Airplane Control

From bailing wire to fly by wire..... A short history of how we fly

Woody Saland, PhD
Director Avionics Programs
and Pilot Training

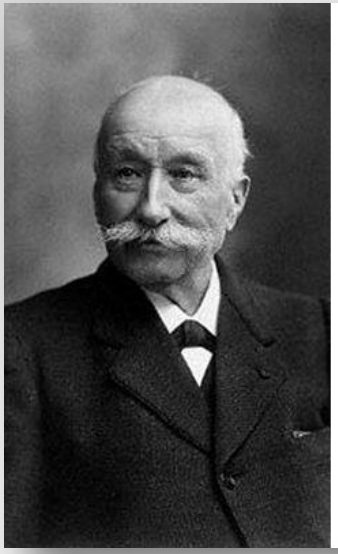
Aviation Game Changers

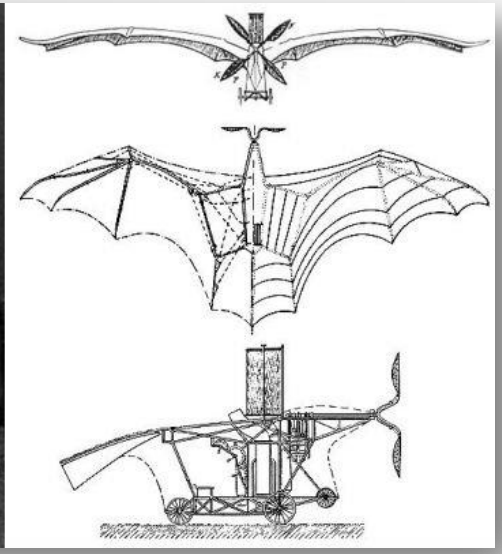
Clement Ader

Robert Esnault-Pelterie

Paul Kollsman & Elmer Sperry

Gilbert Klopstein



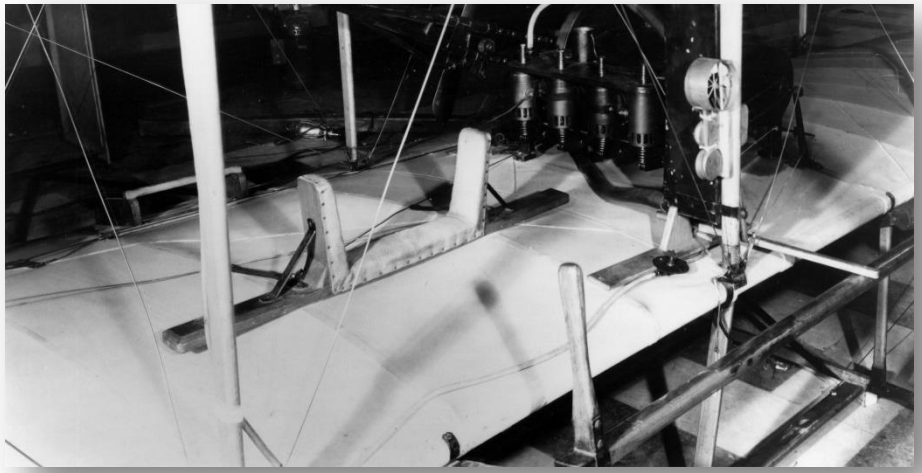


Clement Ader.....

160 feet on October 9, **1890**,
in the suburbs of Paris

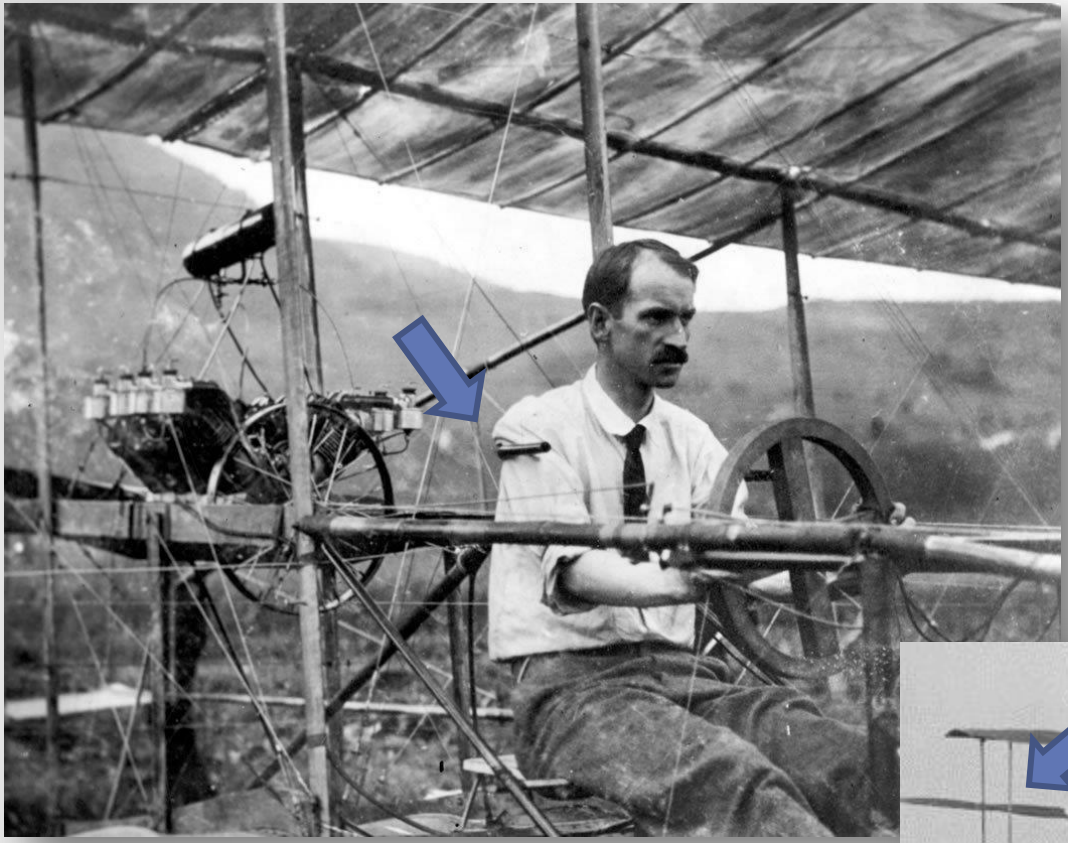
- Built his own 4 cylinder alcohol steam engine
- First stereo transmission
- First V-8
- Wrote Book on Military use of Airplanes and foretold of Aircraft Carriers

The Wright Brothers
First with “Controlled” Flight



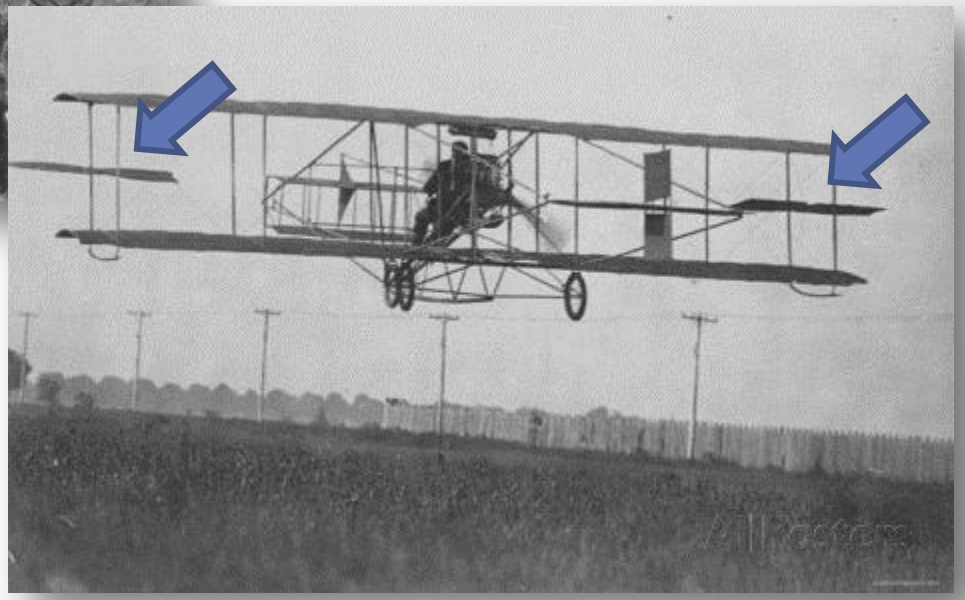
- No Wheels... Needed catapult
- Linked rudder with wing warping... But used hips!

Glenn Curtis and Alexander Bell



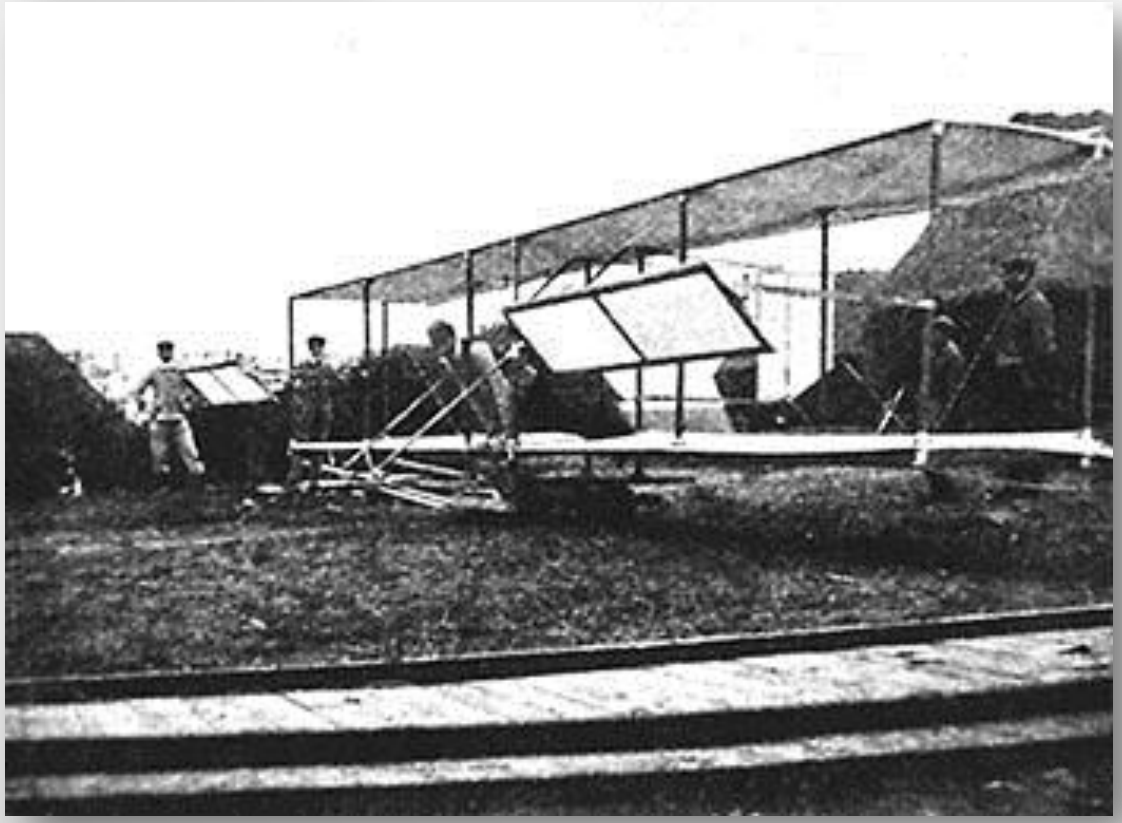
July 4, 1908

Used Ailerons (to get around Wrights Patent), but controlled by yoke around shoulders !



Robert Esnault-Pelterie (1881-1957)

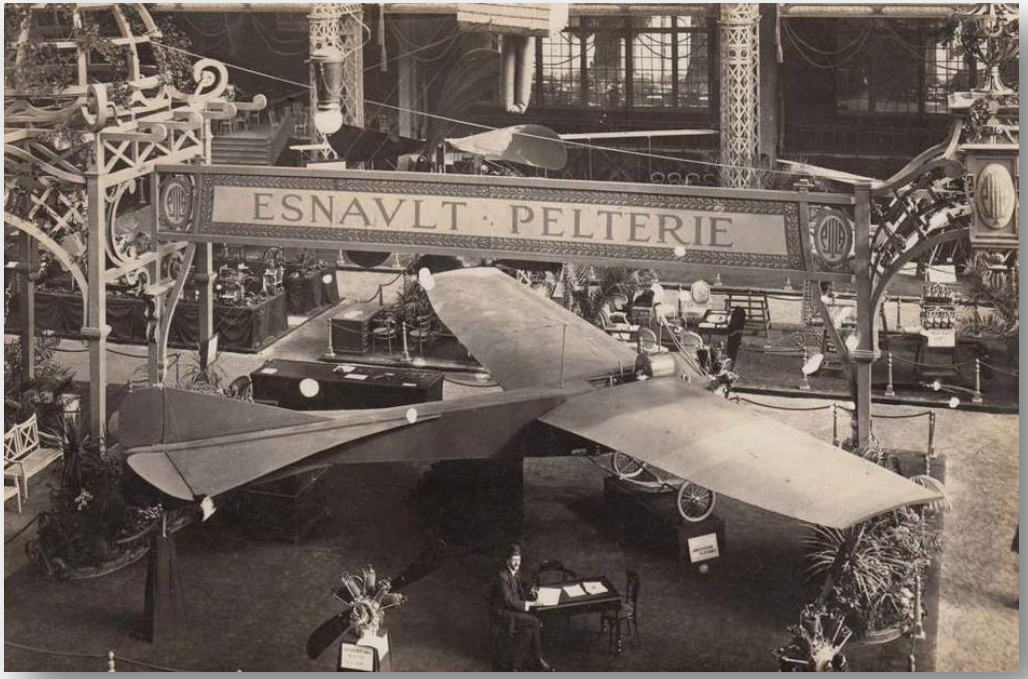
- R.E.P. Monoplane with fully enclosed fuselage with steel tubing
- Invented Ailerons for roll control
- First to employ a single “stick” to control roll & pitch
- Created the REP radial engines



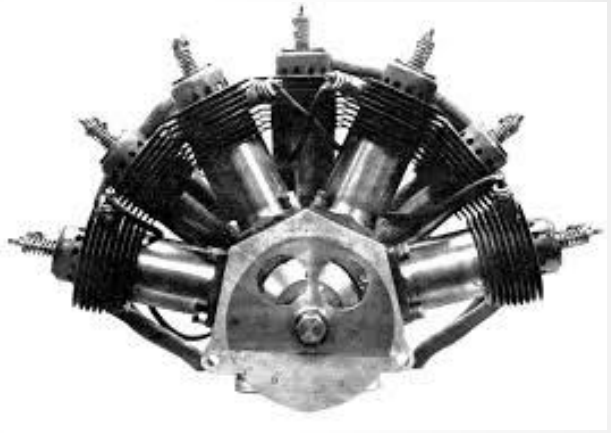
“Wright” glider modified with ailerons....

His family had invested heavily to fund his aircraft designs, and this had left them nearly financially ruined. However, he was the inventor of the "joystick" flight control, and owned a patent on the design. Following the war he was involved in litigation over his joystick patent. Many aircraft built during the war had used this design and the aircraft companies owed him royalties. The damages he won and subsequent royalties made him a wealthy man. This also allowed him to repay his father's significant investment.

He made his first powered flight on October 10, 1907, a distance of 100 m (330 ft) with the Pelterie I (or R.E.P. I). This was driven by a seven-cylinder, 30 hp air-cooled engine of his own design.



1908 design licensed to Vickers

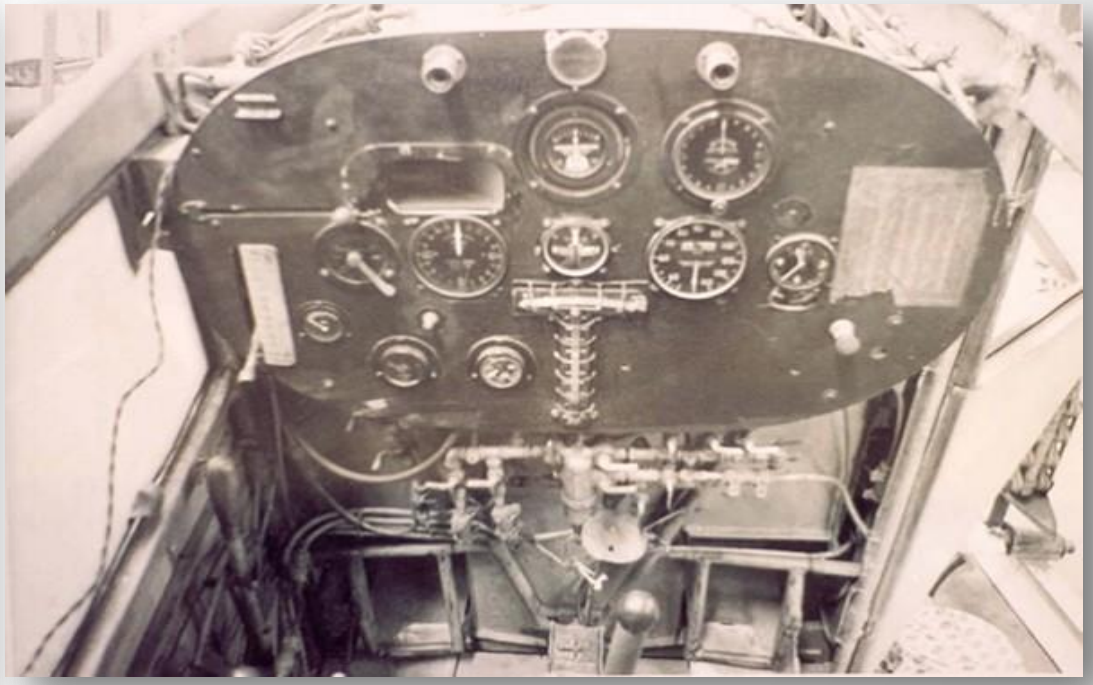


REP Engine
(semi-radial)

Among his interests were horseback riding, playing golf, camping and driving cars. During his lifetime he filed about 120 patents in a variety of fields ranging from metallurgy to automobile suspension. He was the inventor of the "joystick" aircraft control and of a new type of fuel pump. He also developed the idea of rocket maneuver by means of vectored thrust.

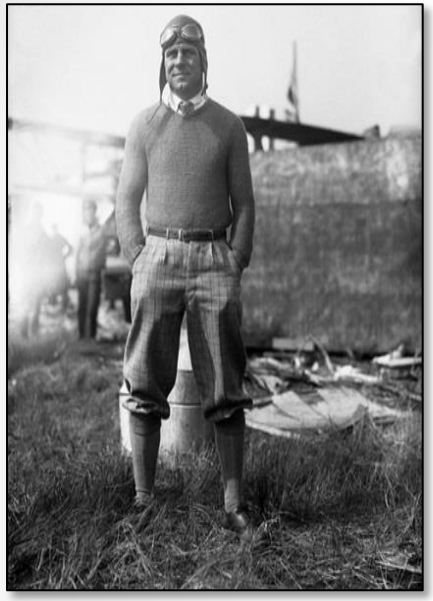
- The crater Esnault-Pelterie on the Moon is named after him

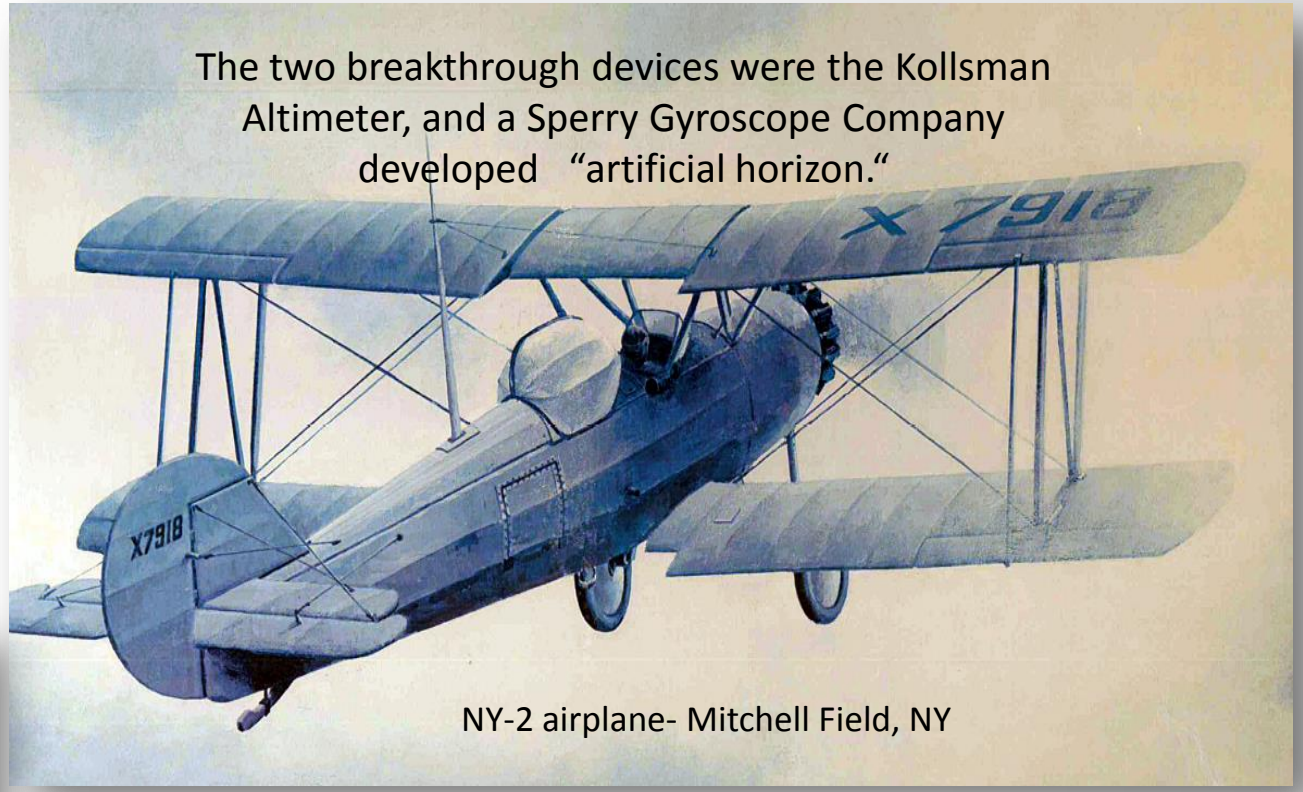
Up until 1929, there was no way to fly in the clouds..... By instruments



Charles Lindbergh's flight to Paris: May 20–21, 1927

Jimmy Doolittle Proves you can fly “blind”





September 24th, 1929

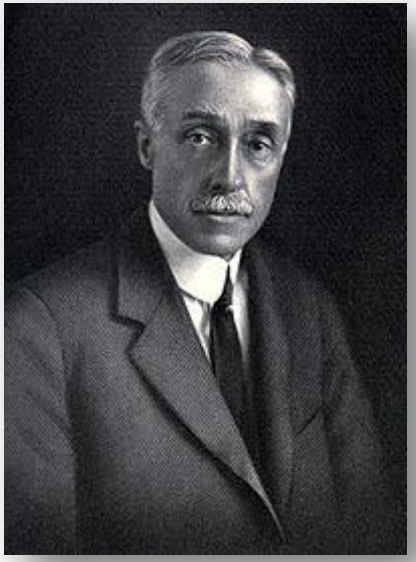
Paul Kollsman

Born: 2-22-1900
Died: 9-26-1982

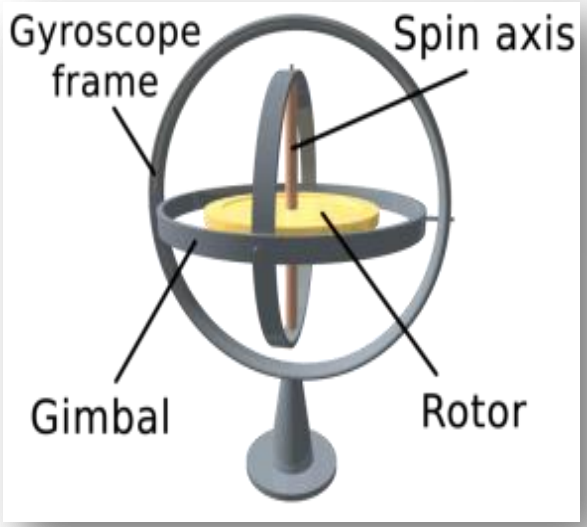
Kollsman window

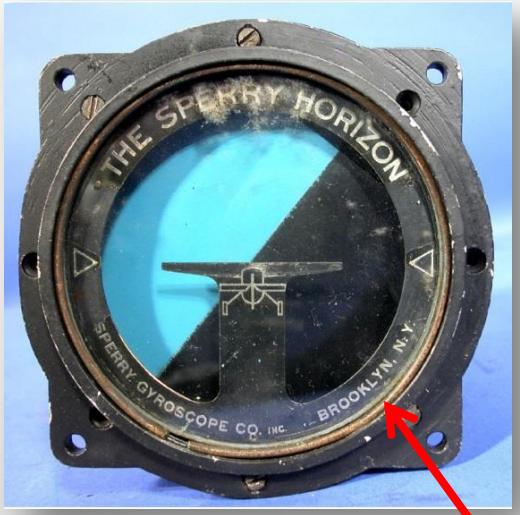
- Studied civil engineering in Stuttgart and Munich
- In 1923 emigrates to America
- Truck driver until finds a position at Pioneer Instruments, in Brooklyn, NY
- 1928 starts Kollsman Instruments with $ 500
- Jimmy Doolittle uses his “altimeter” – recommends all US aircraft to use it
- 1939 sells company for $ 4 million
- 1940 buys 800 acres in Vermont creates Snow Mtn ski resort

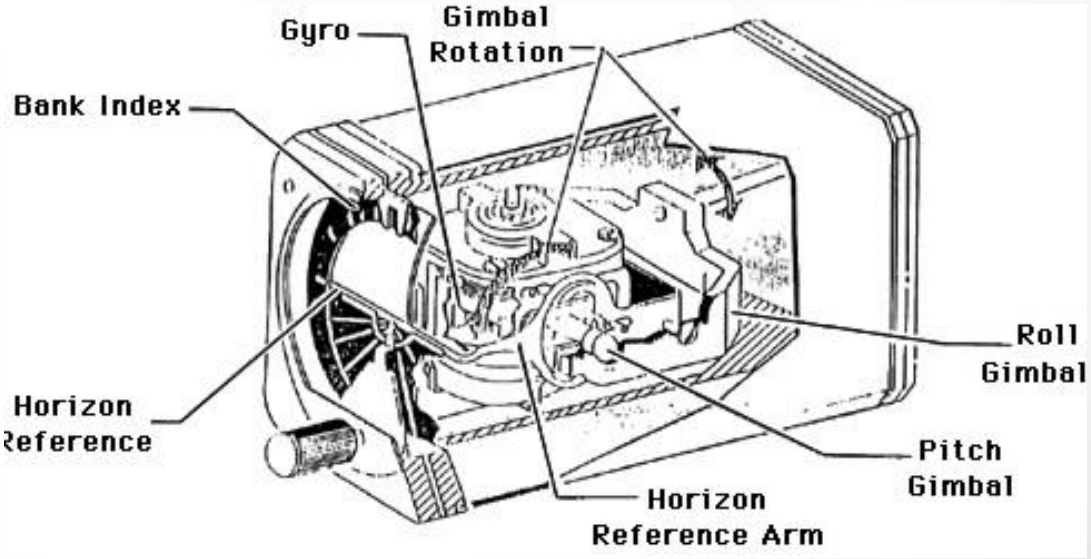
Elmer Sperry – Gyroscopic Instruments – Airplane Referenced



1860-1930







Sperry Gyroscope Co, Brooklyn, NY

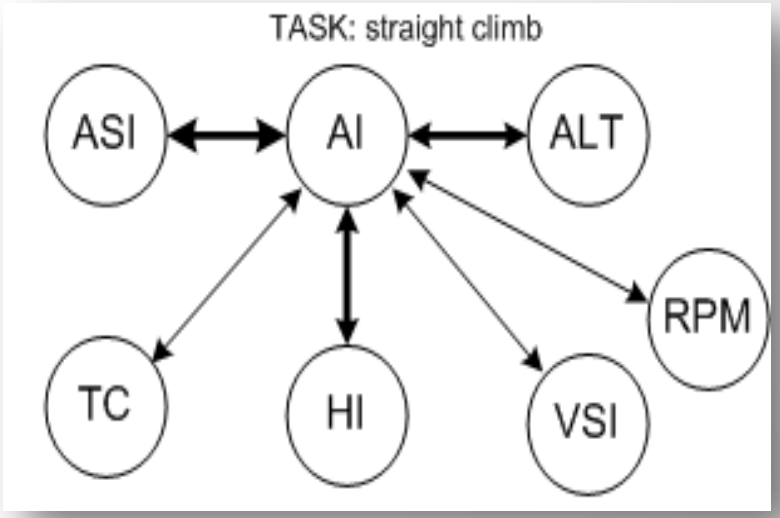
the Attitude Indicator, or Artificial Horizon

Shows you the Attitude of the airplane.... Ie, the pitch or roll, not Path

Its hard to fly “instruments”

Without training and practice, it’s lethal

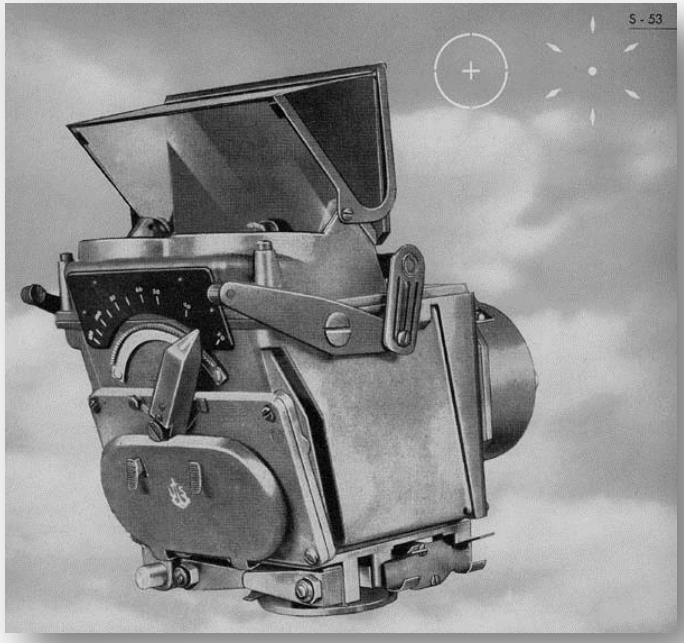
Using a simulator, researchers at the **University of Illinois** conducted a study with **20 pilots** who had **no instrument training** to see the survivability of an encounter with IMC conditions. **All of them lost control**, and the only variable was how long it took. The range was as short as 20 seconds to as long as 480 seconds with the average being 178 seconds.



There has to be a better way to fly “blind”

The Use of PATH in the modern HUD

Up through WWII the early HUDs were gunsights only....



The reflector ring sight was the first "heads up" display. An illuminated sight pattern was projected onto a glass lens. The gunner looked through this lens at his target. This sight, invented by Sir Howard Grubb, the noted Irish optical engineer and telescope maker, around 1900, was used experimentally by the German Air Force in the first World War. It saw service in the early 1930s, **first with the French Air Force,** followed in the mid '30s by the German, British, American and Russian air forces. It saw combat on German and Russian aircraft in the Spanish Civil War, and was well developed by World War II

P-51

A Fighter doesn't have the time to use Pitch/Power

How'd we get from here to here

Gamechanger !

Gilbert Klopstein (Klop)

Father of the modern HUD

Gilbert Klopfstein

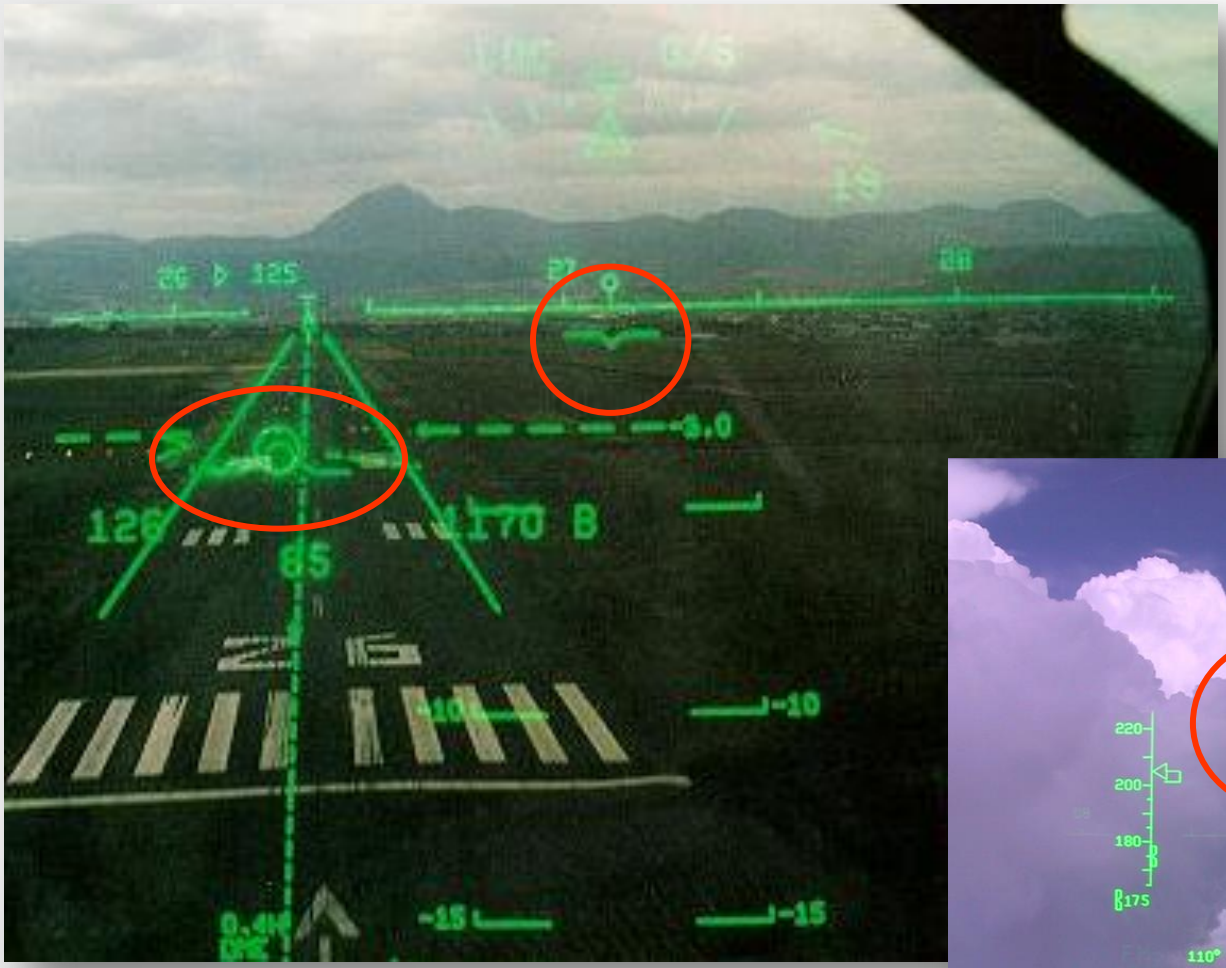
chief engineer and test pilot for the French Flight Test Center

In the 1960s, French test-pilot Gilbert Klopfstein created the first modern HUD and a standardized system of HUD symbols so that pilots would only have to learn one system and could more easily transition between aircraft.

1972 Nord 262 demonstrations to Chuck Yeager and Barry Goldwater

Klopfstein flew Mirage IIIB s/n 225 400 flights to develop the HUD at CEV-

The HUD symbols are “conformal”



Gamechanger !

First Business Jet to use a HUD to CAT IIIa minima

Even though the “look” was harmonized (same speed tapes, same symbols heads up and down), the Flight Director was still a traditional pitch based FD heads down and a PATH based FD heads up…..

Gamechanger !

The EASy Flightdeck
The first cockpit to harmonize the Heads Up with Heads Down

The breakthrough EASy flightdeck not only harmonized the two views but was the first business jet to exclusively use a path based flight director, heads up and down!

SVS- Synthetic Vision- a Daytime HUD

EASy

EASy II with SVS

Now either seat has a HUD view as if it was always Day VFR outside

But what happens if it's IMC, or a Black hole Night ? We'd like to give the PF using the HUD the same situational awareness by using SVS heads up or Enhanced Vision

Gamechanger !

Falcon Eye
The world's first HUD with full time, Combined Vision System (EVS and SVS)

EVS- First Generation were Thermal Cameras-

The New Elbit Multi Sensor Camera
(not just thermal- can “see” quartz and LED lights)

FalconEye CVS

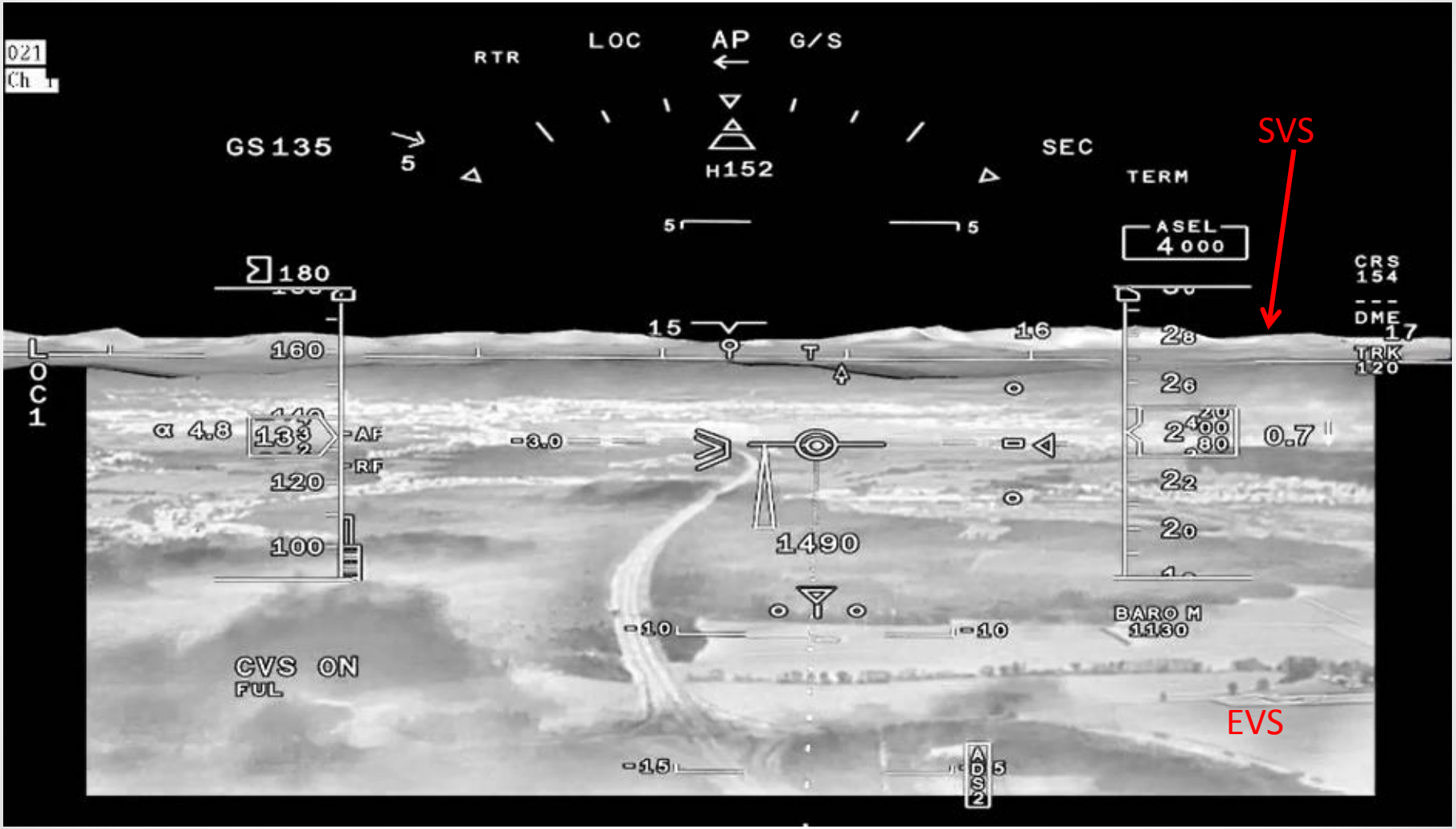
The Industries first true combined vision system

The Problem…… EVS using a thermal camera has physical limits…. principally it can't penetrate water ….. (wet fog, rain, clouds!)

SVS isn't bothered by physical limits, but it isn't "real"…. So you won't see the deer or airplane on the runway, and it has little to offer on the ground

So you'd like to use SVS for the big picture and scenery (ie,mountains) and use the EVS for the landing environment (lights, runway, taxi ways)…. But a monochromatic HUD (everything is green) makes it difficult to understand what you are seeing if the two are overlaid….

Dassault worked, and then patented, a true combination CVS in the new FalconEye HUD.



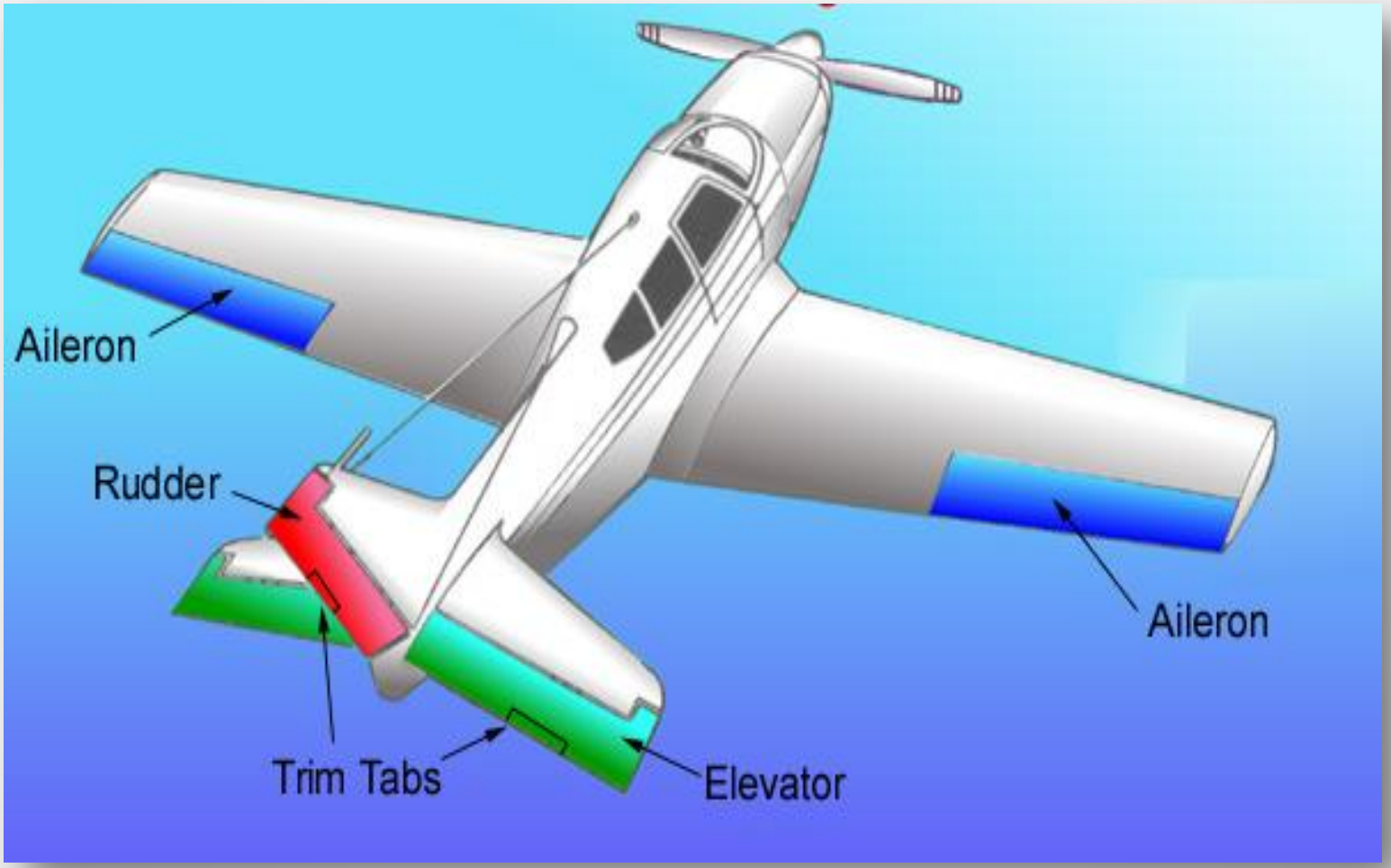
The Breakthrough to CVS is to have Clear Zones in front of and around the runway

FalconEye at the NBAA Falcon Breakfast

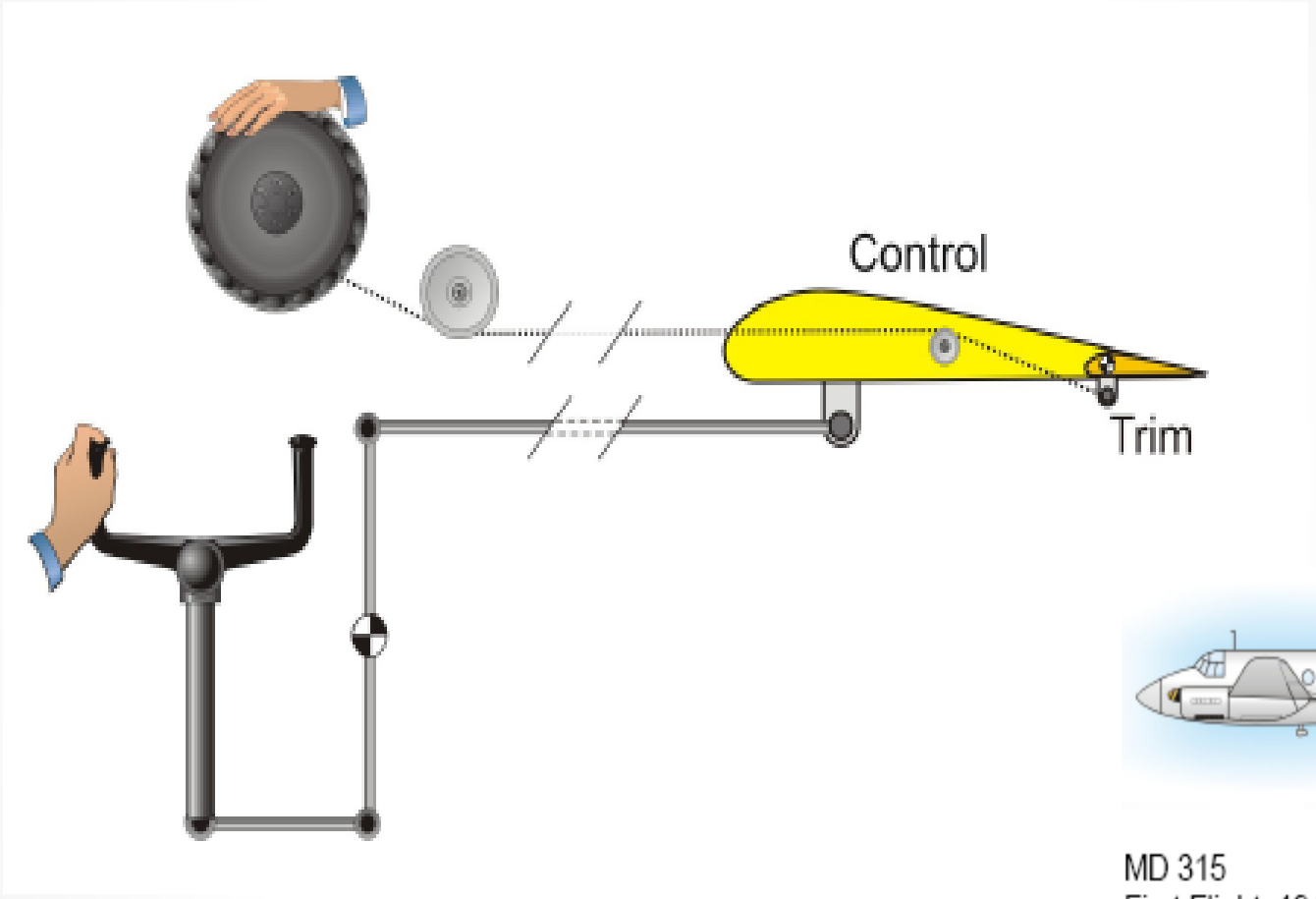
Gamechanger

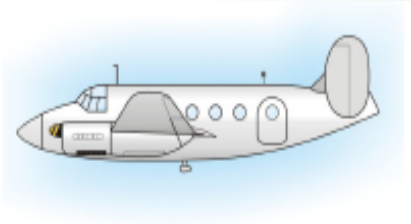
Falcon 7X: the world's first business jet with a closed loop, **Digital Fly By Wire Flight Control**

Classic Airplane Flight Control



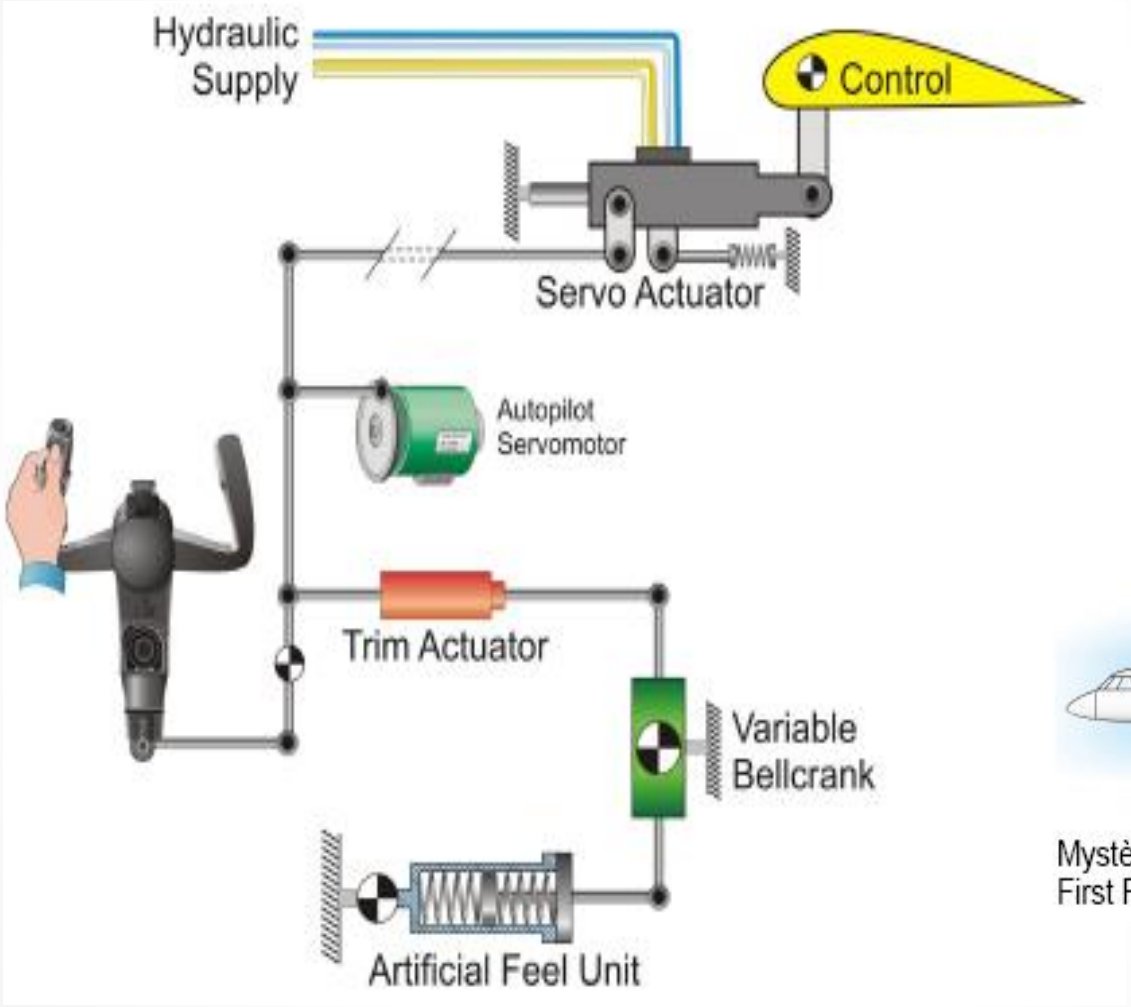
Conventional Controls: Rods & Pulleys & Wires





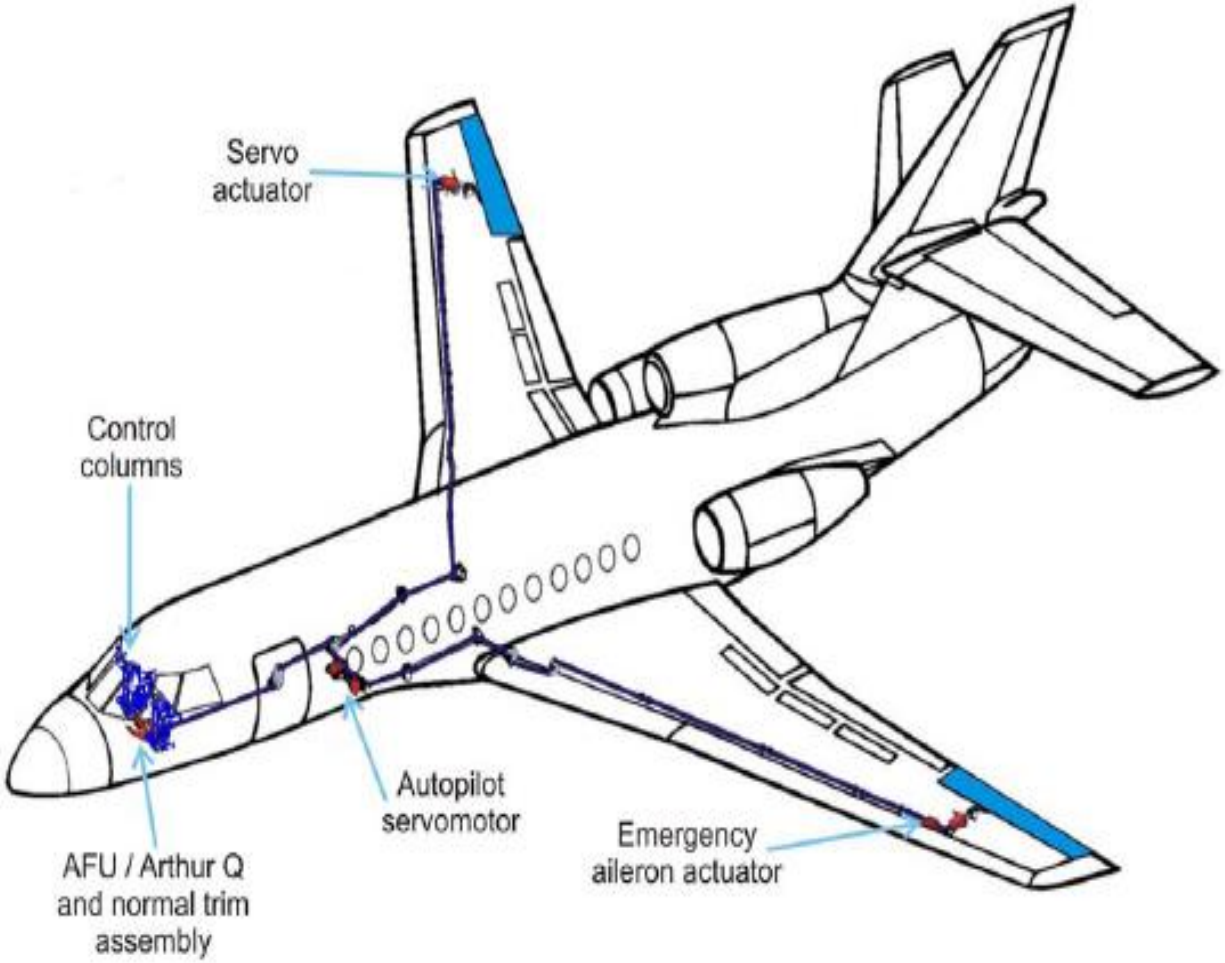
MD 315
First Flight: 1947

Faster Speeds: Hydraulic Boots to Controls



Mystère / Falcon 20
First Flight: 1963

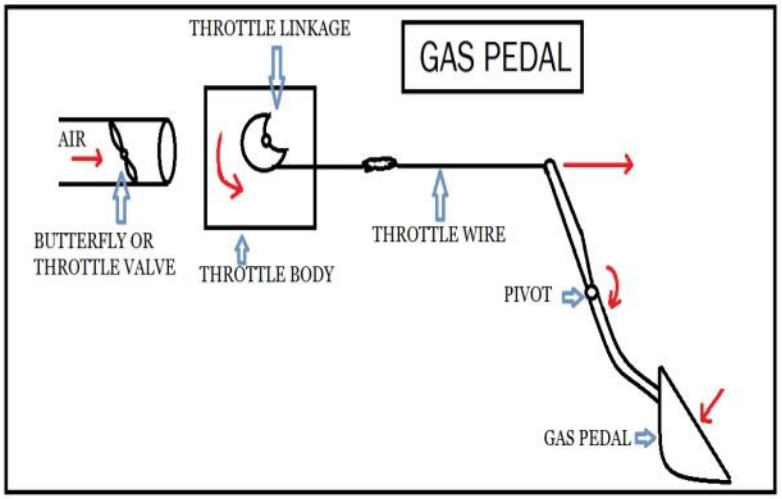
F900EX EASy Aileron Control

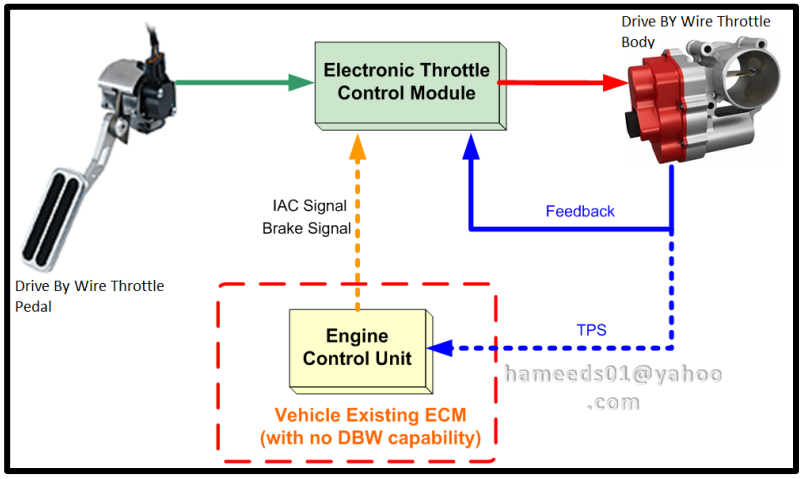


Fly by Wire and Closed vs. Open Loop Systems

Say you want to maintain a constant 60mph in your car....

It doesn't matter if you're old school or new





Manual

- **Open Loop- you control- Classic System**

Antique: gas pedal directly linked to carburetor

Modern Car: "drive by wire": gas pedal feels like the old days but it electronically tells system to "give it gas"

Driver provides the feedback to maintain speed

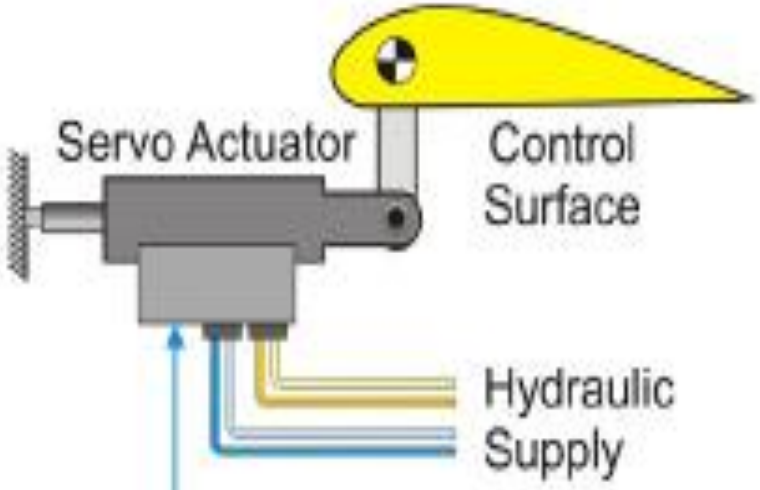
Automatic

- **Closed Loop- computer controls**

Cruise Control: computer uses feedback to maintain speed- driver monitors

Digital Fly By Wire- Auto Trimming to PATH

Autopilot or You Change the Path



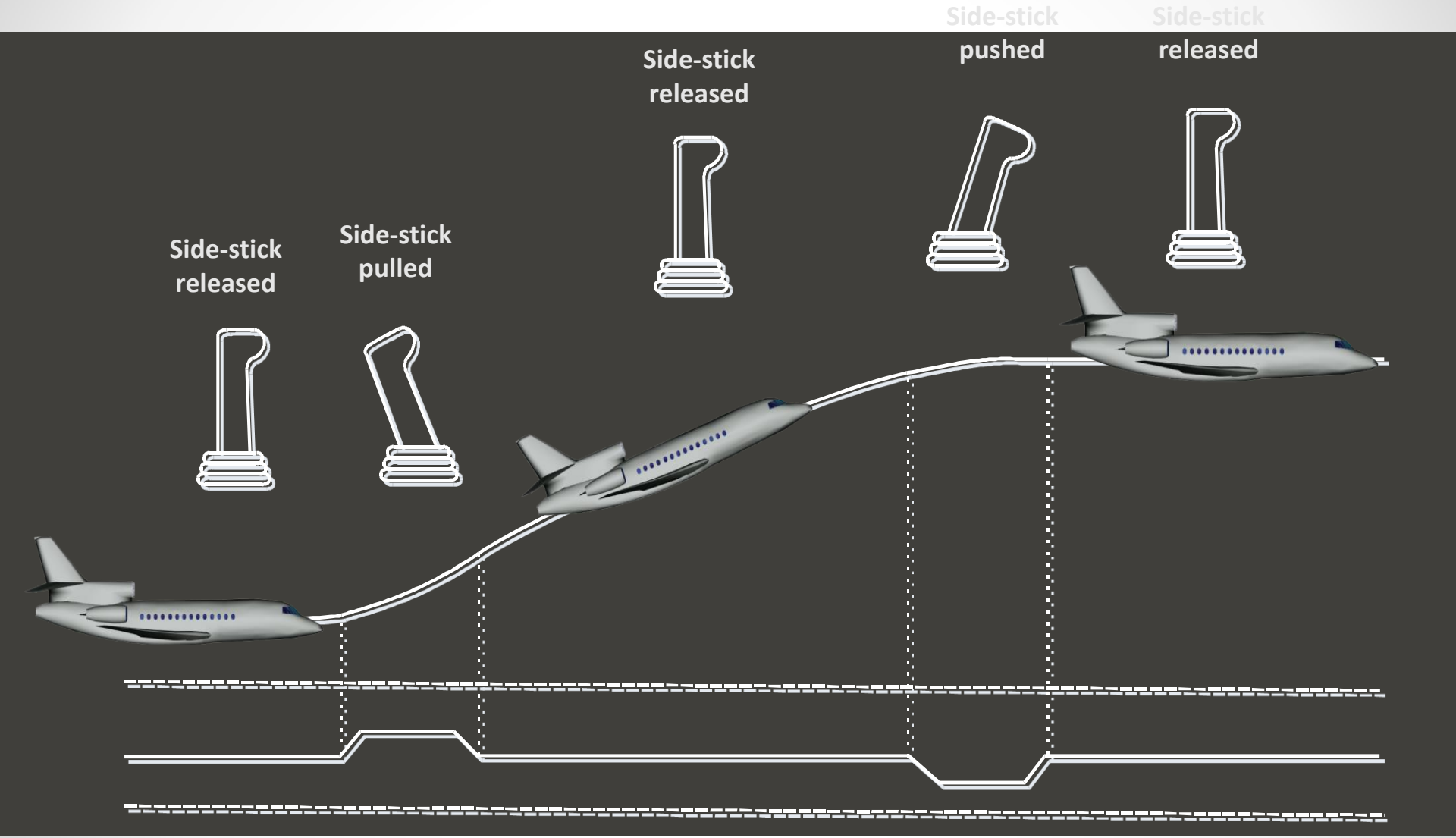
Flight Control Computers

Actuator Control & Monitoring Units

Closed loop feedback

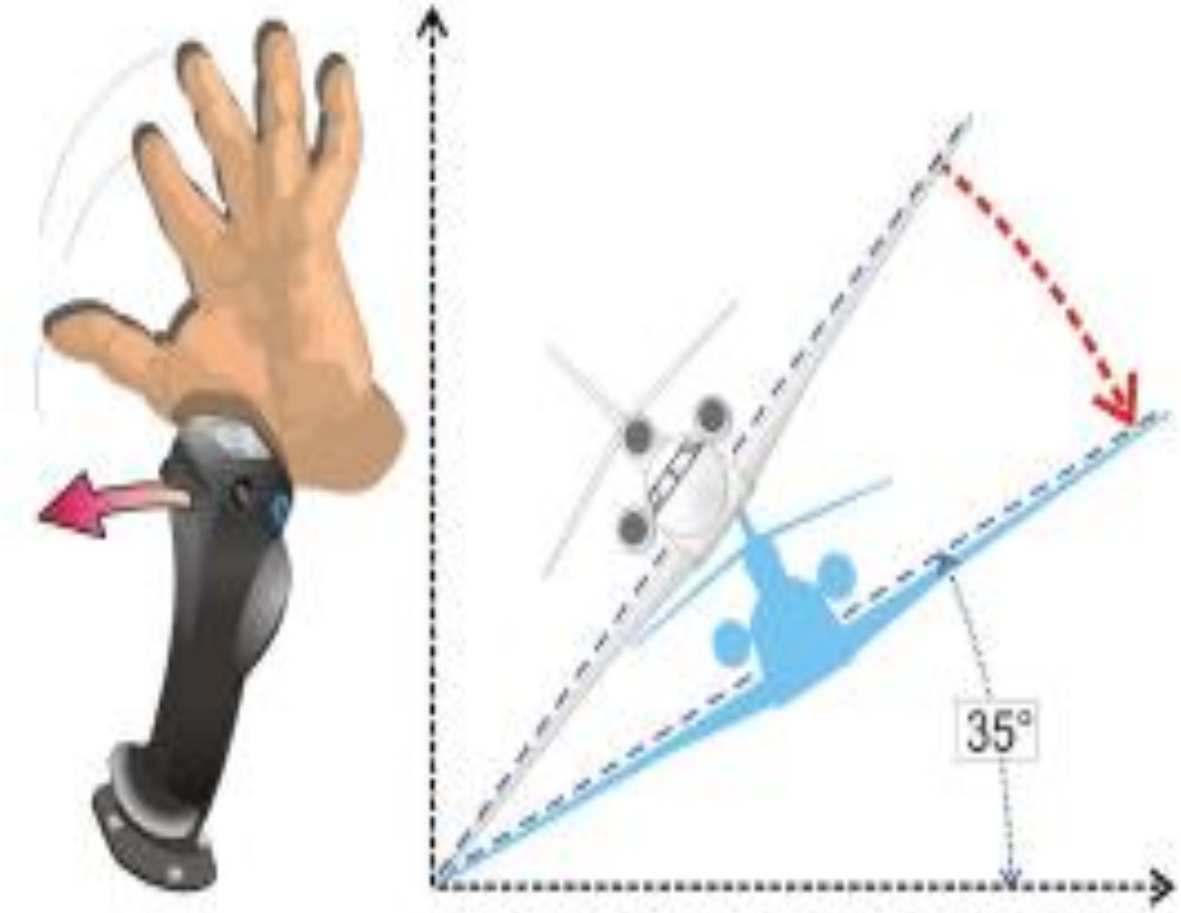
The Genius is in the Control Laws

We use the stick to control PATH- not move the surfaces

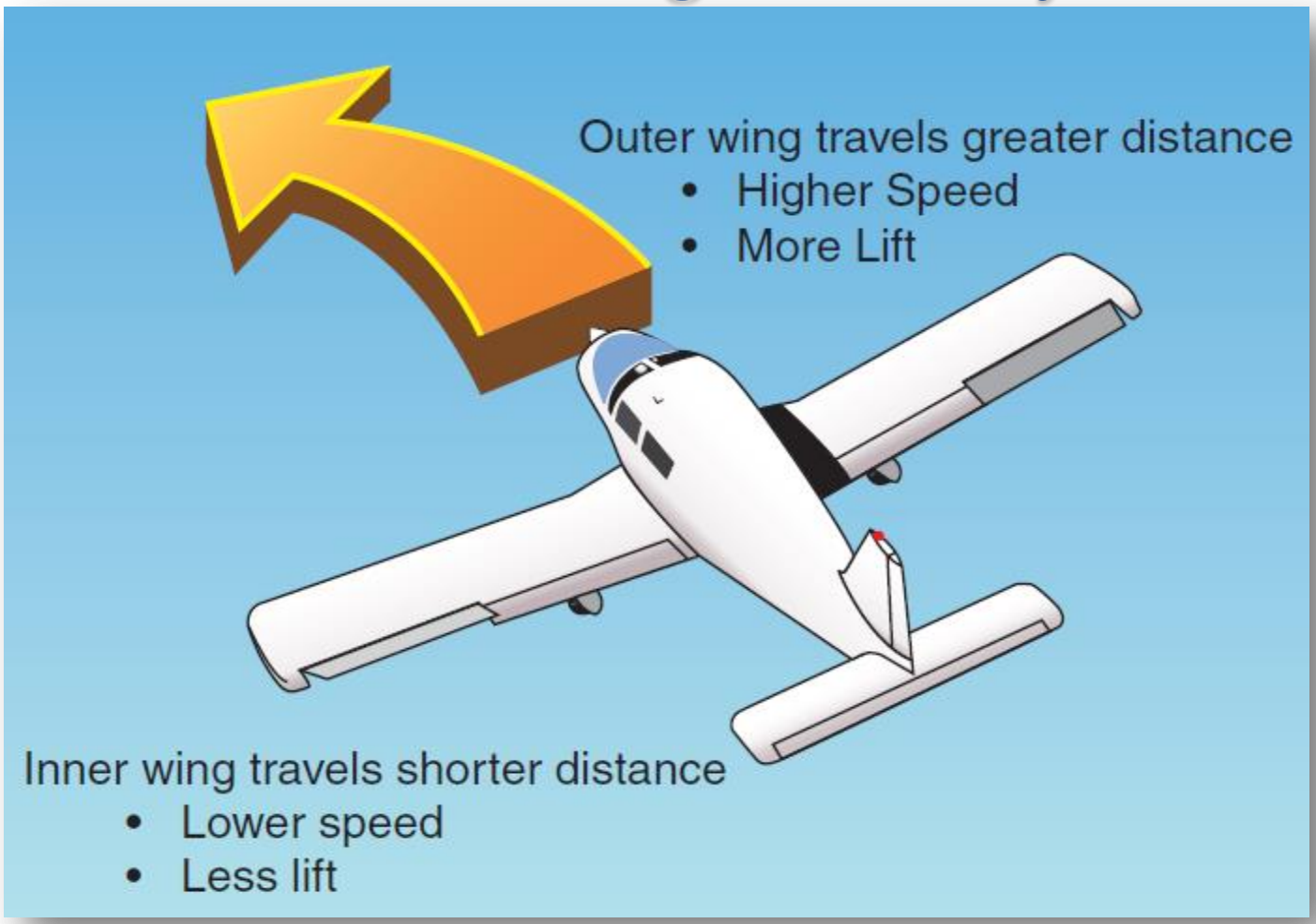


DFCS will hold the bank up to 35^0,

or return you there



Overbanking Tendency



Pilots must use opposite control to prevent over banking

A **Classical FBW** airplane (Boeing/ Gulfstream) will need to compensate to maintain Path
A **Path Stabile FBW** airplane (Falcon/Embraer) will fly and hold the path

We've come a long way…. ..Thank you