Aircraft Configuration Design
PART-I

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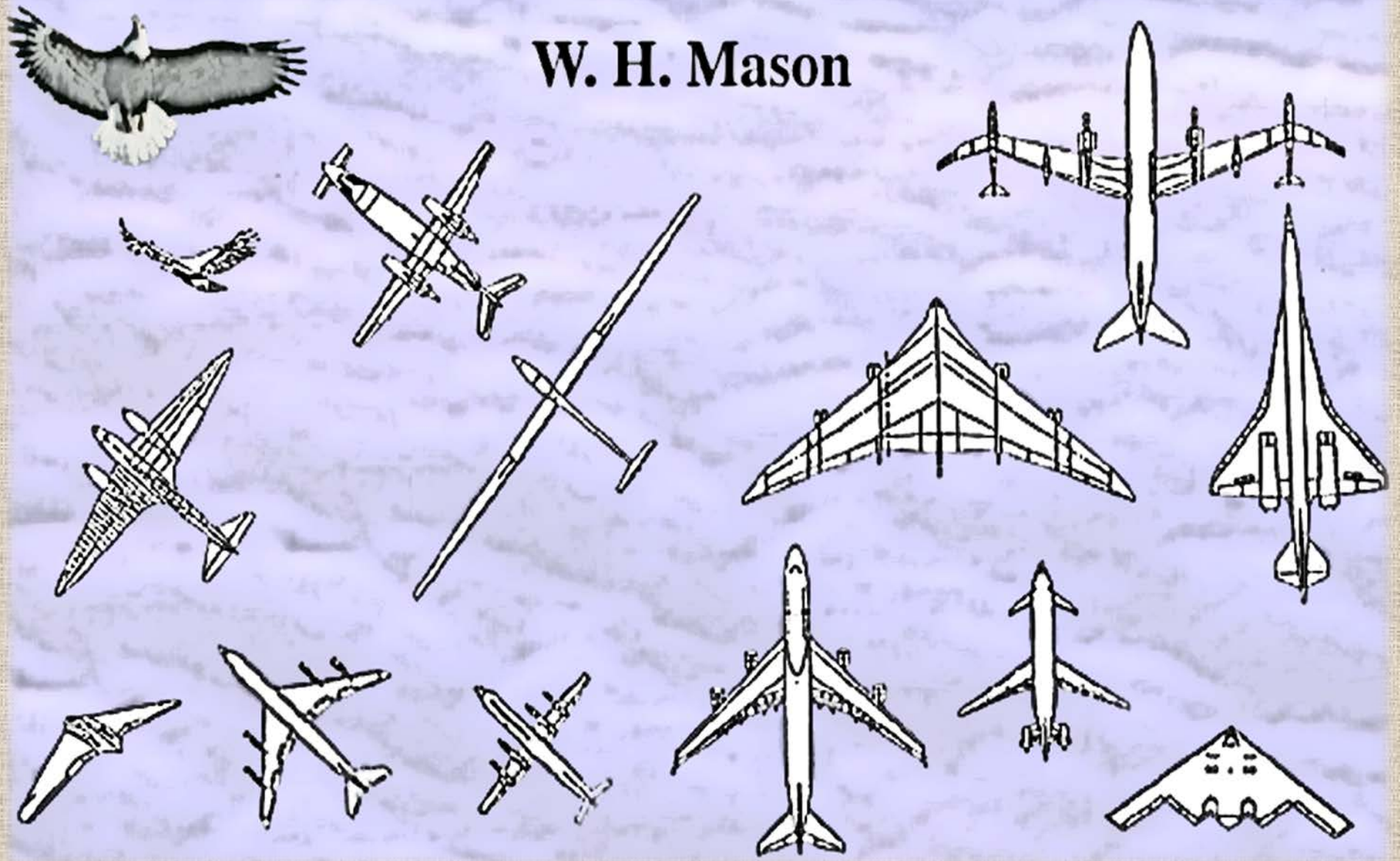
Why Airplanes Look Like They Do

W. H. Mason



About William *Bill* Mason

http://www.aoe.vt.edu/people/faculty/whmason.html

Designer

Technology advances?

A new capability someone might pay to have?

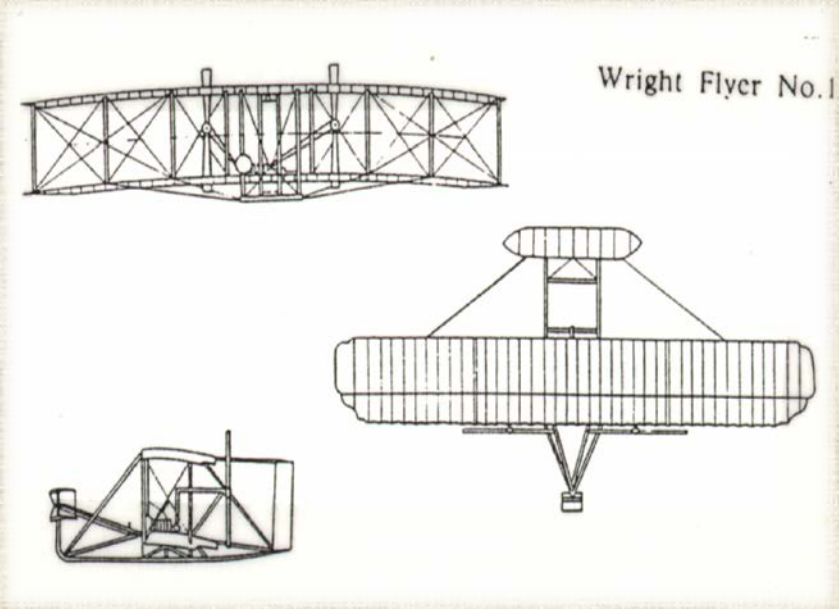
How to exploit technology for capability?

Configuration Concept

Airplane Shapes Have Changed to Exploit Advances in Technology

Configuration Concept:

- Payload
- Lifting surface arrangement
- Control surface(s) location
- Propulsion system selection
- Landing Gear



Wright Brothers:

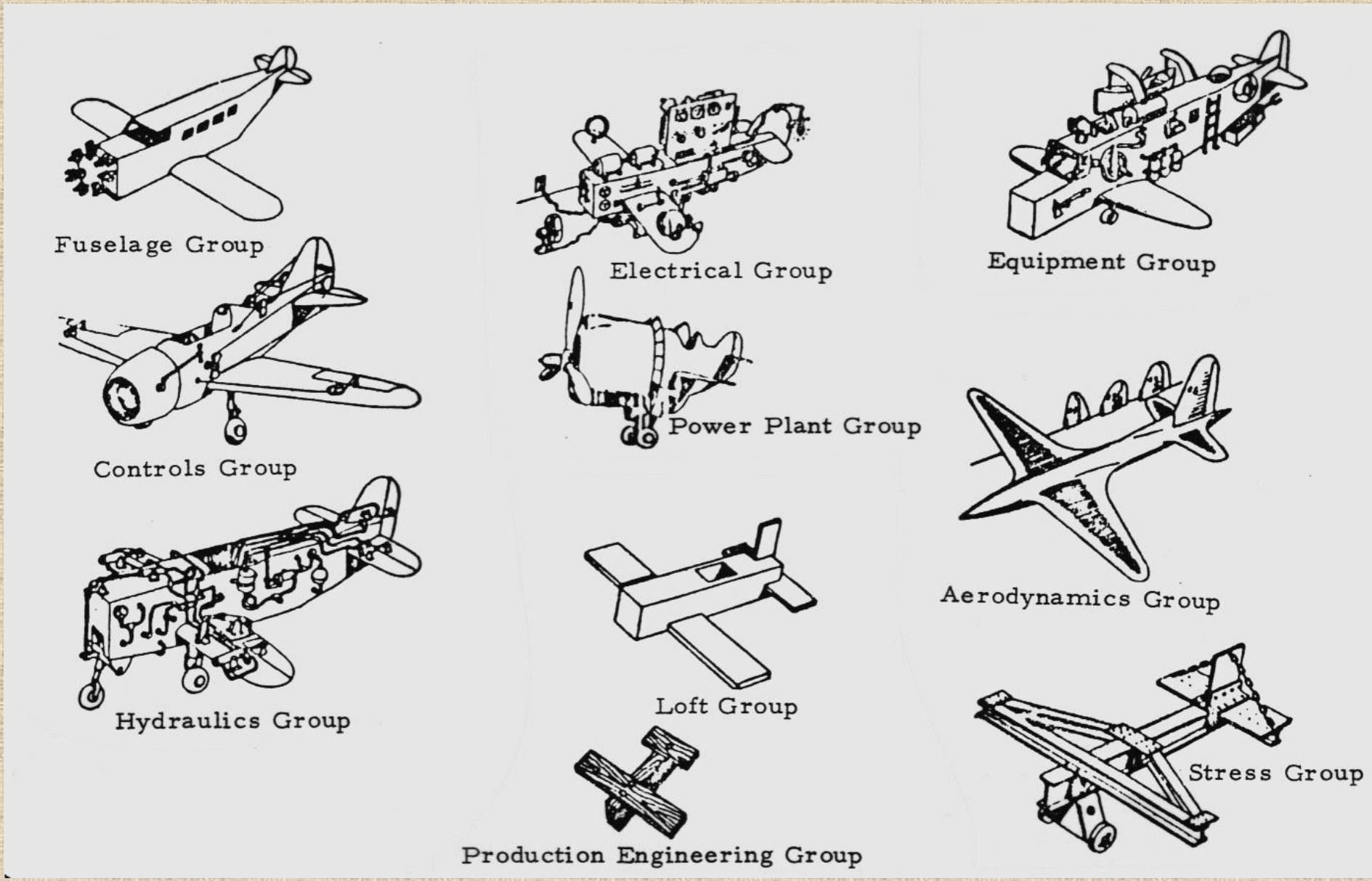
- Innovative control concept
  (more important than stability)
- “Light weight” propulsion
- Continual design evolution/refinement

Basic Laws of Airplane Design

- *Simplicity is the essence of true elegance—*
  - it can also save weight and/or reduce cost.
- *If you can't build it, you can't sell it.*

John McMasters
Boeing Commercial Airplane Company

Beauty lies in the Eye of the Beholder



"Dream Airplanes" by C.W. Miller,
as shown in *Fundamentals of Aircraft Design*, by L.M. Nicolai

Features of Good Aircraft

- Aerodynamically efficient, including propulsion integration (streamlining!)
- Must balance near stability level for minimum drag
- Landing gear must be located relative to *cg* to allow rotation at TO
- Adequate control authority must be available throughout flight envelope
- Design to build easily and have low maintenance costs
- Should be quiet, and have low emissions

Key Technologies

- Aerodynamics
- Propulsion
- Structures

in the late 70s:

- Flight controls

in the 80s and early 90s:

- Systems/avionics/observables & Manufacturing

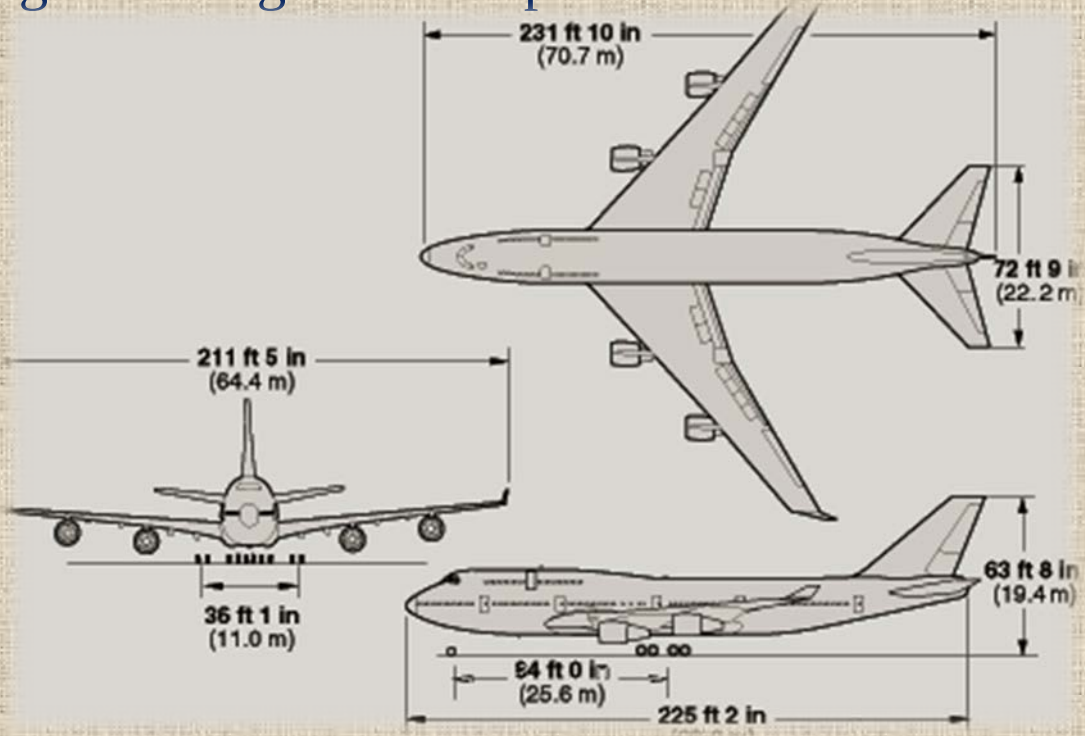
today:

- the design *process* - (includes MDO)

Amazingly Tricky to Integrate Advances in Each Technology

Conventional Subsonic: A Baseline

- Payload distributed around *cg*
- Longitudinal control power from tail (with moment arm)
- Vertical Tail for directional stability, rudder for control
- Minimum trimmed drag at near neutral stability
- Wing/Fuselage/Landing Gear setup works



Boeing 747-400, source: www.boeing.com

Layout Options

- Where do you put
  - the wings?
  - the engines (in fact, what kind?)
- Where do you put the control surfaces?
  - what options are available?
- Do you have room for the landing gear?
- Possible innovative designs?

A few WHYs ??

- *Why podded engines below wing ?*
- *Why Swept wing ?*
- *Why Forward Sweep ?*
- *Why Variable sweep ?*
- *Why Canards ?*
- *Why Flying Wing ?*
- *Why Three-surfaces ?*
- *Why Winglets ?*
- *Why Thrust Vectoring ?*
- *Why ? Why ? Why ? Why ? Why ?*

Why Put Engines in Pods on Wing?

- load relief on wing: weight savings
- access to work on engines (maybe)
- safety
- can be low drag

Original idea by the British – in wing!

If it's small, can't put them below wing

Boeing Made Wing Mounted Engines Work

Why Sweep the Wing?

Subsonic (usually small)

- Adjust wing aero center relative to *cg*
- On flying wing, get moment arm length for control

Transonic (significant, 30° - 35°)

- Delay drag rise Mach (compressibility effect)

- Definition of the Drag Divergence Mach no.?

Supersonic (large, 45° -70°)

- Wing concept changes, must distribute load longitudinally as well as laterally
- Reduce cross-sectional area and area variation

Wing sweep increases wing weight for fixed span

Why Sweep the Wing Forward?

X-29

SU-47