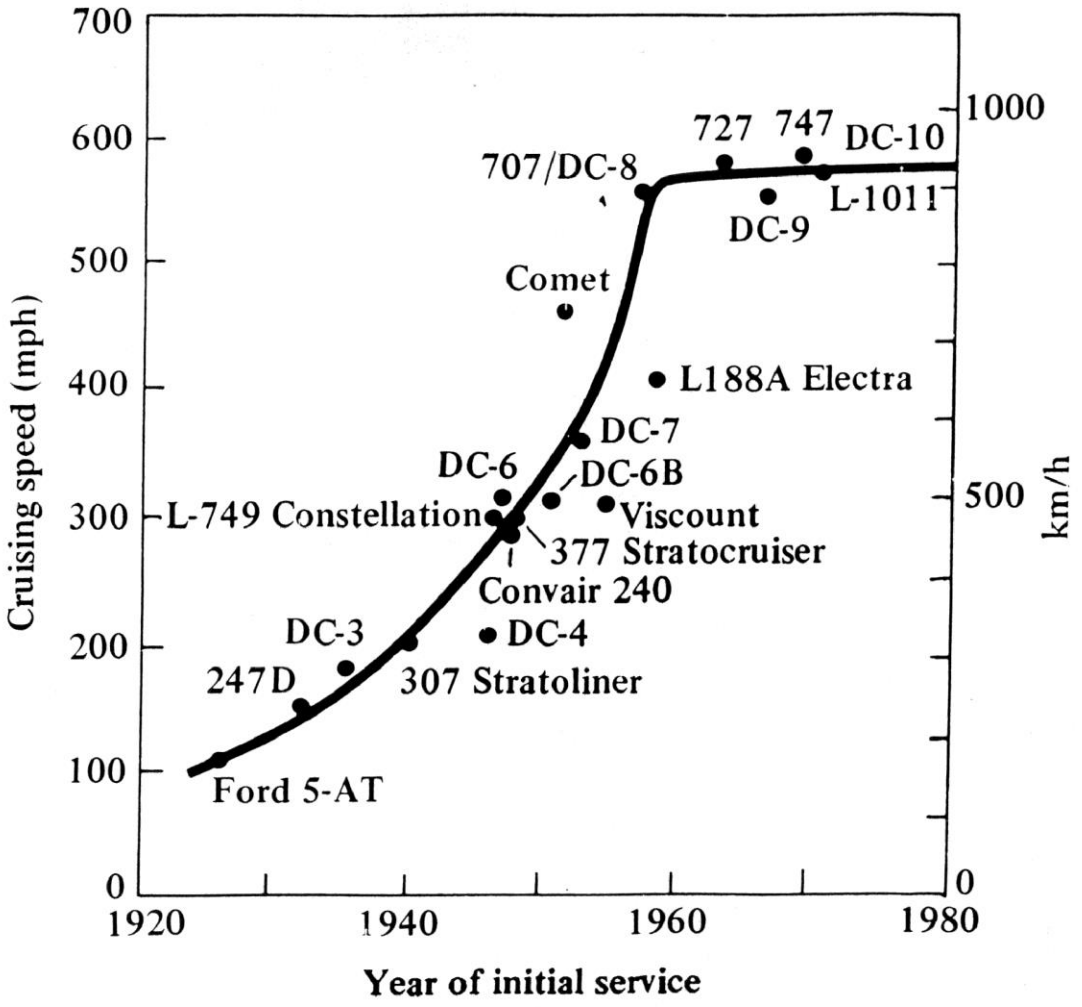
Blended Wing Body Configurations

X48-B built by CranfieldAerospace

Northrop XB49 in 1952

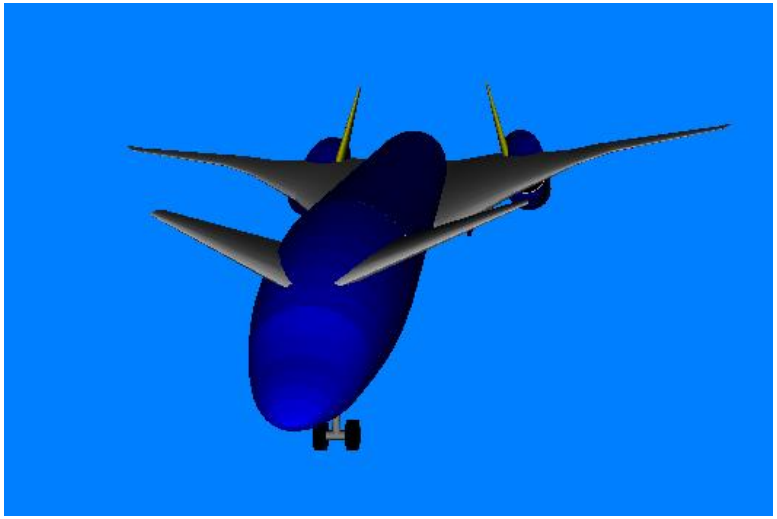
Commercial Transport Aircraft

The Devlopment of speed from the 1920's to the 1990's



Source: "What makes Airplanes fly" P P Wegner

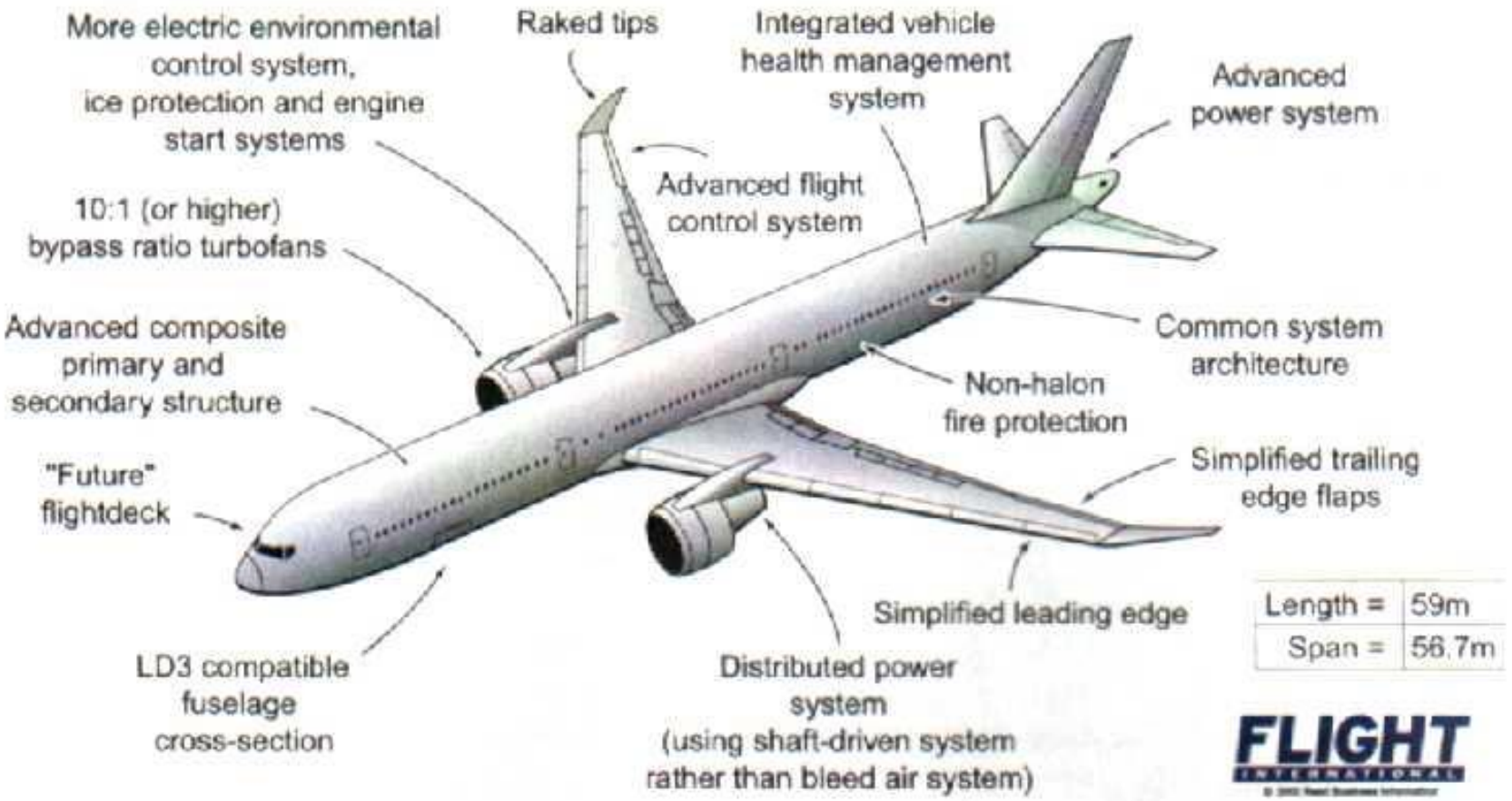
Boeing Sonic Cruiser



Propulsion Requirements for Transonic Design:

- ***Noise, Emissions & Fuel Burn key drivers***
- ***Close to today's High BPR Engines***
- ***Derivative approach***

Boeing 7E7
Super Efficient Aircraft Concept

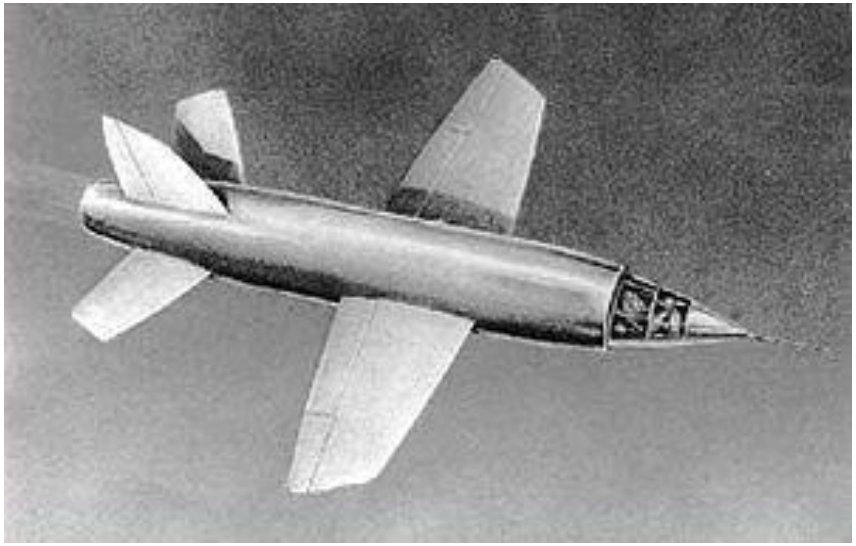


Boeing 787

Airbus 350

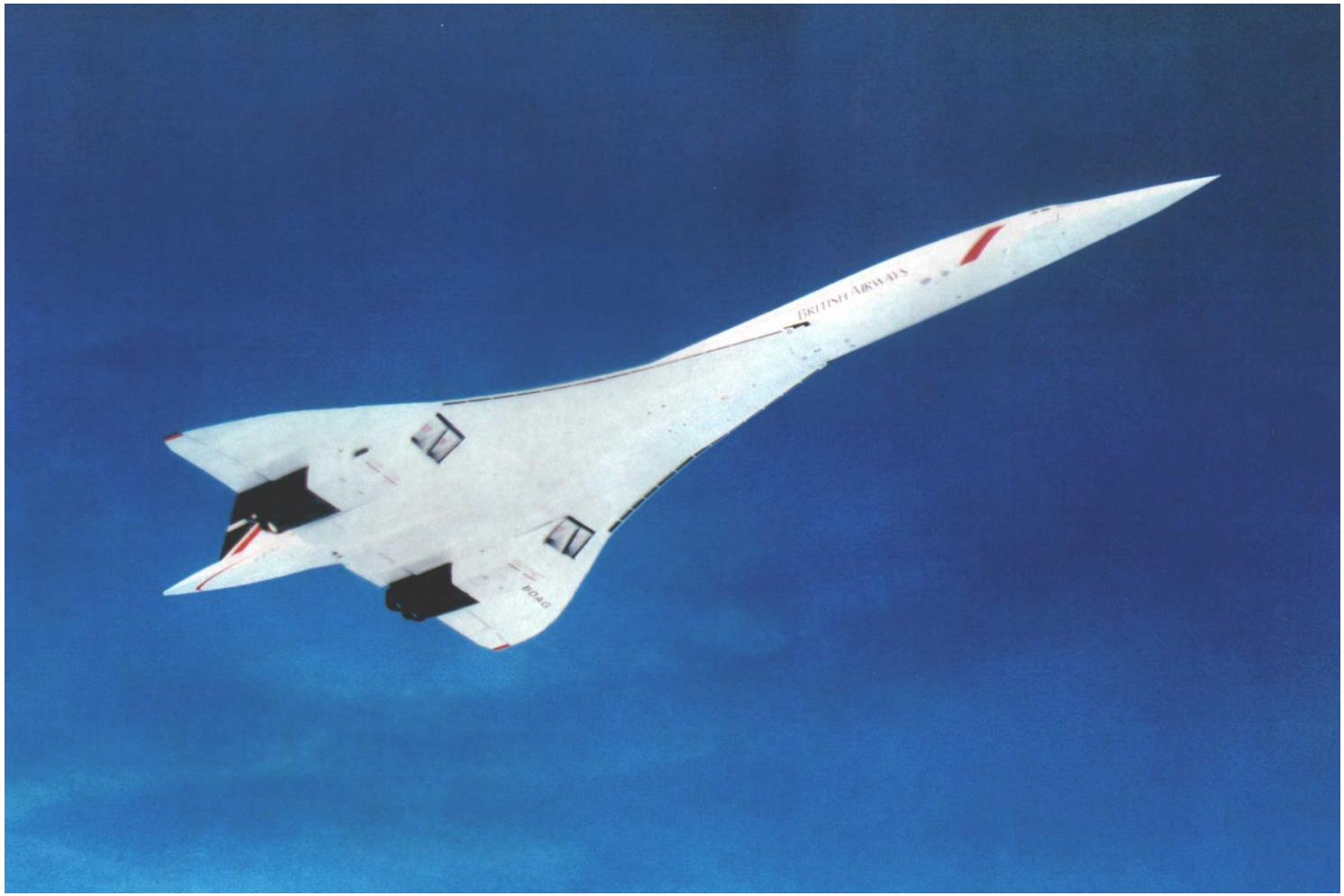
Supersonic Flight

Chuck Yaeger flying the rocket powered Bell X1 in the first supersonic flight 14th October 1947

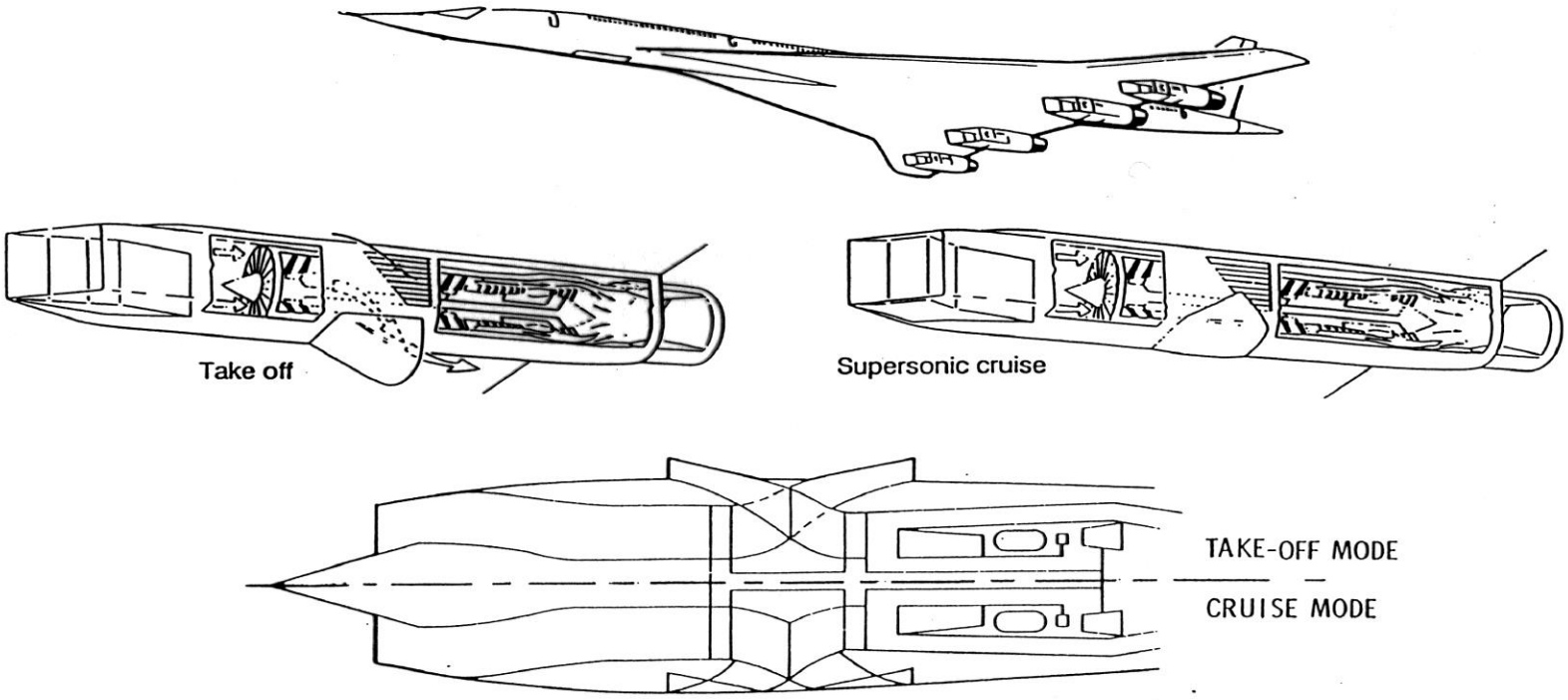


Miles M52 rocket aircraft.
Cancelled in 1946
Models flew at M= 1.38
Many unique features validated
Bi-convex wing; all moving tailplane etc.

Concorde

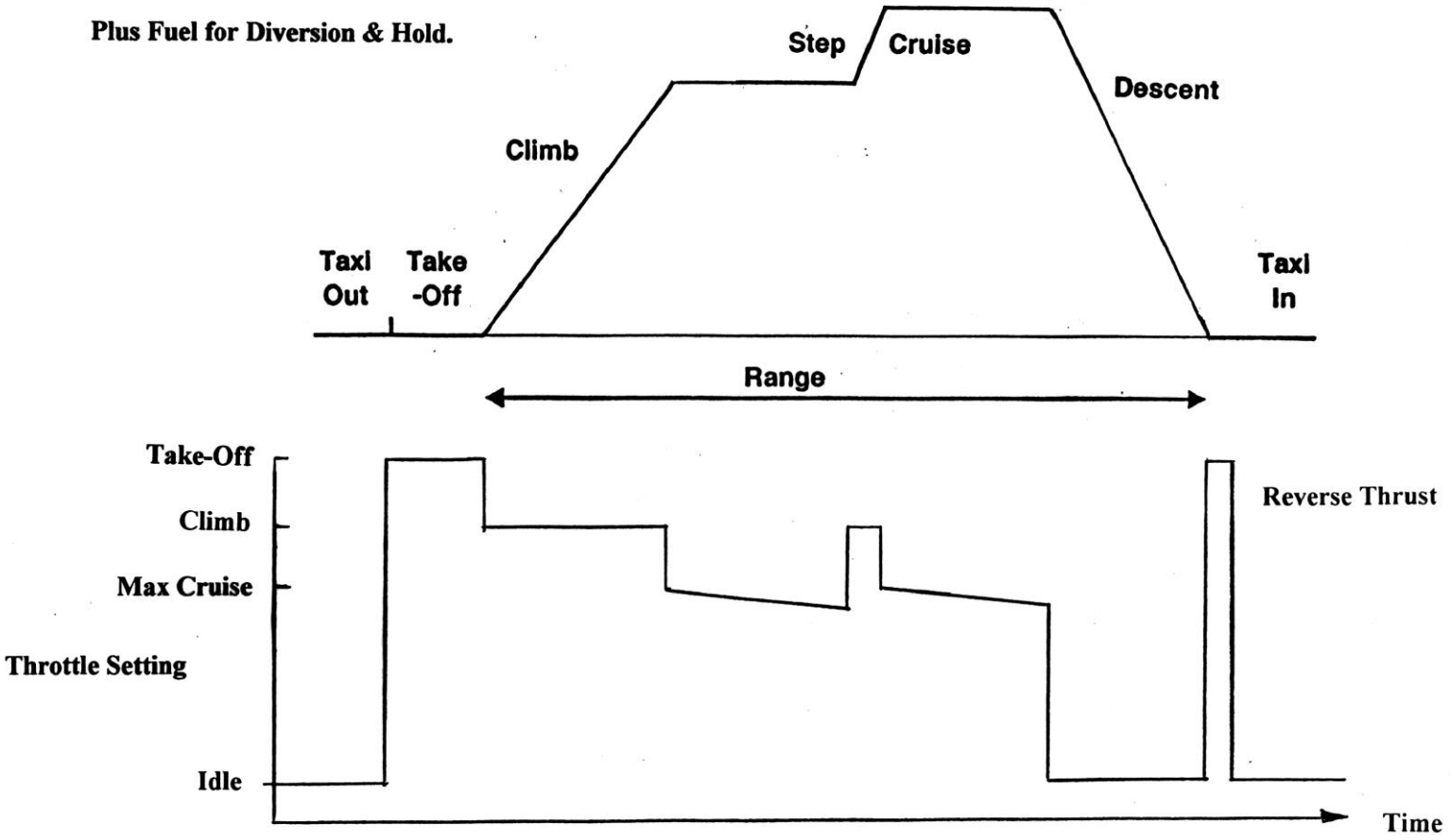


High Speed Commercial Transport



Variable Cycle Tandem Fan

Typical Civil Mission



Combat Aircraft Roles

Role	*Mission Requirements*	*Aircraft Type*
Air Superiority/ Interception	**Highly Manoeuvrable** **Combat Persistence** **Supersonic performance** **Short landing capability** **Short Take Off & Landing (STOVL) ?**	**F15/F16/F18/F22** **EFA/Rafale** **Tornado F3** **JASF**
Interdiction	**Long Range** **Low Obervables** **Sophisicated weapons carriage** **Self Defence capability**	**Tornado IDS** **F111** **F117** **B2**
Battlefield Support	**Survivable** **Large stores carriage** **Highly Manoeuvrable** **Good field performance (ASTOVL) or Rotary wing**	**Harrier/ Jaguar** **A10** **Apache** **JASF**

First World War Piston engined Fighters

Fe2b

Sopwith Camel F1

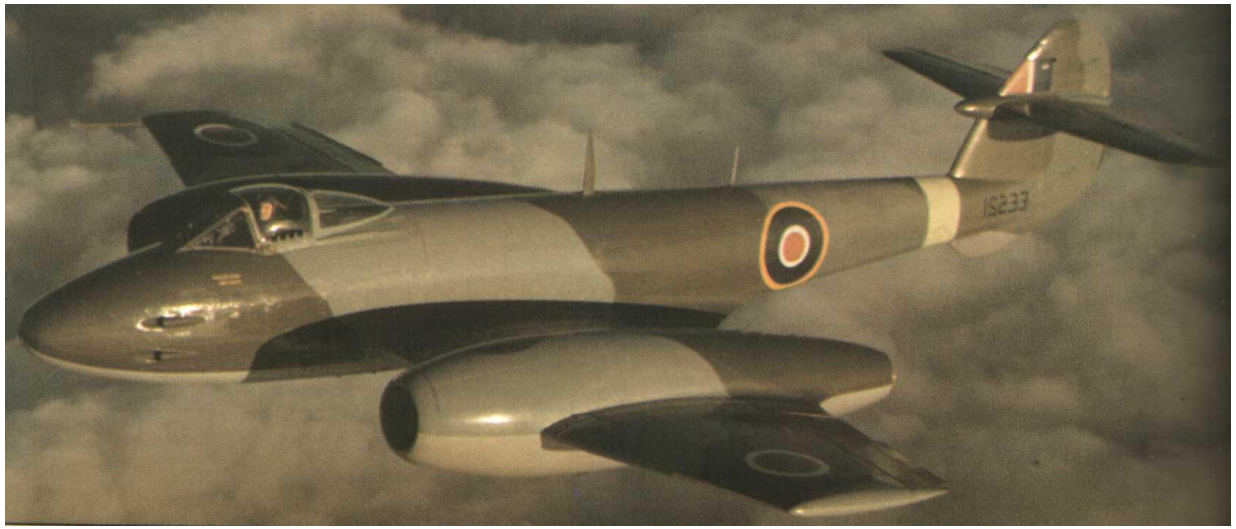
Bristol Fighter

Second World War Piston engined Fighters

Supermarine Spitfire

de Havilland Mosquito

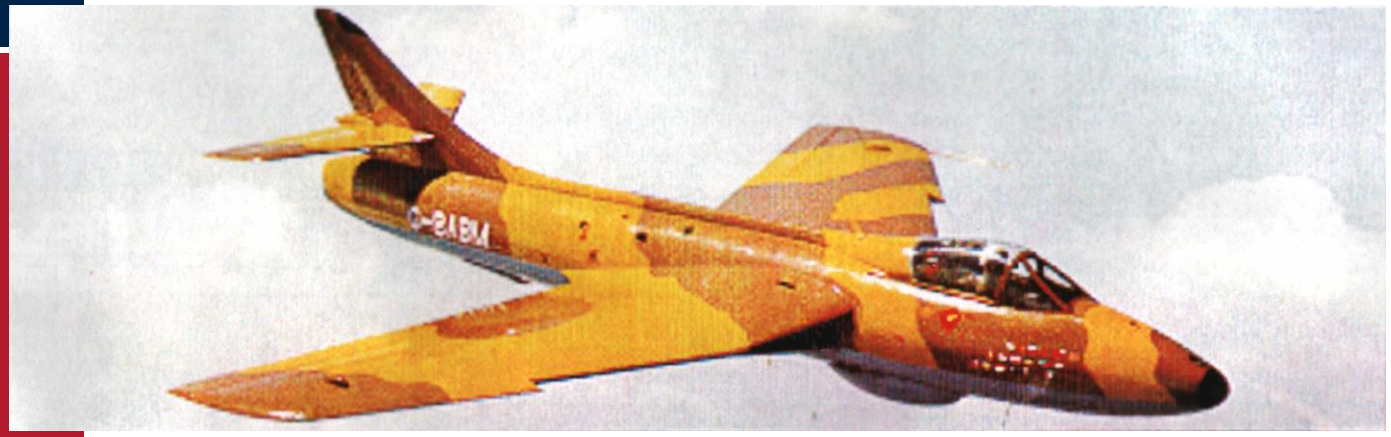
Early Jet-engined Fighters



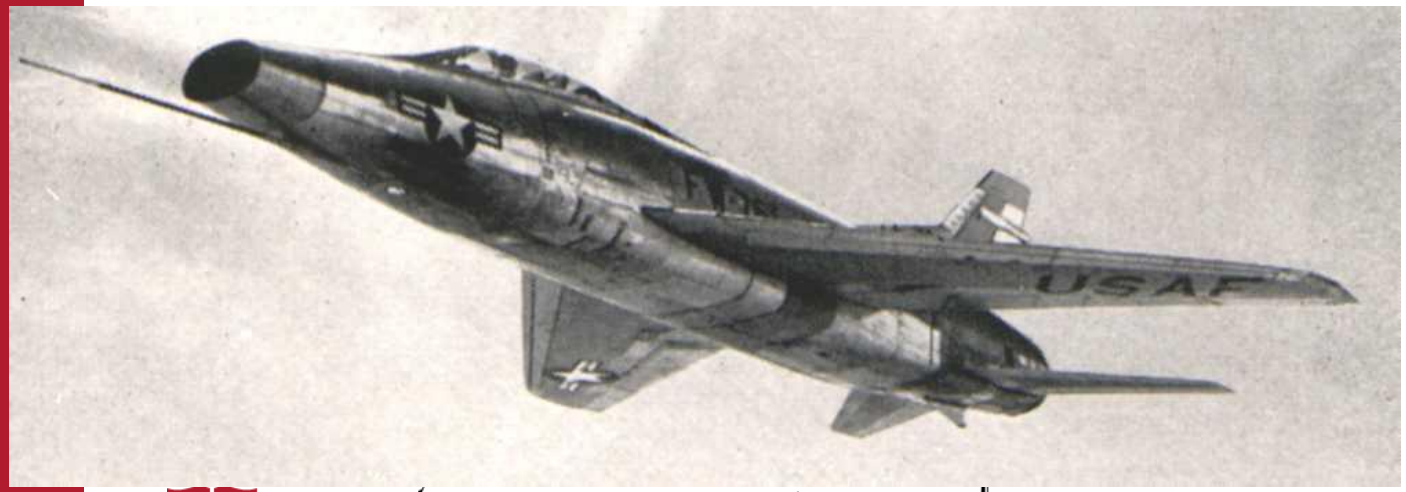
Gloster Meteor

Me262

Fighters of the 1950's

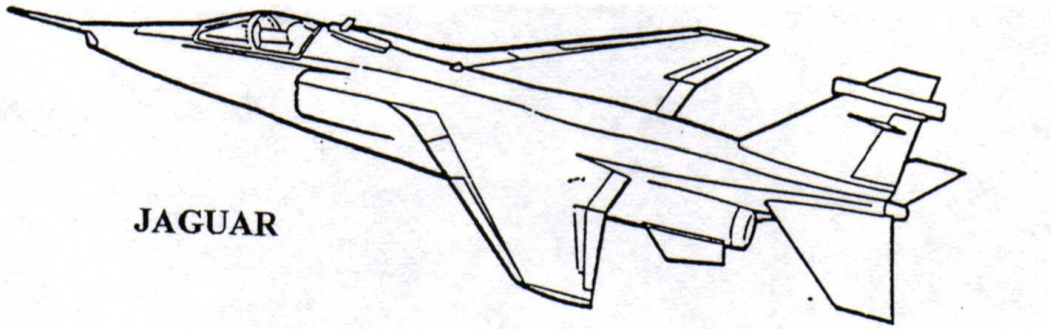


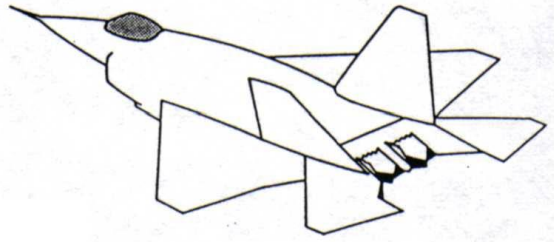
Hawker Hunter

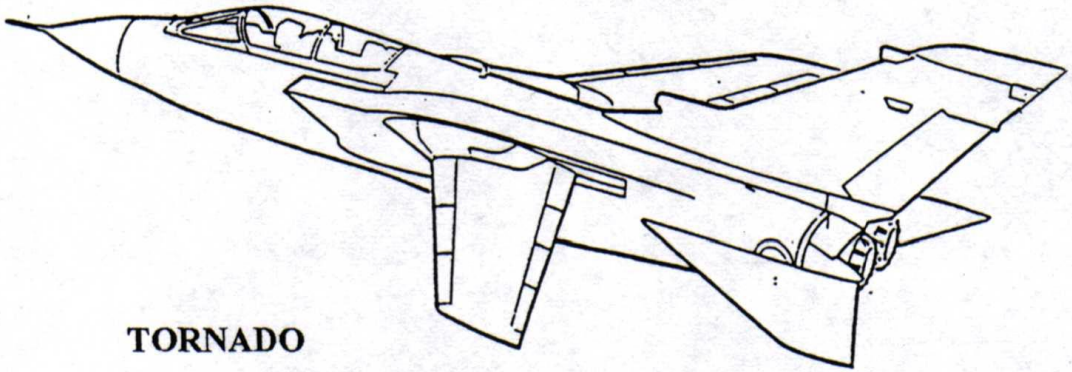


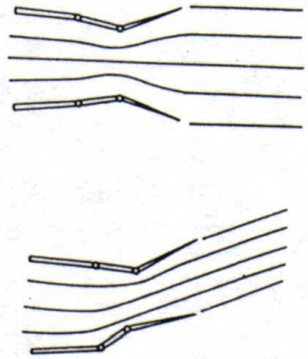
North American F100 Super sabre

Typical Military CTOL Installations



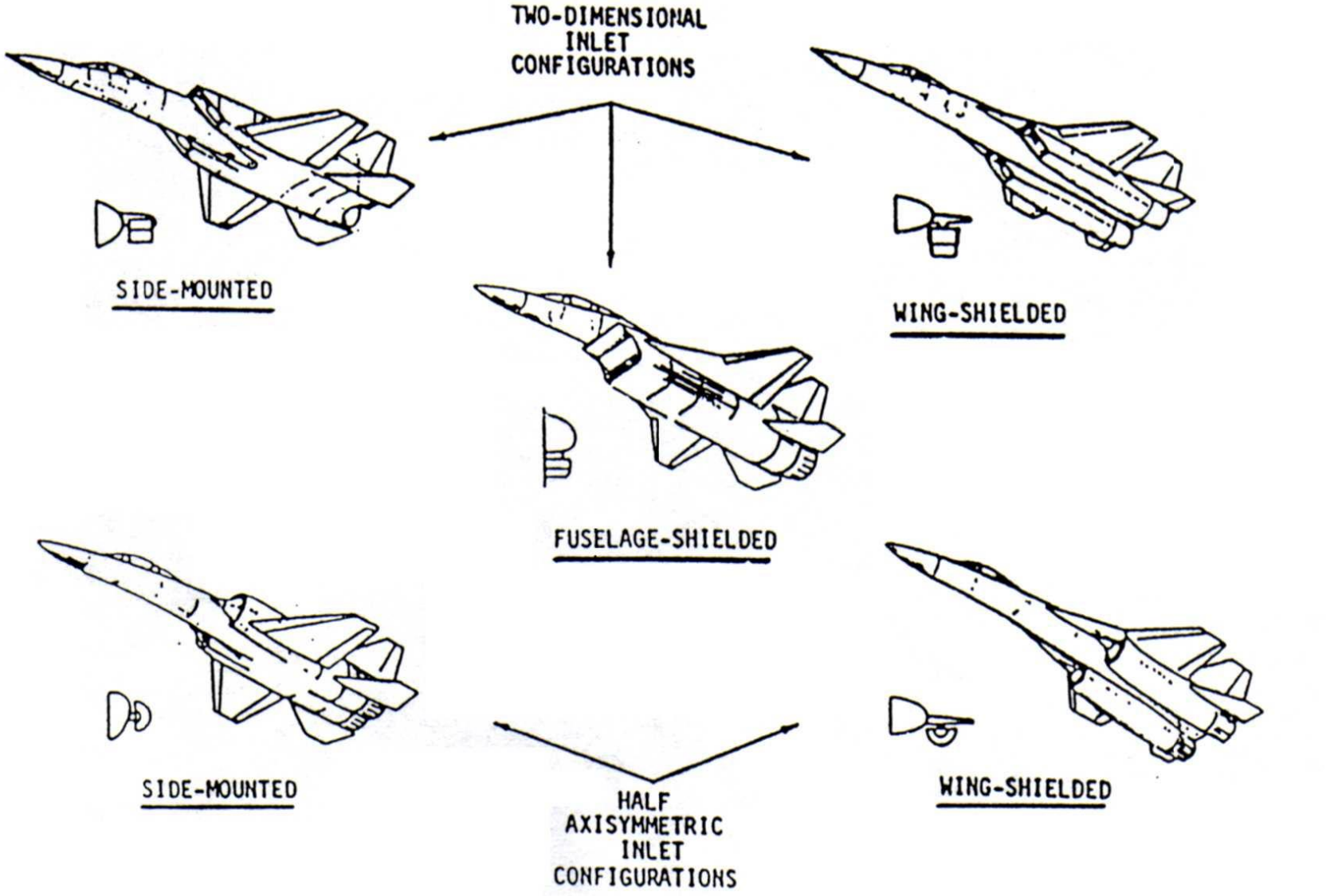






F22 with pitch vectoring.

Supersonic Combat Aircraft Configurations



Fighter Designs 1970's

GD F15

GD F16

Typhoon

Fighter Designs 1990's

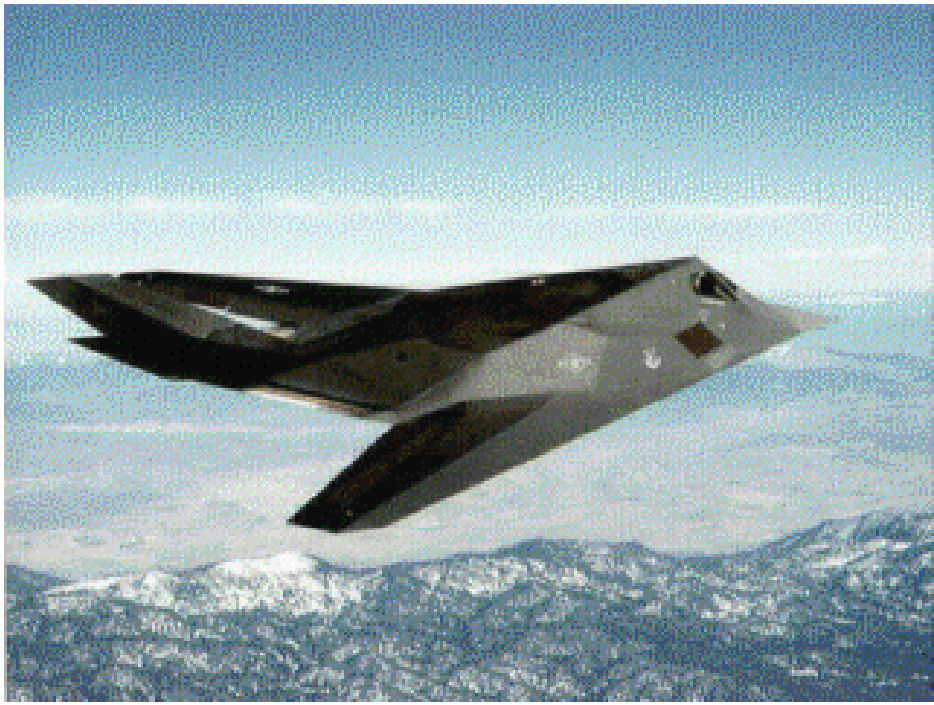
F22 Raptor

Typhoon

F35 Lightning ~
the last manned fighter?

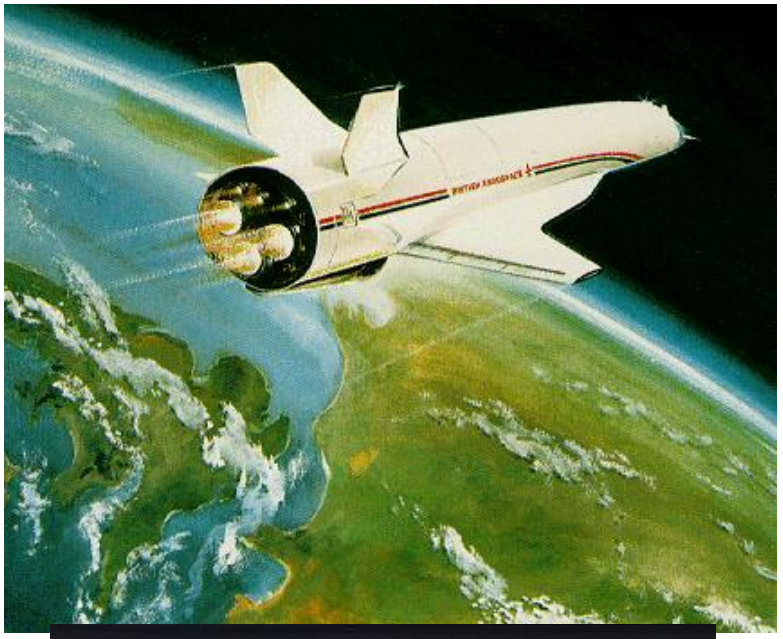
The impact of Stealth on Configuration

- Low obeservability the Key Design parameter
- Optimised for:
  - Low radar signature
  - Low IR signature
- Traditional characteristics e.g. manoeuvrability, combat capability etc. second order.



F117 Stealth Fighter

A glimpse of the Future?



Aerospace Challenges for 21st Century

- **Aviation & the Environment.**

  (Low Fuel burn & Low Emissions)

  - **Unmanned Aerial Vehicles for Military & Civil use.**
  - **Low-cost Delivery System into Earth Orbit.**
  - **Vertical Take-off & Landing Transport Systems for Civil & Military use.**
  - **Supersonic Airliner i.e. Concorde Replacement.**
  - **Plus ???????? ~ over to you!**