Why airplanes

a history of flight through aircraft design

Info. and images drawn from following resources:

http://www.grc.nasa.gov/WWW/K-12/aerores.htm

http://www.grc.nasa.gov/WWW/K-12/UEET/StudentSite/historyofflight.html

Explorer Post 630
Airplane design

Theory

Ask about the “Why·s?”

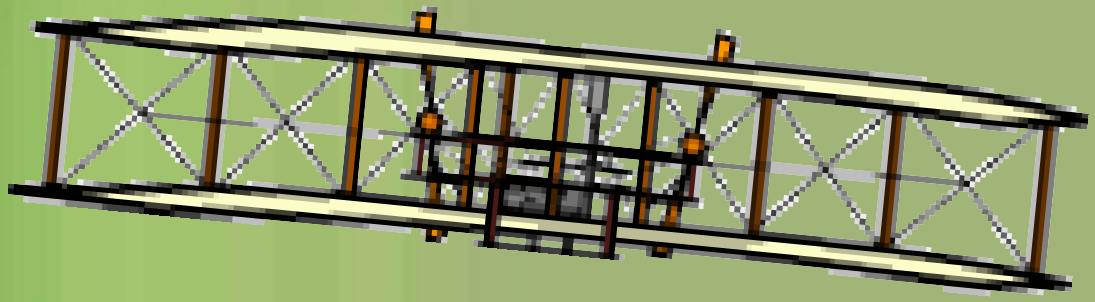
Design/Implement

synthesize

Test/Confirm

H I S T O R Y

– Flight –
nature compared to human



Early attempts

Humans try to fly like birds

For many centuries, humans have tried to fly just like the birds. Wings made of feathers or light weight wood have been attached to arms to test their ability to fly. The results were often disastrous.

Why?

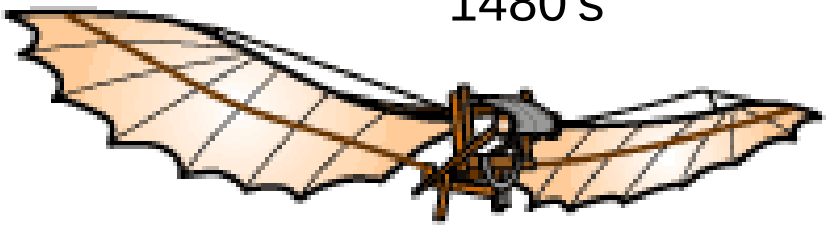
The muscles, joints and bones of the human arms and leg are not like a birds and can not move with the strength of a bird.

They are designed to lift, throw, walk, run, but not fly.

So . . . If we were meant to fly, we had to invent science!

Flight Science in history

1480's

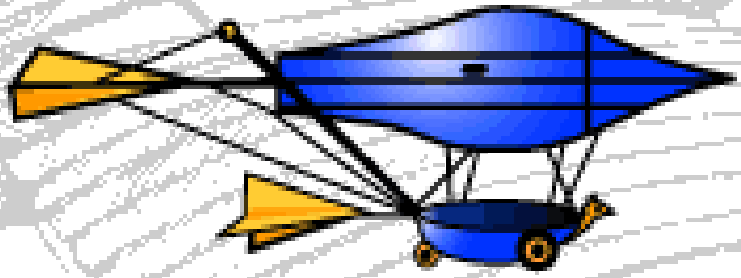


Leonardo Da Vinci
Ornithopter

Montgolfier
Balloon

1783

Hero of Alexandria's
Aeolipile

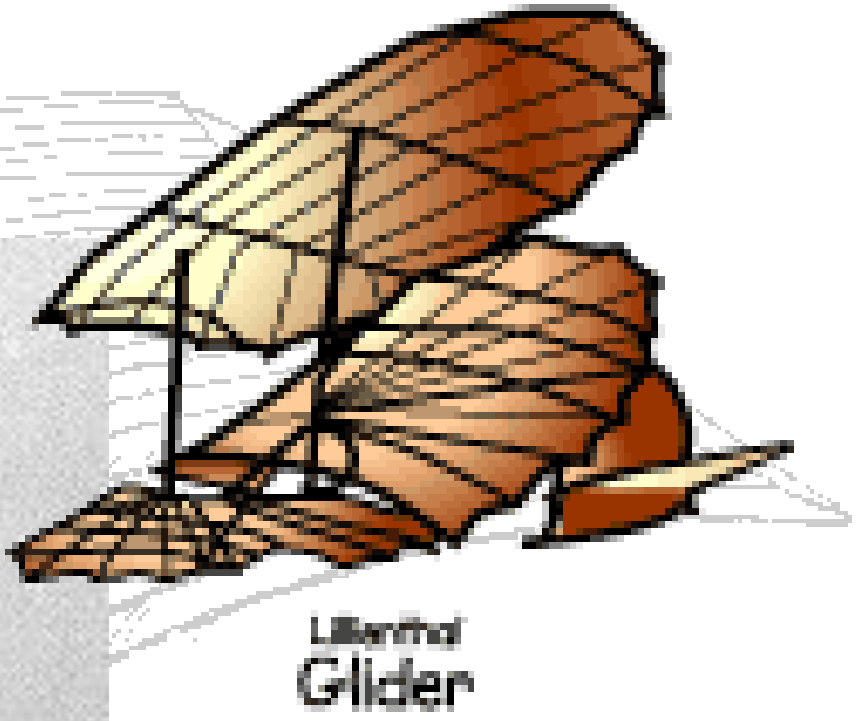


George Cayley
Glider with Tail

1850's

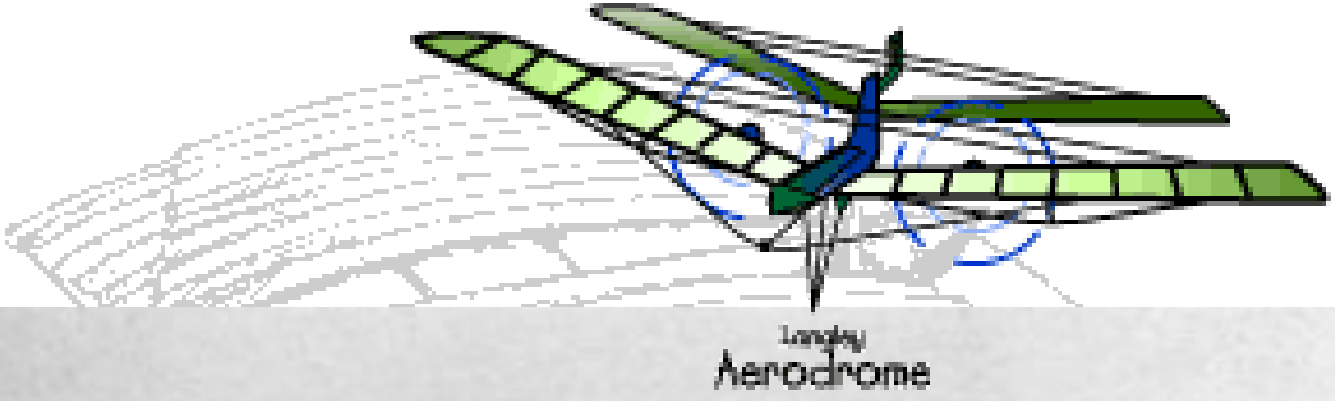
On Ariel Navigation

Flight Science in history



1891 Otto Lilienthal

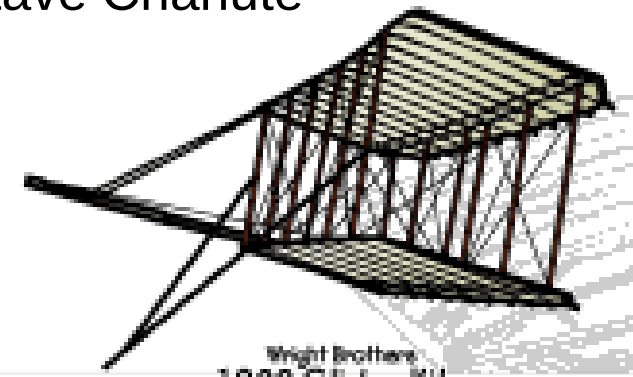
Flight Science in history



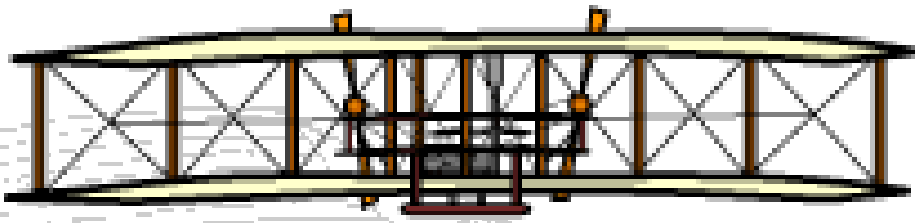
1891 Samuel P. Langley

Flight Science in history

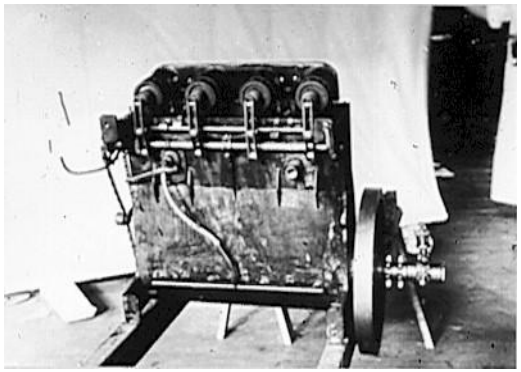
1894 Octave Chanute



Wright Brothers
1900 Glider Kite



Wright Brothers
Kitty Hawk Flyer

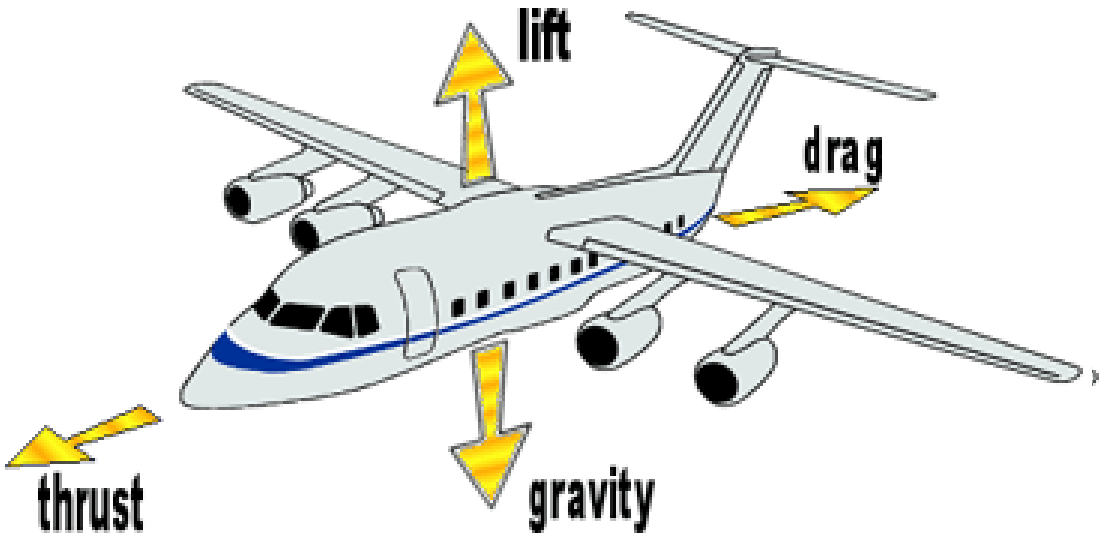


Orville and Wilbur Wright - December 17, 1903

Forces of Flight

Four forces of flight

Lift - upward
Drag - backward
Weight - downward
Thrust - forward

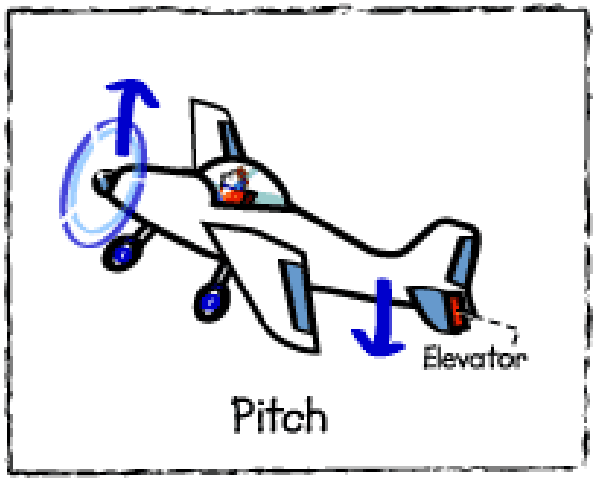


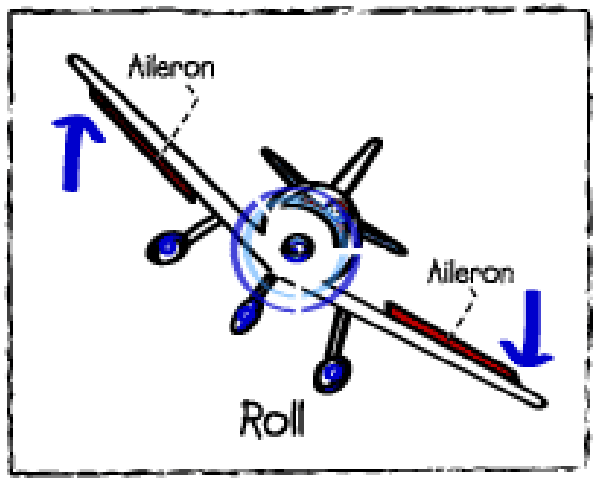
So brush up on your vectors, moments and free-body diagrams

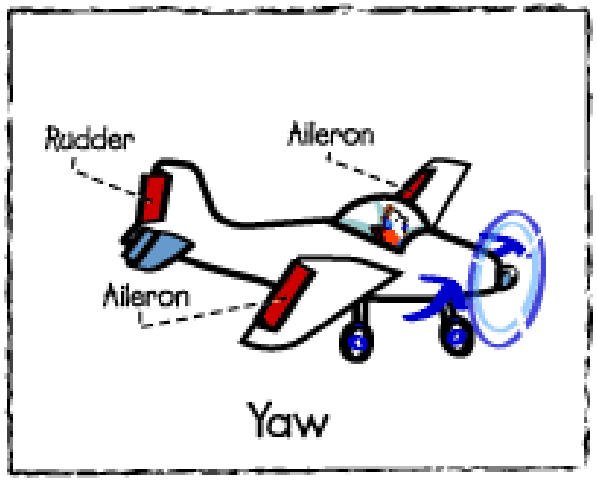
Moments of Flight

Harnessing Forces enable humans to get in the air.

Controlling moments allow us to live afterwards!







Airplane design mission

SIMPLE

- Increase lift
- Decrease weight
- Decrease drag
- Increase thrust
- Stay controlled
- Do all the cool things the customer wants

Wings and Lift

$$\text{Lift} = q \times C_{Lift} \times S_{ref}, \qquad q = (\tfrac{1}{2} \times \text{air density} \times \text{velocity}^2)$$

WHY?

Is it because the air is lower pressure on top?

Is it because air is pushed down?, (so the airplane is pushed up)

Is it that the airfoil causes circulation and circulation is lift?

Is it Bernoulli's theorem?

Is it the mysterious trailing edge 'Kutta' condition?

Is it All the above?

http://www.grc.nasa.gov/WWW/K-12/airplane/foilsime.html

Drag and Shape

$Drag = q \times C_{Drag} \times S_{ref}$, $q = (\frac{1}{2} \times \text{air density} \times \text{velocity}^2)$

WHY?

Drag is friction (air viscosity)

Surface area is sometimes called 'wetted' area

Streamlining reduces drag
bumps, roughness, stalled air, flow separation are evil for airplanes (good for parachutes?)

Turbulence usually reduces drag (not always?)

Shock waves cause drag at and above transonic speeds

Lift causes drag (and drag causes lift?)

http://www.grc.nasa.gov/WWW/K-12/airplane/foilsime.html

Drag ↔ Lift
and aspect ratio, AR

High AR

Low AR

$$Cd = \frac{D}{\rho\ A\ V^2/2}$$

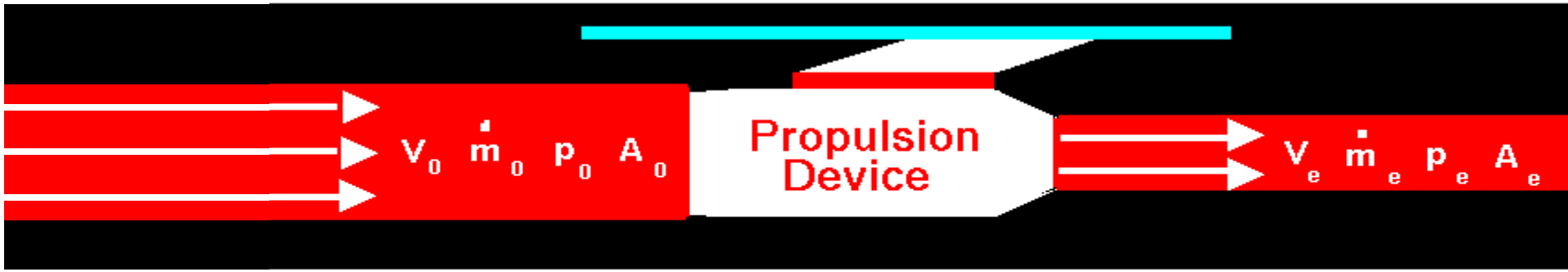
Coefficient Cd contains all the complex dependencies and is usually determined experimentally.

Choice of reference area A affects the value of Cd .

For an aircraft: $Cd = Cd_0 + \frac{Cl^2}{\pi\ AR\ e}$

(aircraft) = (skin friction + form) + (induced)

Thrust



WHY?, what's best

Increased velocity, Delta V. (all aeropropulsion must have)

Increase mass flow, mdot (like turbofans, propellers)

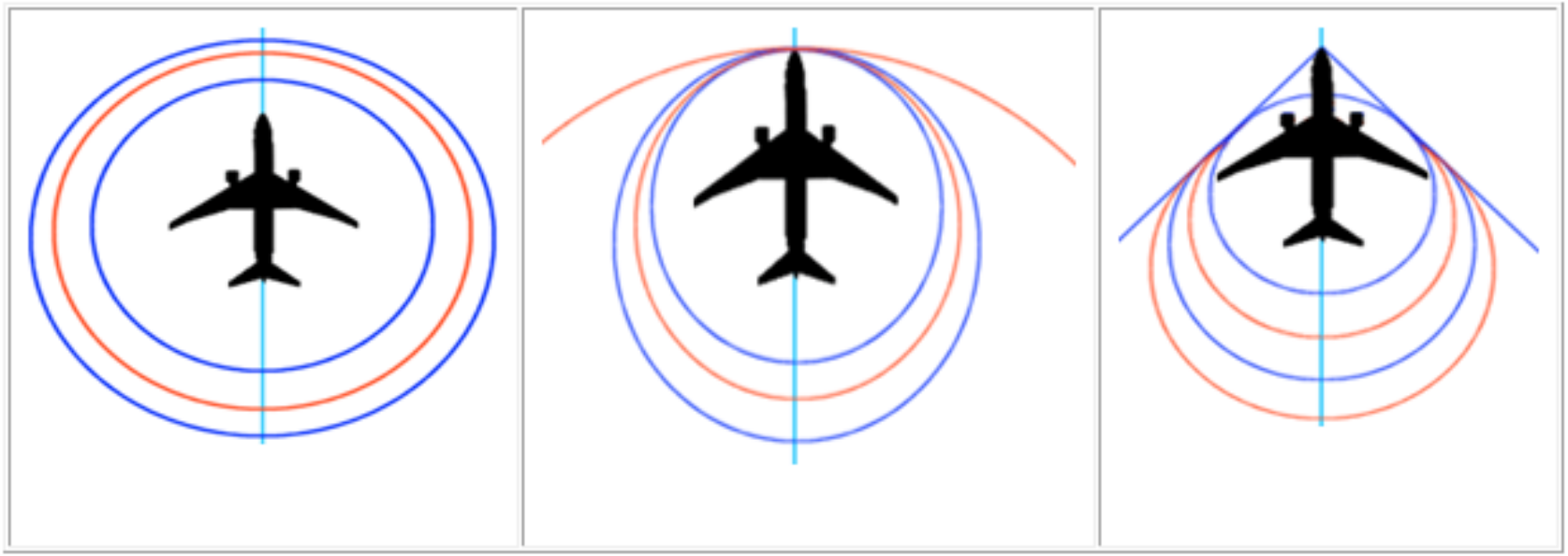
Increased mass flow, Delta mdot (like rockets)

Adding energy (fuel source, what about remote energy)

All the above

http://www.grc.nasa.gov/WWW/K-12/airplane/thrsteq.html

Sound Barrier



Causes:
- wave drag
- wicked controls
- crazy mathematics (non-linear)
- sonic boom

http://www.grc.nasa.gov/WWW/K-12/airplane/sndwave.html

Airplane design mission

NOT SO SIMPLE

- high temperature
- designer materials
- range of conditions
  - takeoff, cruise, turn, high altitude, high speed
- non-linearities, scaling difficulties
- controls, stability versus responsiveness
- payloads with special needs
  - ➢ *Integrate all the cool things the customer wants*

Airplane design history

1905

1913

1919

1932

1934

1944

1947

1949

1959

1960

1966

1964

2016?

1978

1983

1998

Hypersonic Airplane

For 60 years humans have aspired to build faster supersonic airplanes. Jinho and I have been working on some aspects of the engines for these airplanes.

But the near future looks indefinite.

Perhaps the next generation?

That is YOU ALL !!!

Not simple – Wright Bros.

What does an ‘airplane’ look like? (configuration)

How do you build it? (lightweight structure)

Propulsion? (lightweight – high power engines)

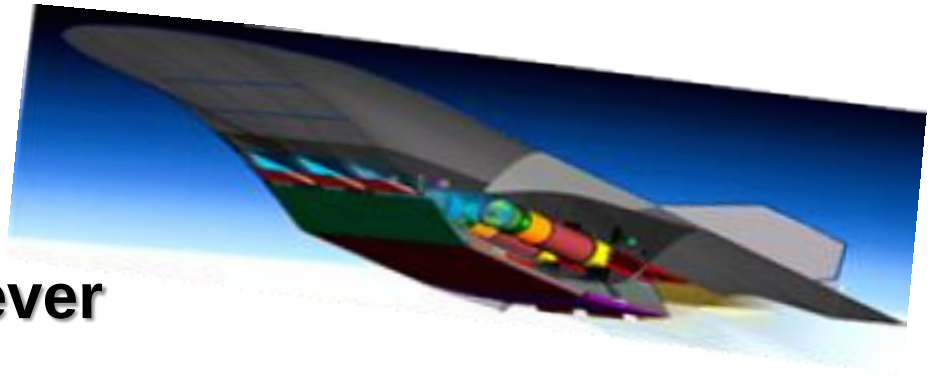
Unknowns? Test before you fly (or die)

Not simple – the process

Requirements + science + test = successful airplane

Requirements:

- **-payload**
- **-how far**
- **-how fast**
- **-mission / manuever**



Flight sciences: aerodynamics, propulsion, materials & structures, controls,

Testing: small labs, wind tunnel, flight testing

Questions ?

What do you think the Wright Bros. wanted to do with their invention ?

What challenges did they face building the first airplane?

What do we face building (or designing) a hypersonic airplane?

Questions ?

Why are airplanes shaped the why they are?

- wing shape, thickness, sweep, winglets, biplanes
- controls: tail, canards, fluidics
- structures: how much are the forces, how to balance light weight trussing with aerodynamics

What about engine types?

- engines: propellers, turbojet, turbofan, ramjet, scramjet, beamed propulsion

What are the future air vehicle missions?

- on planet
  - UAVs, high-speed, surveillance, communication . . .
- off planet . . . ???

Flight sciences –
it's not just aircraft design

1911 - 1958

The Collier Trophy

Aircraft design | Safety | Space

"for the greatest achievement in aeronautics or astronautics in America, with respect to improving the performance, efficiency, and safety of air or space vehicles, the value of which has been thoroughly demonstrated by actual use during the preceding year."

1911 - Glenn H Curtiss, develop. of the hydro- aeroplane.

1912 - Glenn H Curtiss, invention of a single-pontoon seaplane & develop. of the flying boat.

1913 - Orville Wright, develop. of his automatic stabilizer.

1914 – Elmer & Lawrence Sperry, develop. of the gyroscopic control.

1915 - W Starling Burgess, Burgess-Dunne hydro-aeroplanes.

1916 - Elmer A Sperry, develop. of the Sperry drift indicator.

1917-1920 - No award presented.

1921 - Grover C Loening, develop. of the Aerial Yacht.

1922 - US Air Mail Service, a year without a fatal accident.

1923 - US Air Mail Service, night flight.

1924 - Army Air Service, the first global flight.

1925 - Dr Sylvanus A Reed, develop. of the metal propeller.

1926 - Maj E L Hoffman, develop. of a practical parachute.

1927 - Charles L Lawrance, develop. of radial aircraft engines.

1928 – Aeronautics at Commerce, develop. of airways navigation .

1929 - NACA, develop. of cowling for radial engines.

1930 - Harold F Pitcairn, develop. of the safe autogyro.

1931 - Packard Motor Car Co, develop. of the aircraft Diesel engine.

1932 - Glenn L Martin, develop. of a multi-engined, high-speed, bomber (B-10).

1933 - Hamilton Std. Propeller Co, develop. of a controllable-pitch prop.

1934 - Capt Albert F Hegenberger, develop. of a blind landing system.

1935 - Donald W Douglas Aircraft Co, develop. of the commercial DC-2.

1936 - Pan American Airways, est'd. of a transpacific airline with navigation.

1937 - Army Air Corps, design of a substratosphere airplane.

1938 - Howard Hughes & Associates, for a successful global flight.

1939 - The U S airlines, record of safety in air travel.

1940 - Dr Sanford A Moss, develop. of the supercharger.

1941 - Air Forces and U S airlines, world op's. of the Air Transport Command.

1942 - Gen Henry H Arnold, organization and leadership of the USAAF.

1943 - Capt Luis De Florez, develop. of synthetic training devices.

1944 - Gen Carl Spaatz, demonstrating the air power concept in the war against Germany.

1945 - Dr Luis W Alvarez, develop. of Ground Control Approach system

1946 - Luis A Rodert, develop. of a thermal ice-prevention system .

1947 - John Stack, , **Lawrence D Bell**, **& Capt Charles E Yeager,** successful supersonic flight.

1948 - Radio Tech. Comm. - Aeronautics, develop. of a safe Air Traffic Control.

1949 - William P Lear, dev. Auto. Pilot & Approach Controls.

1950 - The Heli. Industry, Mil., & USCG, develop. of Air Rescue helicopters.

1951 - John Stack, develop. of transonic wind tunnel.

1952 - Leonard S Hobbs, designing of the P&W J57 turbojet.

1953 - James H Kindleberger, develop. of supersonic F-100 fighter. **Ed Heinemann**, develop. of the F4D Skyray.

1954 - Richard T Whitcomb, discovered of comp. area rule.

1955 – William Allen & **Gen N. Twining,** develop. and operation of the B-52.

1956 – Chas. McCarthy & **V.Adm J. Russell,** develop. Of F8U Crusader.

1957 - Edward P Curtis, his report, *Aviation Facilities Planning*.

1958 - USAF & industry team, develop. F-104 -- **Kelly Johnson** for airframe; **N.Burgess & G.Neumann** for engine; **Maj H.Johnson,** for landplane altitude & **Capt W.Irwin,** for speed record.

Flight sciences –
it's not just aircraft design

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1959 - USAF, Convair – Gen.Dyn. Corp, &Space Technology Labs Inc, developing the Atlas ICBM.

1960 - Vice Adm William F Raborn, directiion of Polaris fleet ballistic missiles.

1961 - Maj Robert White, Joseph Walker, Scott Crossfield, & **Cdr Forrest Peterson**, - tech. advancement of flight, & for skill as test pilots for X-15.

1962 – LtCdr Scott Carpenter, Maj Gordon Cooper, LtCol John Glenn, Maj Virgil I Grissom, Cdr Walter Schirra, Cdr Alan Shepard, & Maj Donald Slayton, pioneering manned spaceflight in the USA.

1963 - Clarence L "Kelly" Johnson, develop. of A-11 (SR-71) Mach-3 aircraft.

1964 - Gen Curtis E LeMay, achievement w.r.t. air vehicles & defense.

1965 - James E Webb &Hugh L Dryden, rep. Gemini teams that advanced human experience *in* spaceflight.

1966 - James S McDonnell, leadership of aeronautics and astronautics, as exemplified by the F-4 Phantom and Gemini space vehicles.

1967 - Lawrence A Hyland, rep. Surveyor Program team for putting the hands and eyes of the USA on the moon.

1968 - Col Frank Borman, Capt James A Lovell, and LtCol William A Anders, crew of Apollo 8, for the first lunar orbit.

1969 – Neil Armstrong, Col Edwin Aldrin, &Col Michael Collins, epic flight of Apollo 11 & first moon landing.

1970 – Boeing Co, with rec. Pratt & Whitney & Pan Am. Airways, introducing the 747 into commercial service.

1971 - Col David Scott, Col Jams Irwin, &LtCol Alfred Worden, superb skill & courage as Apollo 15 crew, **&Dr Robert T Gilruth**, rep. eng. genius of the manned spaceflight.

1972 - Adm Thomas H Moorer, rep. the 7th and 8th Air Forces & Task Force 77 in Operation Linebacker II.

1973 - Skylab Program, rep. by William Schneider & astronaut crews.

1974 - Dr John Clark, NASA, & **Dr Daniel Fink**, proving the value of LANDSAT space tech. for Earth resources & environment mgmt.

1975 - David S Lewis & **USAF F-16 team**, advancing fighter aircraft effectiveness.

1976 - USAF, B-1 Industry Team, & Rockwell Int'l., develop. of B-1 bomber.

1977 - Gen Robert J Dixon, & TAC developing Red Flag sim. flight-training.

1978 - Sam B Williams, develop. smallest high-efficiency turbofan, for use in powering cruise missiles.

1979 - Dr Paul MacCready, & **Bryan Allen**, human-powered *Gossamer Condor.*

1980 - NASA Voyager team, rep. by **Dr Edward C Stone**, Saturn fly-by & return.

1981 - NASA, Rockwell Int'l., Martin Marietta, Thiokol, & the crew of *Columbia* — **Capt Robert Crippen, Col Joe Engle, Capt Richard Truly, & John Young** — for proving the concept of manned reusable spacecraft.

1982 - T A Wilson and Boeing Co, develop. of the 757 and 767 airliners.

1983 - US Army and Hughes Helicopters Inc, develop. of the AH-64A Apache helicopter.

1984 - NASA and Martin Marietta, with rec.to astronaut **Capt Bruce McCandless, Charles Whitsett ,** & **Walter Bollendonk** of Martin Marietta Co, - develop. of the manned maneuvering units that rescued three satellites.

1985 - Russell W Meyer & Cessna Aircraft safety record of the Citation aircraft fleet.

1986 – Jeana Yeager, Richard Rutan, Burt Rutan, Bruce Evans, & associates, develop. of Voyager aircraft and first nonstop, unrefueled global flight.

1987 - NASA Lewis Research & turboprop team, - develop. adv. turboprop concepts.

1988 - Rear Adm Richard Truly, led recovery of manned space program.

1989 - Ben R Rich & Lockheed-USAF team, production of F-117A Stealth aircraft.

1990 - Bell-Boeing team develop. of V-22 Osprey tilt- rotor aircraft.

1991 - Northrop, Industry Team & USAF, develop. of B-2 stealth aircraft.

1992 - Global Positioning System Team. develop. of GPS navigation & surveillance of air and spacecraft.

1993 – Hubble Telescope Repair Team. renewal of the Hubble Space Telescope.

1994 – McDonnell Douglas C-17 Globemaster, **USAF & Industry Team**

1995 – Boeing Co & the 777 Team.

1996 - Cessna Aircraft Co & the Citation X.

1997 - Gulfstream Aerospace & the G-V.

1998 - U-2S/ER-2 aircraft team.

Flight sciences –
it's not just aircraft design

1999 2011

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1999 - Boeing F/A-18E/F Super Hornet develop. team.

2000 - Global Hawk Unmanned Aerial Vehicle by Northrop Grumman, Rolls-Royce, Raytheon, L-3 Communications, USAF, and DARPA, for designing, building, testing, and operating Global Hawk.

2001 - Pratt & Whitney, with Rolls-Royce, Lockheed Martin, Northrop Grumman, BAE SYSTEMS, and the Joint Strike Fighter Program Office, for designing, developing, and demonstrating the Integrated LiftFan Propulsion System,.

2002 - Sikorsky S-92 helicopter, for designing, manufacturing, testing, and introducing into service the S-92 Helicopter.

2003 - Gulfstream G550 Team, for achievement in designing, testing, and building an innovative aircraft while incorporating measurable safety enhancements and far-reaching advances in aerospace technology.

2004 - Rutan SpaceShipOne Team, for the successful develop. of the first privately financed, built and flown space vehicle.

2005 - Eclipse Aviation Corp for leadership, innovation, and the advancement of general aviation.

2006 - Lockheed Martin, Boeing, Pratt & Whitney, Northrop Grumman, Raytheon, BAE Systems, and USAF, for designing, testing, and operating the revolutionary F-22 Raptor.

2007 - The Automatic Dependent Surveillance-broadcast (ADS-B) Team Of Public And Private Sector Groups
for conceptualizing, developing, and initially implementing the next generation performance-based air-ground, ground-air, and air-air surveillance system.

2008 - The Commercial Aviation Safety Team
For achieving an unprecedented safety level in U.S. commercial airline operations by reducing risk of a fatal airline accident by 83 percent, resulting in two consecutive years of no commercial scheduled airline fatalities.

2009 - NASA And The International Space Station Team Of The Boeing Company, Draper Laboratory, Honeywell Corporation, Lockheed Martin Corporation, United Space Alliance And United Technologies Corporation
For the design, development and assembly in space of the world's largest spacecraft, an orbiting laboratory, promising new discoveries for mankind and setting new standards for international cooperation in space.

2010 Sikorsky & The X2 Tech. Demo.Team
for demonstrating a 250 knot helicopter.

2011 The Boeing Company
for designing, building, certifying, delivering, and supporting the Boeing 787 Dreamliner

2012 ????

???? The future

Score card

	Aircraft design	Safety	Space
#yrs.	55	24	18
%total	57%	25%	19%
%since 1959	59%	9%	34%