INTERNATIONAL CAMPUS OF EXCELLENCE

03 – Historical Background

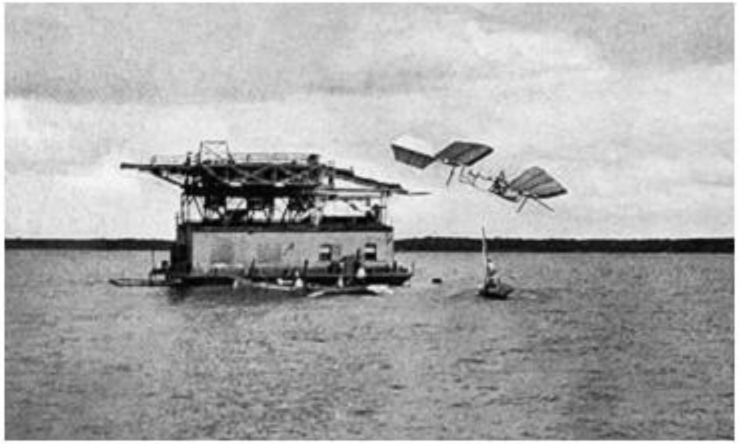
Wilbur Wright, 13May 1900, noted “*It is possible to fly without motors, but not without knowledge and skill. This I conceive to be fortunate, for man, by reason of his greater intellect, can more reasonably hope to equal birds in knowledge, than to equal nature in the perfection of her machinery*.”

Vibraciones y Aeroelasticidad
Dpto. de Vehiculos Aeroespaciales

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA AERONÁUTICA Y DEL ESPACIO
UNIVERSIDAD POLITÉCNICA DE MADRID

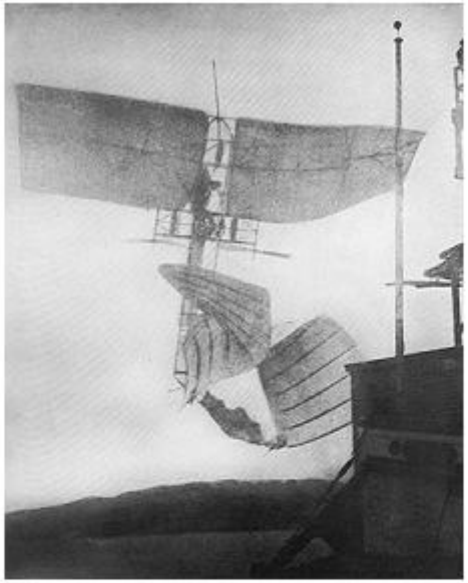
1903: Samuel P. Langley Aerodrome First Flight Attempt

1890-1900: Samuel P, Langley



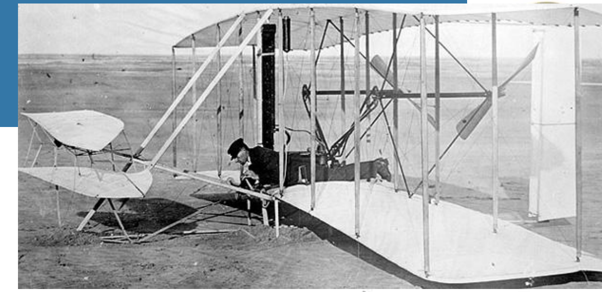
- Airplane “*Aerodrome” (from greek words meaning “air runner”)*, capable of being launched from a houseboat anchored in the Potomac River near Washington, D.C.

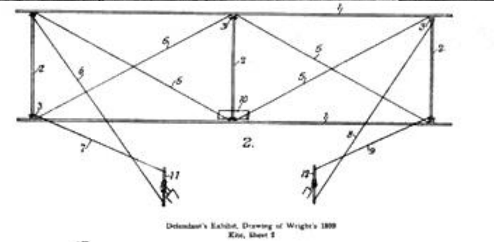
- This airplane failed on each of two attempts:
  - *1st failure*: a portion of the aircraft is caught in the launching apparatus
  - *2nd failure*: insufficient wing-torsional stiffness that lead to structural static divergence

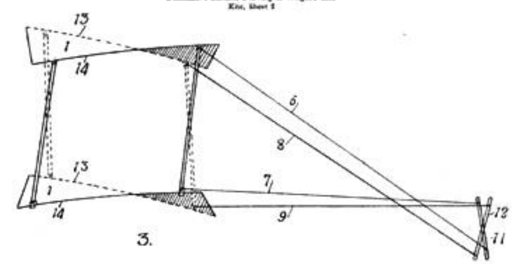


More information in:

http://www.flightglobal.com/pdfarchive/view/1914/1914%20-%200765.html







❑ 1901: Wright Brothers

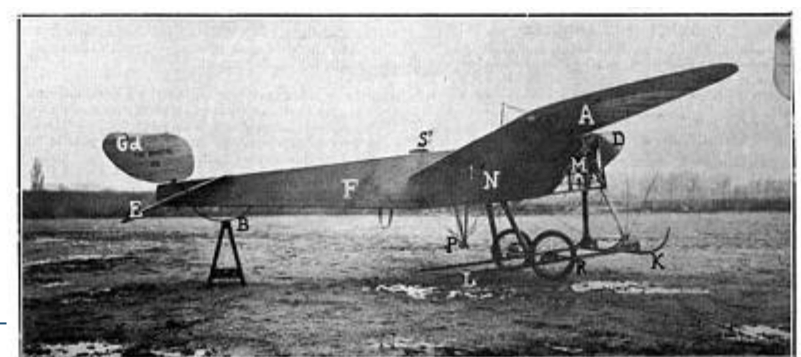
Wing Warping & Propeller Blades Torsion

- ► Controlled, anti-symmetrical biplane wing structural twisting (“warping”) to create aerodynamic rolling moments → Wing warping control requires relatively low wing torsional stiffness.
- ► Torsion of the propeller blades: the “little jokers” and manufacturing of backward sweep blades.

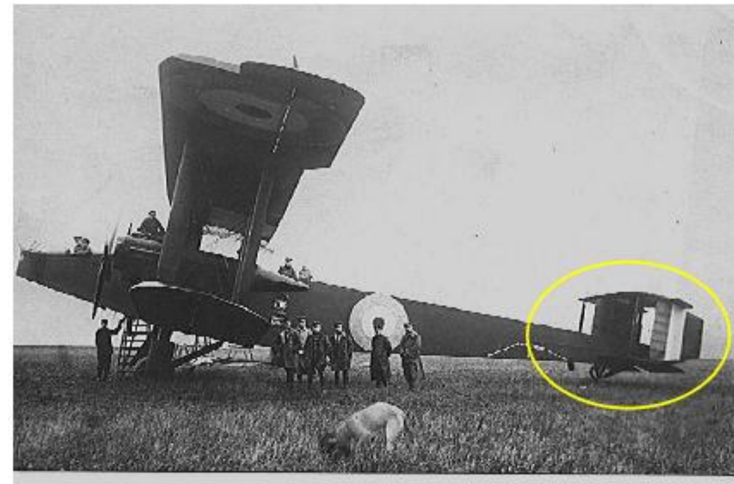
❑ 1912: Bleriot XI & Bristol Prier

Monoplanes → Wing Divergence

- ► As engine power and airspeed increase, low torsional stiffness created aeroelastic problems that led to wing failures at high speeds.
- ► Almost 15 years later, in 1926, Hans Reissner published his landmark paper “New Static Structural Problems of Wings”.



1915: WORLD WAR I: FIRST FLUTTER INCIDENT
HANDLEY PAGE O/400



- Handley Page Type O
  - Biplane bomber used by Britain during 1st World War
  - On reaching 70 mph (110 km/h), the tail unit began to vibrate and twist violently: the pilot immediately landed, and an inspection showed severe damage to the rear fuselage structure
  - Investigations in 1916 revealed that the O/400 tail flutter failure was caused by interaction between fuselage twisting oscillation and the antisymmetrical elevator rotation (right and left elevator were actuated independently). This vibration coupling was eliminated by connecting the elevators to a common torque tube to eliminate antisymmetric elevator motion.

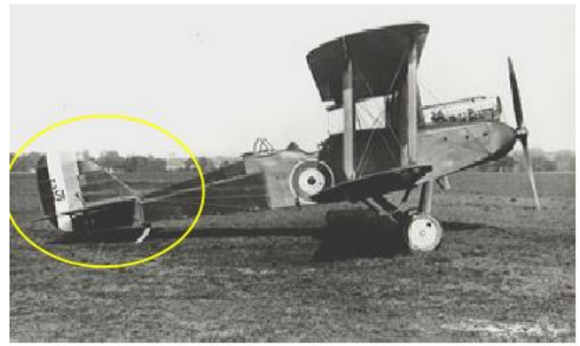
1915-1930: FROM WING WARPING TO AILERONS

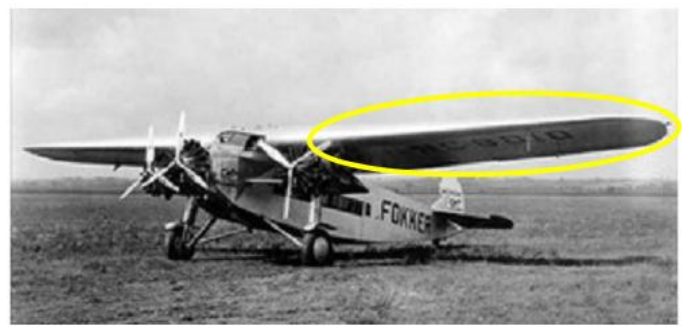
- Farman (with the aircraft Farman III) was the first to make ailerons an integral part of the wing
  - Farman'a aileron was more effective and less complicated than wing warping
  - Orville Wright finally converted to aileron design in 1915

- Wing/aileron & rudder/vertical tail flutter were common in 1920's
  - British Gloster-Grebe aircraft; wing-aileron flutter victim
  - British Gloster Gamecock, successor of the Grebe. Vertical fin/rudder flutter and high accident rate

Before 1930'
The beginning of a problem w/o adequate engineering methods (Trial & Error)

- 1st (1914) HANDLEY PAGE O/400
  - Tail Flutter
  - Reasons: Low stiffness / Lack of Aeroelastic knowledge
- 2nd (1914): De Havilland DH-9 Bomber
  - Tail Flutter
  - Reason: Low stiffness / Lack of Aeroelastic knowledge
- 1930: Gee Bee
  - Wing Flutter & Aileron Reversal
  - Reason: Wrong mass balance
- 1931: Fokker F10 Trimotor
  - Wing Flutter
  - Reason: moisture had leaked into the interior of one wood-laminated wing over a period and had weakened the glue bonding the structural members (called struts or spars)
  - Famous football coach “Knute Rockne” died
  - Establishment of the FAA
- 1938: Ju-90 V1
  - Flutter: all crew were killed including flutter experts
  - Reason: inaccurate determination of flutter speed

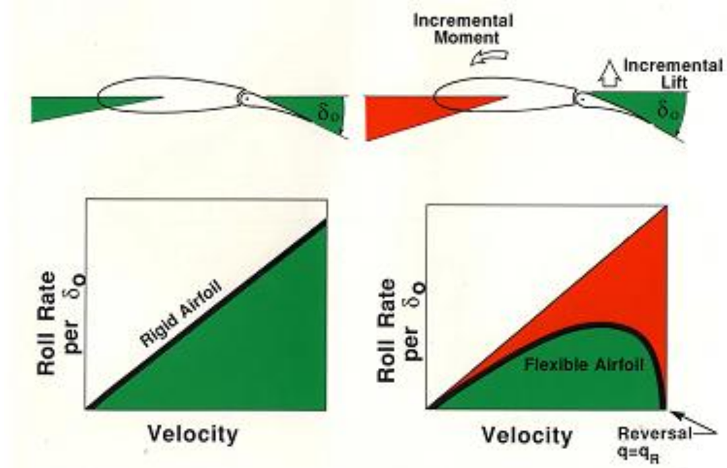




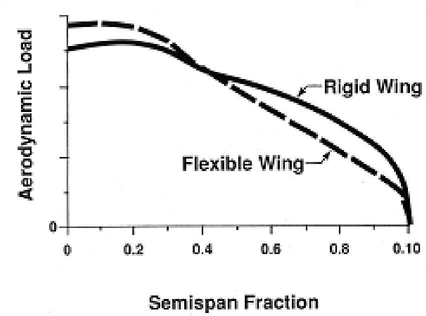
From 1930' to end WW2 (1939-1945)
Development of Engineering Methods and quick progress of aviation during WW2

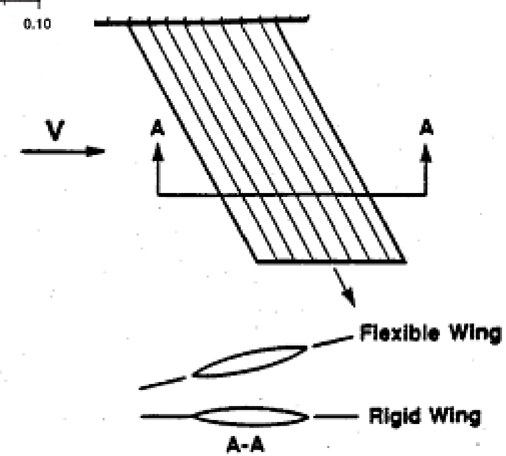
- 1930':
  - Development of Engineering Methods:Theodorsen, Küssner, R.T.Jones,…

- Control effectiveness was a typical problem since 1920's
  - Twisting of wing/HTP as a consequence of aileron/elevator rotation



- Late in WW2: Swept Wings
  - 1935: A. Busemann proposes sweeping wings to delay the onset of Mach~1.0 wave drag
  - Wing lift redistribution
  - Sweepback exacerbates control reversal
  - Coupling Flight Mechanics – Aeroelasticity (R.B. Skoog, NACA Rep. 1298, 1951)

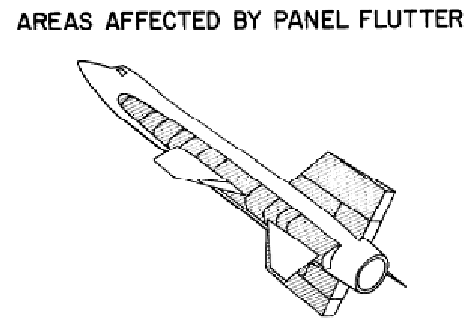


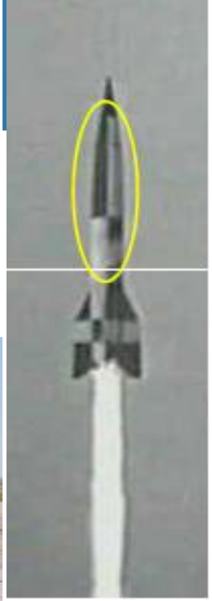


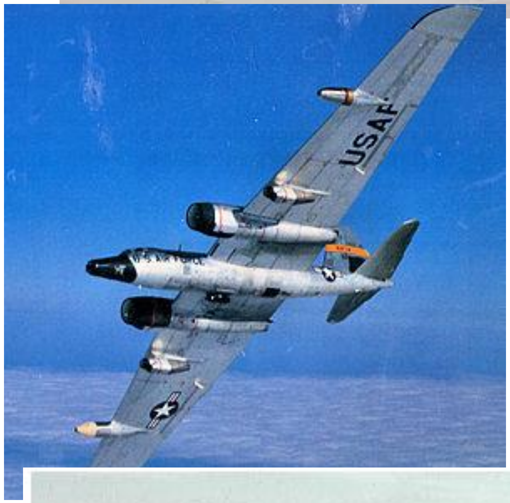
From end WW2 to 1960’
Brand New Aeroelastic Phenomena

- **Mach > 1 High-Speed: Panel Flutter**
  - 1943-44: 70 German V-2 Rockets destroyed
  - 1947: Bell X-1 breaks the sound barrier
  - 1958: X-15 flies at hypersonic speeds near the edge of the Earth’s atmosphere
  - 1982: Space Shuttles operates from subsonic to hypersonic
- **1DOF Flutter: control surface buzz**
  - Shock-wave/boundary layer interaction triggers separated flow with periodic shock wave reattachment
- **Body Freedom Flutter**
  - Post-WWII: short-period mode couples with flexible vibration modes such as wing beding
- **1960’s: Lockheed Electra**
  - Propeller-Whirl Flutter: dynamic oscillations of the engine mounts interacts with the gyroscopic torques produce by the engine/propeller combination

The adequate models to cover the majority of the aeroelastic phenomena were developed but … even modern aircrafts undergo aeroelastic-type disasters







MODERN AEROELASTICITY

- 1997: F117
  - Aileron's flutter
  - Reason: Control surface freeplay due to incorrect as technical inspection

- 2011: Boeing 747-8
  - Wing-tip flutter
  - Reason: re-design of Boeing 747 wing

- Future:
  - Weight optimization leads to more flexible aircrafts:
    - Non-linear aeroelaticity
    - Coupling with Rigid Body Modes (Flight Mechanics)
  - Development of Aeroservoelasticity:
    - Active Control Surfaces
  - Limit Cycle Oscillations
  - And… AAA

X-56: USAF & LOCKEED MARTIN – Aug 2013

USAF

The objective is to embed sensors in the X-56's wings to detect flutter and gust loads and counter the resulting bending and twisting with the aircraft's control surfaces. Eventually, real-time control of those flexing movements might be possible.

Ironically, controlling the flex of the wing would revive a control technique used by the Wright brothers. Their 1901 and 1902 gliders and successful 1903 "Flyer" mimicked birds by "wing warping", although modern aircraft have long since opted for rigid wings and control by moveable spoilers or ailerons.

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