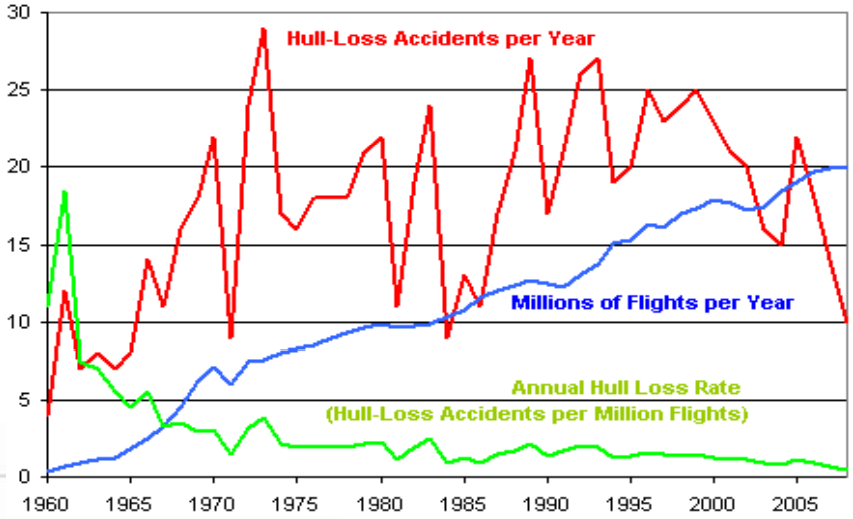
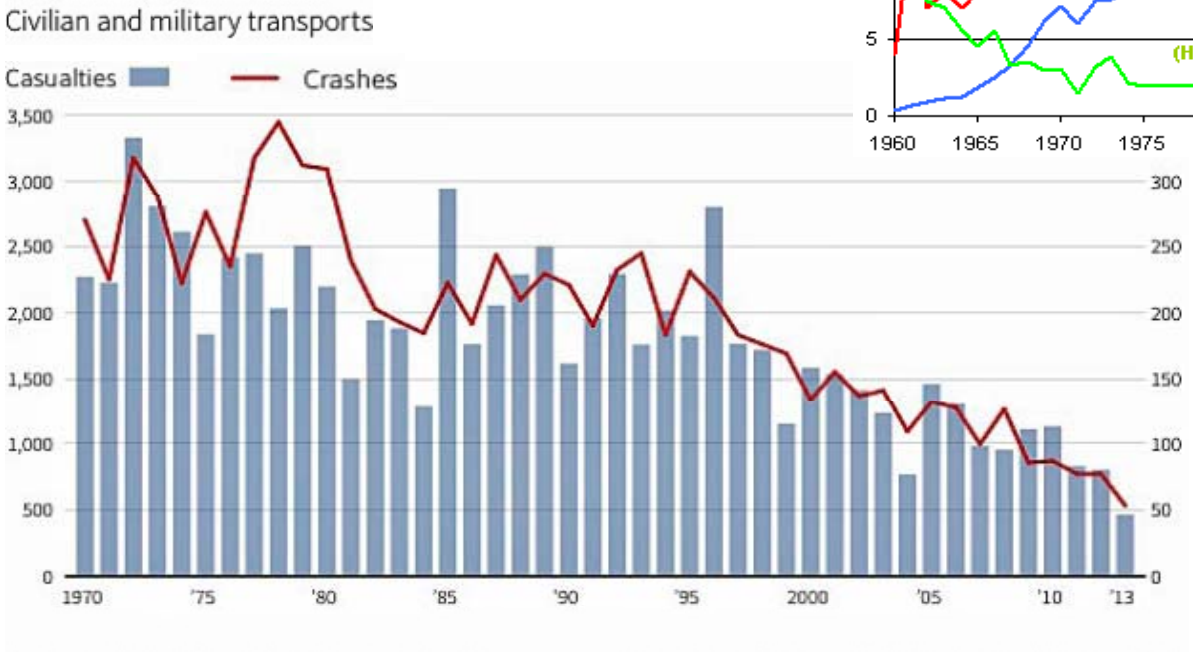
Accidents & Safety





Accidents & Safety

- Aviation is incredibly safe, and getting safer
- Some statistics about commercial flights in the US, in jets weighing 30 tons or more, i.e. no older than a 707 and no smaller than an Embraer 170.
- Hull-loss accidents have hovered around 15-25 a year, over all the decades of jet aviation
- Flights have gone from about 1 million per year to about 20 million per year.
- So the **chance of being in a hull-loss accident** on your next flight has gone from one in 50,000 (1960s) to **literally one in a million**.
- This is thanks to how regulations require additional airplane capabilities and/or maintenance practices in the wake of each accident, to prevent the same problem from causing future accidents.
- See LessonsLearned.FAA.gov to read about dozens of major accidents, their causes, and how regulations and industry practices have changed to prevent repeats.
- Several websites, presentations, and documents summarize all these trends and data, for example:
  http://www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf

Crashworthiness = Survivable Hull Losses

1


2


5


3


4


6


7


8


9


11


12

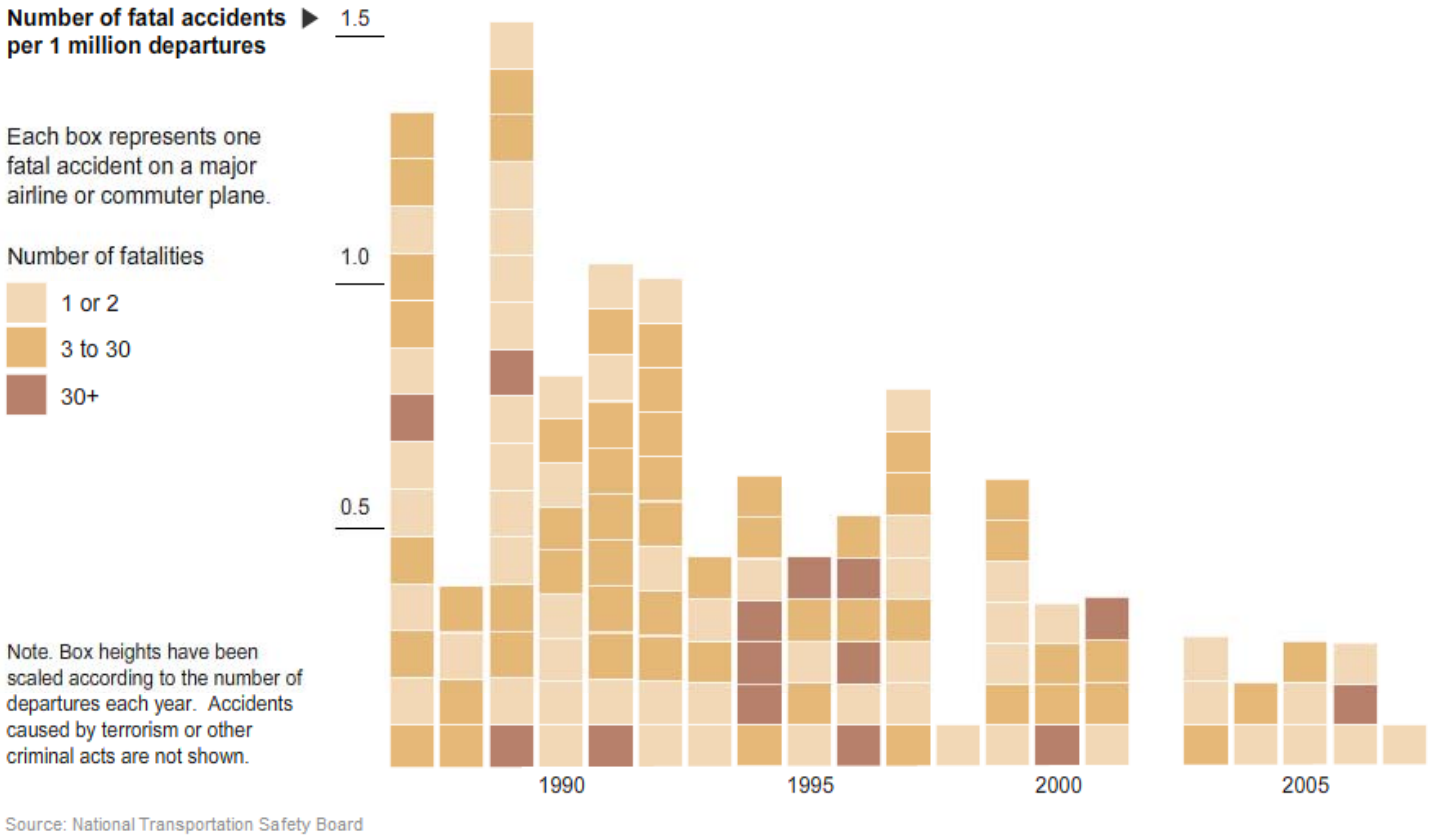

10


	Flight	Year	Survivors	Fatalities
1	American 1420	1999	134	11
2	Britannia 226A	1999	245	0
3	Air France 358	2005	309	0
4	British Airways 38	2005	309	0
5	China Airlines 120	2007	165	0
6	US Airways 1549	2009	155	0
7	Turkish 1951	2009	126	9
8	Aires 8250	2010	129	2
9	Dagestan 372	2010	166	2
10	Caribbean 523	2011	163	0
11	Asiana 214	2013	305	2
12	Air Canada 624	2015	138	0

Crashworthiness = Survivable Hull Losses

- Also, hull-loss accidents are increasingly survivable
- This is thanks to increased crashworthiness requirements, by the FAA and also internally within the manufacturers, as well as improved training and operational practices by the airlines.
- People say “It was a miracle there were so many survivors”. No, it was thanks to very deliberate and complex engineering work!

Safety since the 1990s (modern jets)

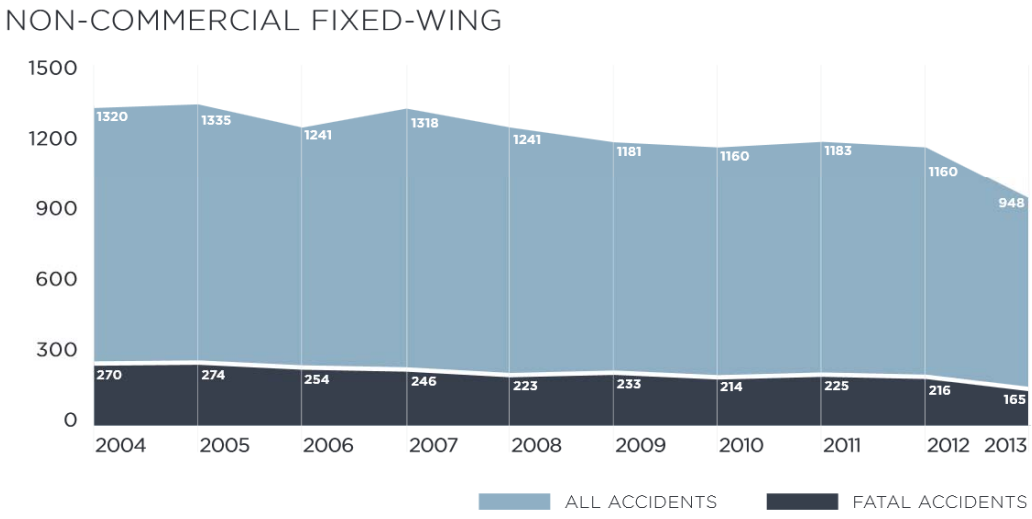


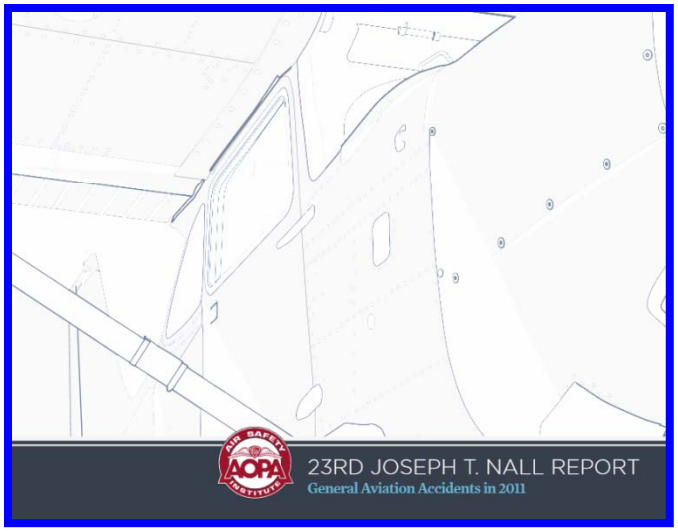
http://www.nytimes.com/interactive/2007/09/28/business/20070930_SAFETY_GRAPHIC.html

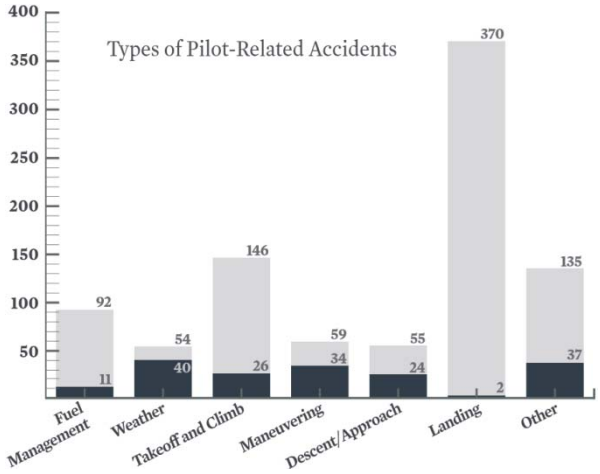
Safety since the 1990s (modern jets)

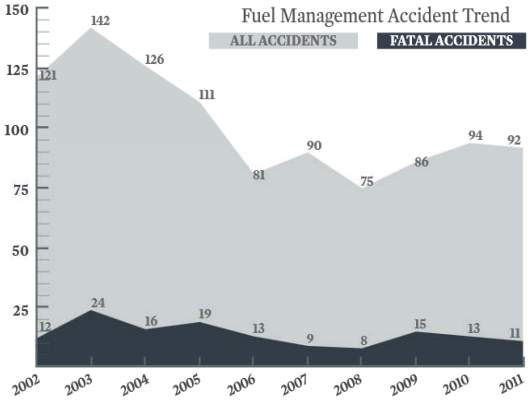
- The “Hull loss per million flights” graph flattens out on the right. Has safety plateaued?
- No! Zoom into that, and you can see each individual accident. The curve is still going down!
- Let’s get data for fatal accidents (not hull-loss accidents) in flights by US operators (not flights on US soil) in any size commercial airplane (including small turboprops).
- The downwards trend is still clear.
- Note how most incidents have 1 or 2 fatalities. These are typically flight-line workers, not passengers.
- So **not only is aviation ridiculously safe; It’s still getting safer!**

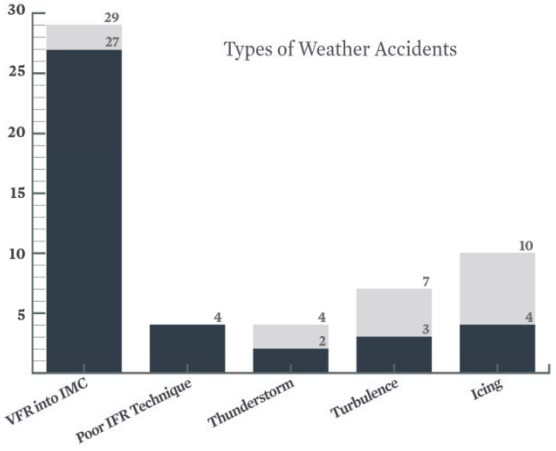
General Aviation Safety











General Aviation Safety

- Previous slides are regarding commercial flights and military transports.
- The AOPA's "Nall Report" goes over General Aviation trends each year: http://www.aopa.org/Pilot-Resources/Safety-and-Technique/Accident-Analysis/Joseph-T-Nall-Report (where "General Aviation" basically means non-commercial, e.g. recreational).
- Not as safe as commercial flight.
- **Nearly all accidents are caused by pilot error.**
- Nearly all accidents are caused by one of three causes:
  - "**Loss of control**": This mostly means, right after takeoff or just before landing, going too slow or pulling too hard into a turn or climb. Either way: stall, sometimes spin, too little altitude to recover.
  - **Fuel mismanagement**: Fuel exhaustion, clogged tubes, etc. Airplane fuel gauges are unreliable, leaks (or just an engine that burns a little too fast, due to old age or sub-optimal settings) can be hard to catch or to account for.
  - **Visual flight into low-visibility conditions** ("VFR into IMC", i.e. flight under Visual Flight Rules into Instrument Meteorological Conditions but not transitioning to instrument flight rules). Pilots become disoriented, crash into terrain. Don't fly if low visibility or obscured horizon is beyond your capabilities, don't fly if marginal weather might end up giving you no option but to fly into clouds!

Latest Developments

Latest Developments

A lot of cool innovative stuff has been happening in aeronautical engineering lately. If anyone thinks that airplanes are not getting better and have not gotten better over the past decade or two, show them this list! Roughly in chronological order, starting in the late 1990s…

- F-22
- 777-200LR
- V-22
- F-35
- A160
- X-45, X-47
- X-43, X-51
- X-48, X-56
- Phantom Eye
- Helios, Solar Impulse
- Mars airplane
- Space X
- SpaceShip Two, X-37
- 787, A350
- Kitplanes, LSAs, Cirrus

Latest Developments; Fighters

F-22 RAPTOR

F-35 JOINT STRIKE FIGHTER

Latest Developments; Fighters

F-22 Raptor:

- Superior to F-15 and F-117 in every way.
- Stealthy
- Supercruise
- Thrust vectoring, overall great agility
- More thrust than any other fighter. Can break Mach 1 on a vertical climb fully loaded.
- No expenses spared! Crazy expensive.

F-35 Joint Strike Fighter:

- Single most powerful engine on any fighter
- Stealthy, supersonic, and VTOL !!!
- Not “cheap”, but design focused on affordability and commonality
- Will substitute a wide array of airplanes: Harrier, A-10, F-16, F-18, various international jets.
- Troubled development program, not as cheap as originally expected. (But if Boeing also tried to make a stealthy supersonic VTOL fighter under a strict budget – a.k.a. the X-32 – there would probably be roughly the same number of problems…)

Latest Developments; Airliners

777-200LR

787

A320 NEO

CS 100

MRJ

Latest Developments; Airliners

777-200LR Worldliner

- Can fly halfway around the world, i.e. from any sufficiently long runway to any other sufficiently long runway!
- Not some experimental prototype. A commercial product available to you and me.
- Airbus released a competing version of the A340 but shut down production a few years later because it did not sell very well.
- Humankind has been struggling with long travel for thousands of years. Now we can go to the opposite corner of the globe in less than a day, comfortably. Think about that!

787 Dreamliner

- Rather than riveting together hundreds of small panels and beams, the 787 is made of only a few HUGE pieces of plastic. Completely different approach to manufacturing.
- Maneuver Load Alleviation, tailored layups, advanced alloys, high-speed machining of integral structure… all add up to much lighter weight. This in turn allows for thinner, higher-aspect-ratio wings, which can be curvier too thanks to composites. Much lower drag.
- No bleed air, all electric… Fly-by-wire… All kinds of innovations.

CS 100, A320 NEO… soon, MRJ and 737MAX

- Bombardier has recently flown the first airliner with a large geared-turbofan engine. Airbus flew theirs shortly afterwards, and Mitsubishi and Boeing are not far behind. These have a geared-down engine so that the turbines at the back of the engine can spin more quickly than the turbofan they power, allowing for larger fans (without the tips going supersonic) and faster-spinning turbines (lighter and more optimal), although in part offset by the energy losses and weight of the reduction gear. This had previously only been used on small jets such as business jets.

Latest Developments; Rotorcraft

V-22
OSPREY

A160 HUMMINGBIRD

AGUSTA 609

Latest Developments; Rotorcraft

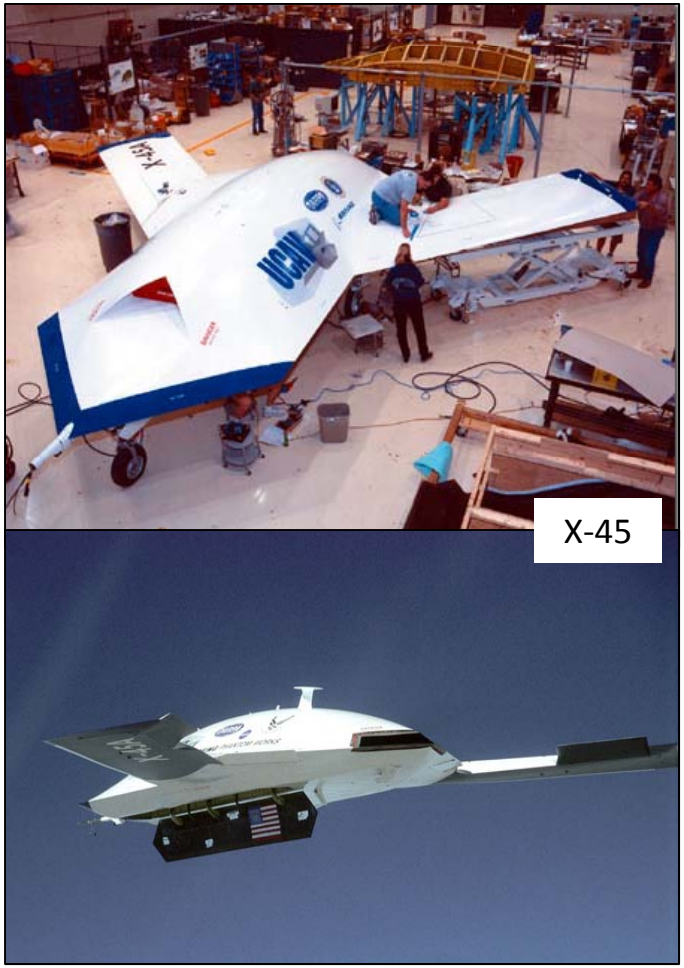
V-22 Osprey

- After many decades of experiments, finally a VTOL transport enters service.
- Same speed and range as a turboprop, same hovering capabilities as a helicopter
- Agusta currently developing a civilian tilt-rotor, the AW 609.
  Huge potential markets in executive transport, search and rescue, hauling gear to remote places… Far faster and more economical than an equivalent helicopter. We might see lots of these soon.

A160 Hummingbird

- By simply tailoring rotor RPM and blade stiffness, the A160 Hummingbird drastically reduced the amount of power needed for a helicopter of its size to fly.
- The prototype was powered by a car engine from a Subaru!
- Beat records for helicopter endurance: Only helo that can fly 18-24 hours non-stop, unrefueled.

Latest Developments; UCAVs



Latest Developments; UCAVs

X-45 / Phantom Ray and Northrop X-47

- Autonomous stealthy UAVs
- X-47 has landed and taken off on carriers, autonomously, and also performed in-flight refueling
- X-45 has flown missions where multiple airplanes take off with different fuel and weapons loads to go attack a target, and are surprised by pop-up threats. Have to coordinate: Which airplane attacks the new target? Does the other one fly around it? How far out? Once arriving at each target, what speed and angle is best for releasing each kind of weapon? The airplanes decided and executed all this. The only human interaction was approving the request for weapons release.
- That's some pretty sci-fi AI stuff…

Latest Developments; X Planes

X-43

X-48

X-51

X-56

Latest Developments; X Planes

X-43 / X-51

- Scramjet engines, can sustain combustion inside the engine even if airflow is supersonic all the way through the engine
- Fastest air-breathing aircraft ever
- X-43 got to Mach 10 !!!
- X-51 could fly for four minutes, which gets you surprisingly far at one mile per second
- Technology may allow for faster travel and for cheaper access to space. Will certainly allow for better missiles.

X-48 / X-56

- Exploring lower-drag configurations for almost-sonic jets (e.g. airliners)
- The blended-wing-body has very low drag. One key problem in the way of wider adoption: How does it stall? How does it spin? How can it be shaped to make stalls and spins predictable and easily manageable / recoverable? No one knew for sure. The X-48 program explored this regime and generated tons of great data, from three slightly different BWB configurations. Lots of promise for cargo freighters.
- Jets can't have wings that are too slender or they will flutter. But the onset of flutter could be delayed by cleverly laid-up composites, by active suppression systems (i.e. fast-acting control surfaces), and by other means. The X-56 was built to explore these possibilities. The wings are modular, and can be easily replaced once one set of wings has supplied enough data for the development of the subsequent, improved set of wings. Hopefully it will help jet transport manufacturers develop and use even longer and more glider-like wings than the 787 and 777X.

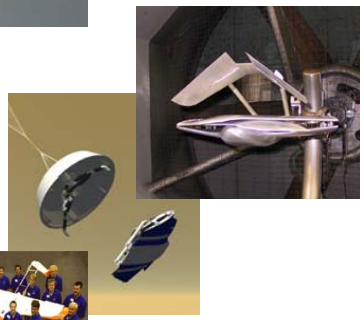
Latest Developments; HALE

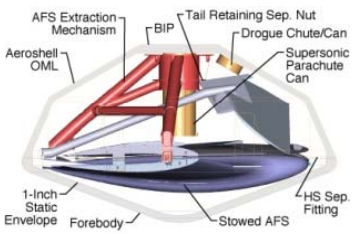
High Altitude
Long Endurance

PHANTOM EYE

SOLAR IMPULSE

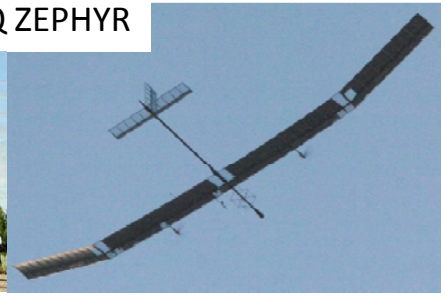
NASA MARS AIRPLANE





GLOBAL OBSERVER

QINETIQ ZEPHYR



Latest Developments; HALE

Helios (not shown)

- NASA solar-powered airplane, same wingspan as 747
- Unmanned, could theoretically fly for months
- Initially had batteries that could only fly during the day and a few hours into the night. Was in the process of having them replaced with fuel cells that could hold enough energy to charge during the day and fly all through the night.
- Highest-flying airplane ever (excluding zoom climbs and rocketplanes dropped from motherships), ~100,000 feet, just a little higher than the Blackbird.

AeroVironment Global Observer

- Powered by hydrogen fuel cells, similar performance to Phantom Eye (but smaller)

Solar Impulse 1 & 2

- Swiss solar-powered airplane, also about same wingspan as 747
- Will fly all the way around the world. Will take weeks, to be done in multiple hops

Phantom Eye

- About same wingspan as a 767 but only 2.5% of the weight
- Each engine is out of a Ford Fusion, but converted to run on hydrogen
- Can fly for several days at high altitude

QinetiQ Zephyr

- Solar-powered HALE UAV, has made flights of over 3 days

Mars airplane

- The atmosphere of mars is similar to Earth's atmosphere at high altitude. HALE (**High Altitude Long Endurance**) Airplanes like these, especially the Helios, could fly over Mars… if only we could get one there. Many NASA people regularly do studies about what it would take to deliver an airplane to Mars and what we could learn from it. Note: Due to the 20-minute radio delay (speed of light), the airplane would have to be autonomous!

Latest Developments; Spaceplanes

SPACESHIP TWO

SPACEX

X-37

BLUE ORIGIN

Latest Developments; Spaceplanes

SpaceX

- Already successfully launched many satellites to orbit and resupplied the ISS
- Developing reusable rockets that run on jet fuel. This is a BIG DEAL.
- Part of why spaceflight is so expensive is that the rockets are single-use. A 747 may cost half a billion dollars, but a two-way trip by 747 does not cost a billion dollars (split between several hundred passengers), because all you have to pay for is fuel and labor, not the whole airplane (just 1/30,000th of the airplane's cost, if it can fly about 30,000 flights).
- A reusable rocket has to carry a lot of extra fuel, to get it back down on the ground. This gets subtracted from the payload, i.e. you end up with a bigger rocket that can only carry smaller things (or a much bigger rocket to carry the same payload as a smaller one-time-use rocket). But that's ok, because the customer only pays for the fuel, not for the rocket.
- If it becomes far cheaper to get a satellite into orbit, think of the possibilities! Satellite connectivity everywhere. Real-time Google Earth. FedEx intercontinental ballistic shipping?
- After a couple of failed attempts, managed to land a first stage at the end of a satellite launch mission.

SpaceShip Two

- Yes, it crashed, but the program keeps moving forward: a second one was already being built.
- First spacecraft (1) developed with no government funds and (2) being certified to carry commercial passengers.
- Hundreds of people have already paid hefty deposits for a place in line.

Blue Origin:

- Developing a suborbital passenger rocket, like SpaceShipOne/Two but single stage & lands vertically like SpaceX's.

X-37

- Started as DARPA X-40 space maneuvering test vehicle. Only glide-tested in atmosphere.
- X-37 is larger, actually flies into space (on the tip of a disposable launch vehicle), can stay up for over a year, re-enters and glides back autonomously
- No one knows the mission or payload. Could be anything. Spyplane? Bomber? Going up to service old satellites, or to shoot them down? Versatile payload bay and small size means the X-37 could be launched on short-notice (like an ICBM) to go on various kinds of missions, from temporarily standing in for a destroyed/malfunctioning satellite (e.g. military communications satellite, GPS…) to being a space-fighter.

Latest Developments; General Aviation

CIRRUS

SPORTSTAR LSA

BD-5J

HOMEBUILTS:

LANCAIR

“BALLY BOMBER” B-17

HIGH-LANDER

VELOCITY

TITAN MUSTANG

SONG 120 ELECTRIC

Latest Developments; General Aviation

Homebuilts

- Have been fertile ground for aeronautical innovation since the 1950s. Pioneered the use of composites.
- Much more “fun” airplanes than the popular trainers and rentals: aerobatic airplanes, super-efficient canards…
- Currently being built at far greater rates than certified general-aviation airplanes.
- Models include jets, turboprops, twins, electric airplanes, motorgliders, bushplanes, warbird replicas, racers… each of them more “uncompromising” than any certified airplane (because certified airplanes try to please everyone).

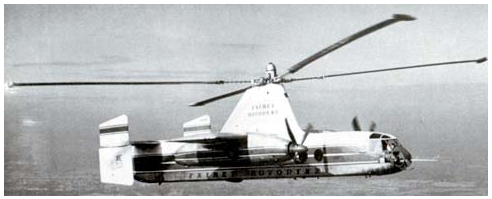
LSAs

- It costs many many millions of dollars to certify even a small single-engine airplane
- FARs contain many specific details about what tests should be run and how, what specific technologies must be in the instruments (gyroscope, magnetic compass…), etc.
- Industry groups got the FAA to approve a far easier certification path for “light sport airplanes” (LSAs), i.e. airplanes with 1-2 seats, 1320 lbs or less, max sustained speed 138mph, VS1 45mph or less, etc. Much simpler requirements (ASTM, not FAR), can be met in any way the designer can imagine and demonstrate. (These regulations were actually implemented by the FAA as a way to regulate “fat ultralights”, two-seaters that had been getting exemptions for Part 103 flight but had a worsening safety record).
- Within a few years of this (2005) there were dozens of new LSA designs. Far more advanced materials, panels, engines, and aerodynamics than conventional FAR 23 airplanes.
- Requirements also lowered for Light Sport pilots: Only 20 hours of training, no medical.
- It was hoped (by the EAA, AOPA…) this would usher in a new era of inexpensive flying that would attract many new pilots. In practice, the lack of medical requirement meant that most Sport pilots were old ex-pilots who had lost their medicals. They tended to have a lot of money… so most LSAs are actually more like a mini Cirrus than a new Piper Cub.

Cirrus

- Designed a couple of four-seaters, the SR20 and SR22. Better design than most single-engine airplanes: All composite, faster-than-average speeds, etc. But not really on a class of their own, comparable to old Mooneys and Bonanzas. However, Cirrus did three things that set them apart.
- One was a luxury interior. All leather, car-like, beautiful panel, super slick. Good autopilot, high-tech instruments… Cirrus knew their customers would be rich and would be turned off by anything less.
- The second was working with BRS to develop an all-airplane ballistic parachute. This had been used in ultralights and some small aerobatic airplanes but not in a four-seater. It makes the airplane feel much safer.
- The third was marketing: Displaying airplanes at luxury car showrooms, ads in the right magazines… Again, targeting the 1% and speaking their language. Cirrus now manufactures more single-engine airplanes than any other company.

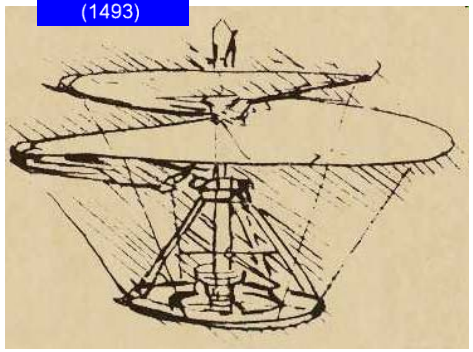
Vertical Take-Off & Landing (VTOL)

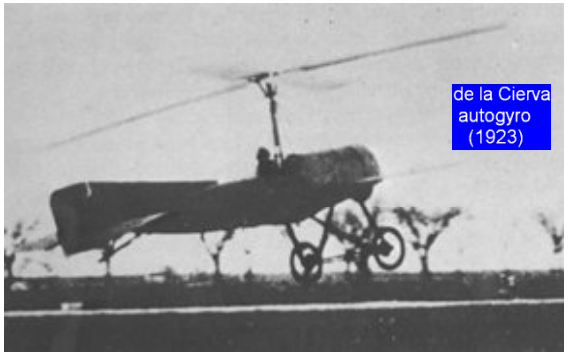


Vertical Take-Off & Landing (VTOL)

- Most people in the aerospace industry (ok, most airplane geeks) know about the Harrier, the Osprey, and the Joint Strike Fighter, which can take off and land vertically like a helicopter, requiring zero runway.
- However, most people do not realize that these three airplanes are just the tiny tip of a huge iceberg. Ever since ~1950, the aircraft manufacturers have been experimenting with "vertical take-off & landing" (VTOL) technologies, i.e. technologies that allow an airplane to hover like a helicopter.
- Unfortunately, most of these technologies require significant hits in useful load. They typically also reduce fuel efficiency, increase cost, and decrease range and reliability. The aircraft are also often difficult to fly, and some cannot operate in high winds or low visibility.
- Despite these obstacles, VTOL experimentation has been happening continuously for decades. While most of it has not impacted the mainstream aviation world, it is an extremely interesting field full of creative solutions and fascinating inventions. (Reading about them when I was a teenager was a big part of what led me to want to become an aeronautical engineer). Let's take a quick tour. (For a video of me presenting this section, see https://vimeo.com/20424855)

VTOL: Helicopters

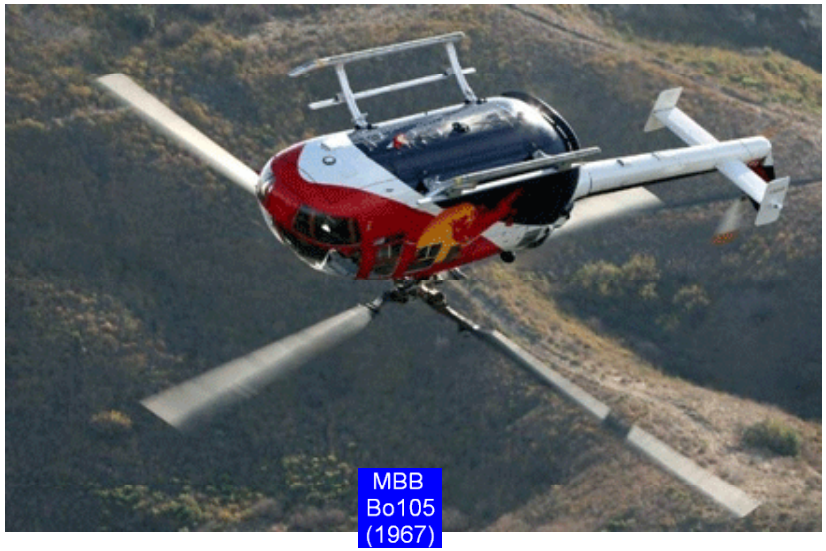

daVinci concept (1493)


de la Cierva autogyro (1923)


Sikorsky VS-300 (1939)

Boeing-Sikorsky RAH-66 (1996)


Sikorsky MH-60 Jayhawk (1974)


MBB Bo105 (1967)

VTOL: Helicopters

Most successful and popular VTOL aircraft type.

Basic Principle:

- Move the wings relative to the rest of the aircraft.
- Air flows over wing (generating lift) even when aircraft is stationary.

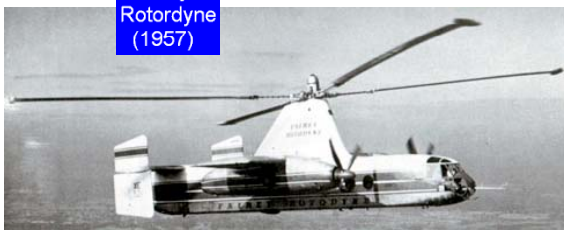
Timeline:

- Idea dates back to Da Vinci (1400s).
- First successful rotorcraft were autogyros/gyrocopters (1920s), have unpowered rotors that windmill when the aircraft moves forward
- First helicopters by Sikorsky (1930s)
- Today we have stealth helicopters, aerobatic ones, unmanned… a big and diverse part of the modern aviation ecosystem

Disadvantages:

- In VTOL mode *all the time*. Must *always* generate more thrust than the aircraft's weight. Consequence: Very high fuel burn, low fuel efficiency.
- Low top speed. The faster it flies, the greater the difference in airspeed between the blade swinging forwards around one side, and the blade swinging aft around the other side. This asymmetry cannot be compensated past a certain speed. (Pure helicopter speed record = ~250mph)

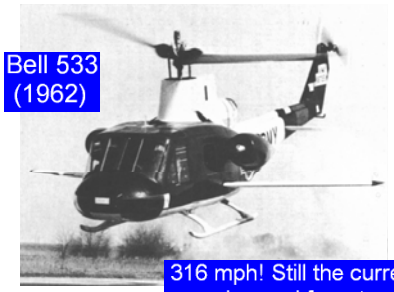
VTOL: RotorWings and Compound Helicopters


Fairey Rotordyne (1957)


Lockheed XH-51 (1962)


The biggest rotorcraft ever! The size of a 737!
Mil V-12 (1968)


Kamov Ka-22 (1959)


Bell 533 (1962)
316 mph! Still the current speed record for rotorcraft


Boeing 347 (1970)


Boeing X-50 (2003)


Lockheed AH-56 (1967)


Sikorsky X-Wing / S-72 (1976)

Sikorsky X2 (2008)

Eurocopter X3 (2010)

VTOL: RotorWings and Compound Helicopters

Basic Principle:

Like helicopters, but better in different ways:

- Have wings so that the rotor does not have to supply all the lift

  and/or

- Have dedicated forward-thrust engines/fans so that the rotor does not have to supply all the thrust

  and/or

- Stop the rotors for forward flight ("rotor-wing", e.g. S-72 and X-50)

VTOL: Tail-Sitters


Focke-Wulf Triebflügel Concept (WW2)


Convair XFY (1954)

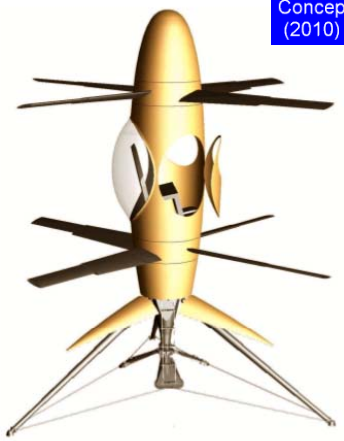
Lockheed XFV (1954)

Ryan X-13 (1955)


SNECMA Coléoptère (1959)


McDD DC-X rocket (1993)


AeroVironment SkyTote UAV (2004)


Tiltplane Concept (2010)

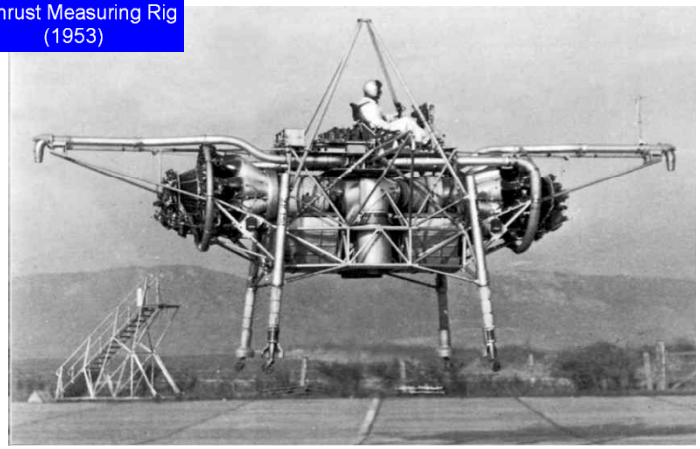
VTOL: Tail-Sitters

Basic Principle:

- Airplane with engine that only produces “forward” thrust (i.e. normal airplane)
- Thrust to weight ratio > 1 … The thrust can overcome weight even without wing lift
- Airplane can fly straight up like a rocket
- Can airplane land onto its tail?
  - Issues: Control system, visibility, structural, ops
  - Final verdict: Impractical.
    Prohibitively hard to land, especially if there is wind.
- Multiple UAVs today are tail-sitters
- DC-X crashed in the 1990s. SpaceX is currently experimenting with tail-sitter rockets (e.g. Grasshopper and 1st-stage Falcon 9)

VTOL: Jet Platforms

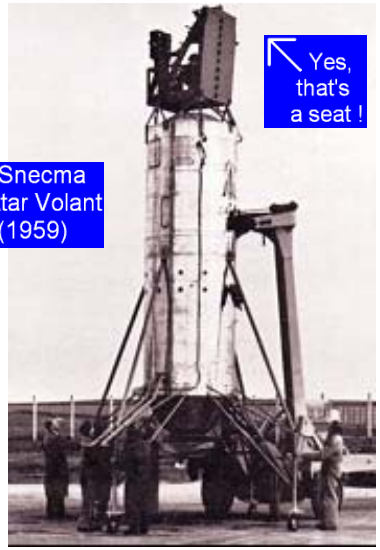
Rolls-Royce
Thrust Measuring Rig
(1953)



RR Avon
testbeds
for X-13
(early 50s)

Bell
Lunar Lander Research Vehicle
(1964)

Look the LLRV up on
YouTube for a
fun video of Neil Armstrong
crashing one !



Yes,
that's
a seat !

Snecma
Atar Volant
(1959)

Vereinigte Flugtechnische Werke
Schwebegestell SG 1262
(1966)

(testbed for
VAK 191 B)

VTOL: Jet Platforms

(a.k.a. “flying bedsteads”)

Basic Principle:

- Early research into using
  sustained vertical jet thrust
  and zero-airspeed Reaction Control Systems
- Not practical for transport;
  Much less fuel-efficient than rotorcraft
- The only non-research application:
  Lunar Lander flying simulator to train Apollo astronauts

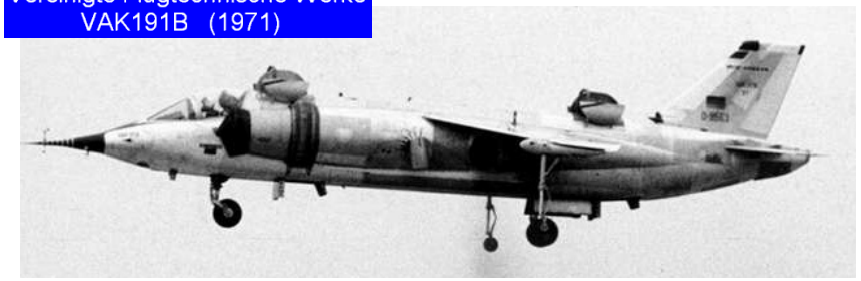
VTOL: Lift Engines

Short SC.1 (1957)

Dassault Balzac (1962), Mirage 3V (1965)

Lockheed XV-4 (1962)

Vereinigte Flugtechnische Werke VAK191B (1971)



The only one of these to go into production, flown by Russian Navy

Yakovlev Yak38 (1971)

Yakovlev Yak141 (1987)

VTOL: Lift Engines

Basic Principle:

- Combination of normal airplane and jet platform
- Cruise engines mounted horizontally for normal flight, and additional lift engines mounted vertically for VTOL
- Big problem #1: Carrying big lift engines around during cruise is detrimental to payload capacity!
- Big problem #2: Engine failure = hull loss ☹ (redundancy is impractical, so you need all of the multiple engines to work all the time)

VTOL: Thrust Vectoring

Yakovlev Yak36 (1963)

Bell X-14 (1957)

Hawker P.1127 (1960)

The only one of these to go into production

BAE / McDD Harrier (1969)

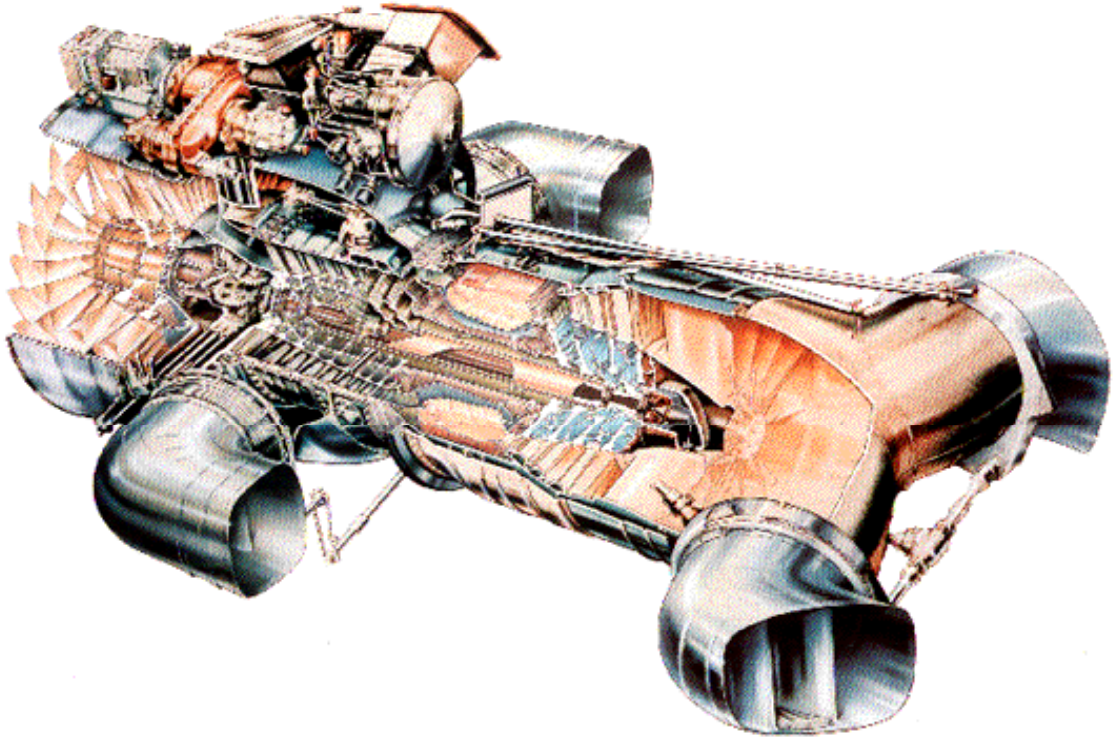
Boeing X-32 (2000)

Boeing's failed entry to the Joint Strike Fighter competition (lost to Lockheed's X-35/F-35)

VTOL: Thrust Vectoring

Basic Principle:

- Engine exhaust can point aft for cruise flight or downwards for VTOL
- Not much extra weight for VTOL capability.
- Only disadvantage is non-optimal nozzle.



VTOL: Tilt-Rotors, Tilt-Wings, Tilt-Fans, Tilt-Engines


Transcendental 1G (1954)


Bell XV-3 (1955)


Curtiss X-100 (1959)


Curtiss X-19 (1963)


Vertol VZ-2 (1957)


Hiller X-18 (1959)


Canadair CL-84 (1965)


Hiller-Ryan XC-142 (1964)


Nord 500 (1968)


Doak VZ-4 (1957)


Bell X-22 (1966)


EntWicklungsRing VJ 101 (1963)


Bell 65 (1965)


Bell XV-15 (1977)


The only one of these to go into production

Bell-Boeing V-22 (1989)


Bell 609 (2003)

VTOL: Tilt-Rotors, Tilt-Wings, Tilt-Fans, Tilt-Engines

Basic Principle:

- Instead of just tilting the nozzle of a jet engine when you want vertical thrust, you can tilt…
  - the rotor or fan of a rotorcraft
  - the whole engine
  - the whole wing
- Rotors/Fans are already an inherent zero-speed control system (no need for RCS).
- More fuel-efficient in hover than a VTOL jet…

  … but more complex

VTOL: Lift Fans


Vanguard Omniplane (1959)


Ryan XV-5 (1964)


Lockheed X-35B / F-35B (2000)


The only one of these to go into production


XTi TriFan 600

VTOL: Lift Fans

Basic Principle:

- Fans embedded in airframe for VTOL.
  Requires some extra volume but little extra weight.
- Can be powered by main engine shaft
  (more reliable and less heavy than lift engines)
- Airplane can have nozzle optimized for forward flight, or vectorable to help fan.
- Transition from “engine generating thrust for forward flight” and “engine shaft powering the fans” is tricky (especially after VTO) but doable

VTOL: Personal Platforms

DeLackner HZ-1 (1954)

HILLER VZ-1 (1955)

Bell Rocket Belt (1961)

Williams X-Jet (1985)

Williams Jet Belt (1969)

Gennai Yanagisawa (1998)

Franz Schoffmann (2002)

SoloTrek XFV (2001)

NASA Puffin concept (2010)

VTOL: Personal Platforms

Basic Principle:

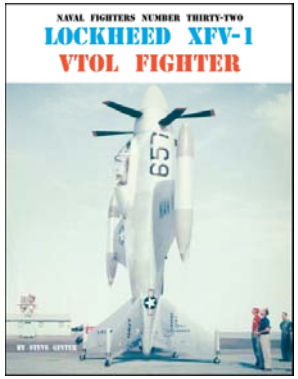
- Small vertical-only source of thrust
- Payload = 1 person
  - Allows for small, simple machine
- Can be a rocket, a ducted fan, a personal helicopter, etc

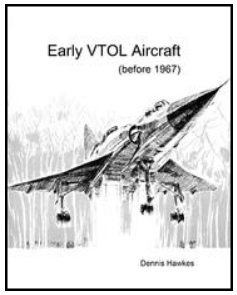
Lots of military research in the 50s. But range is prohibitively short.

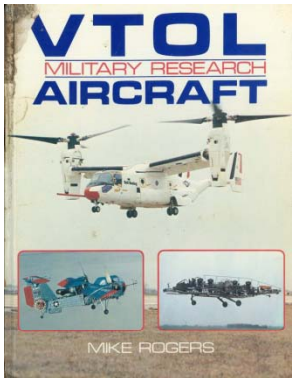
Today, you can buy (or build) a rocket belt or personal helicopter!
Many people do.

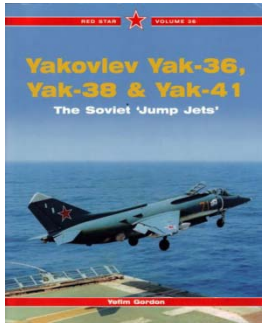
For more info on VTOL…

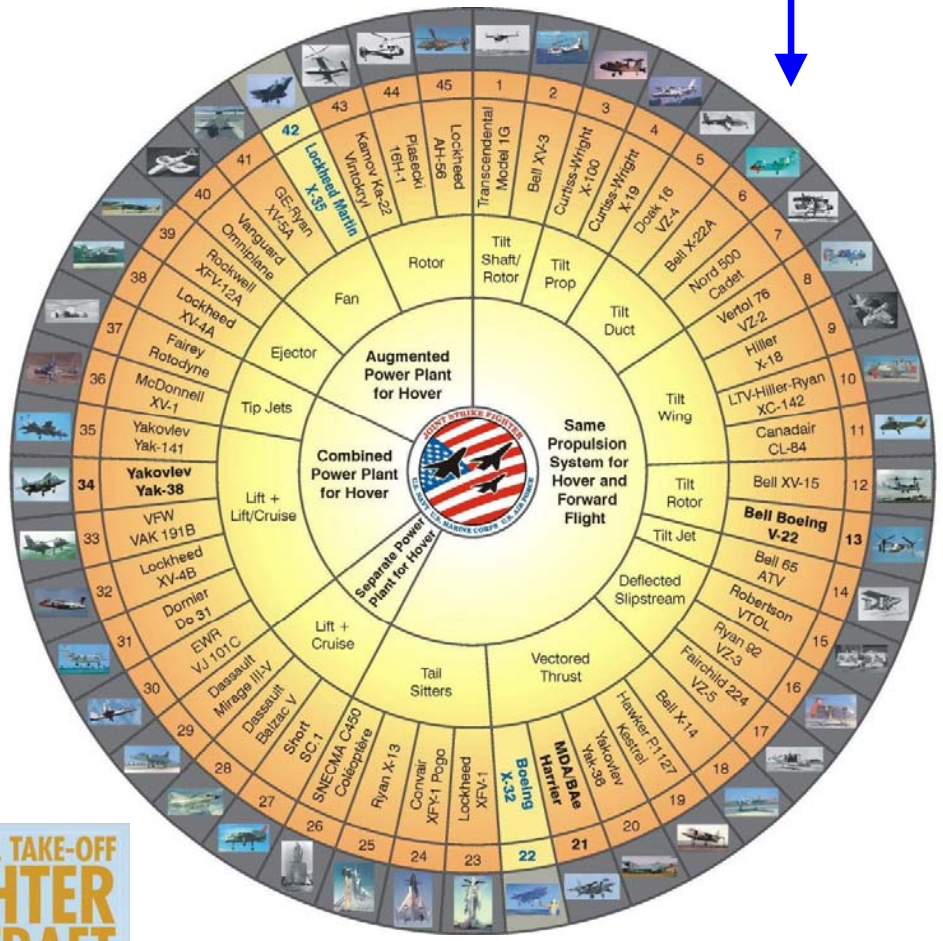
VSTOL.org

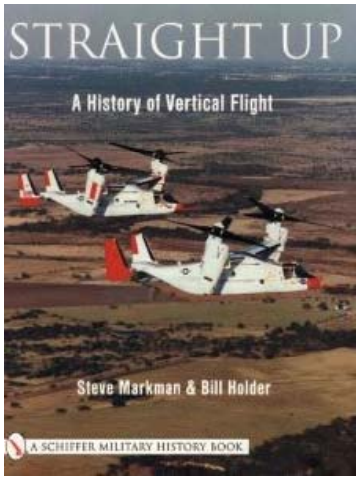


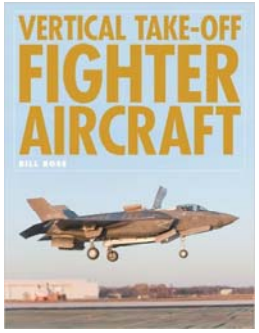












Just one vacation picture in this slideshow…

Me at the Russian military aviation museum in Monino
with the three Yakovlev VTOL prototypes
(which I had read about since I was a little kid):

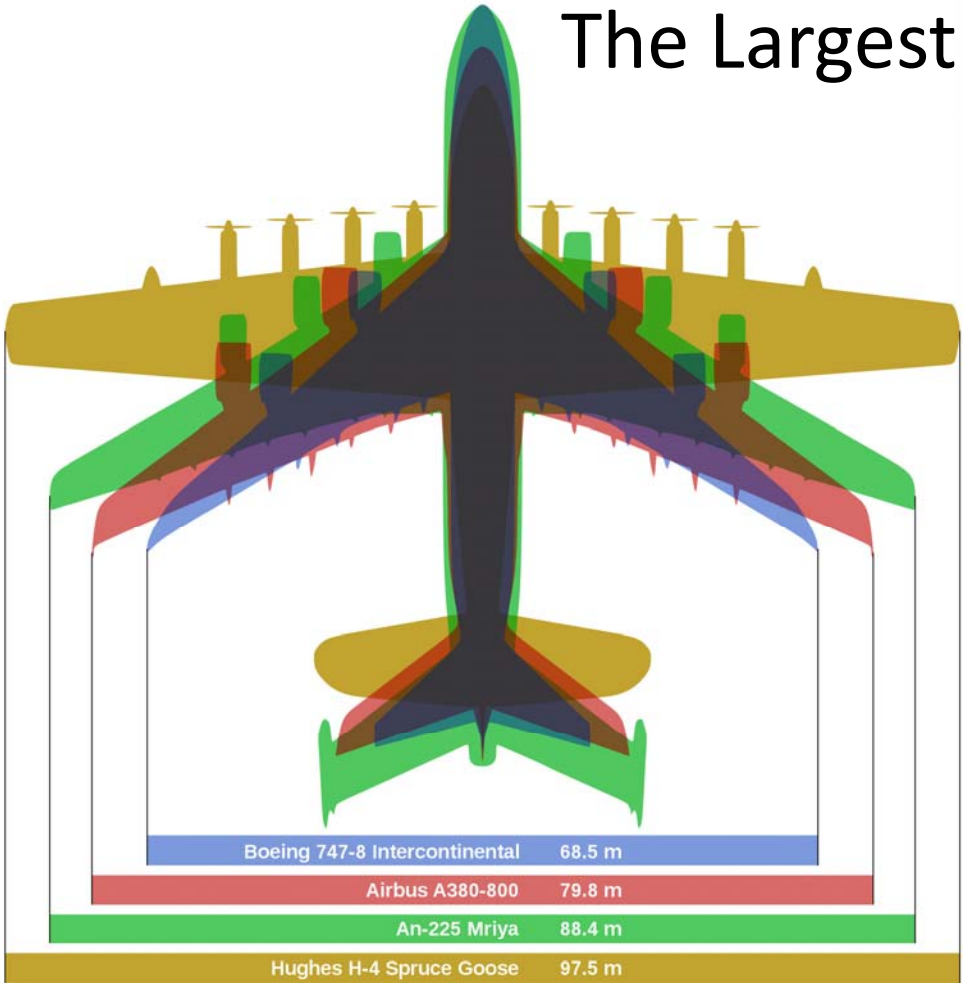
Yak-36 Yak-38 Yak-141

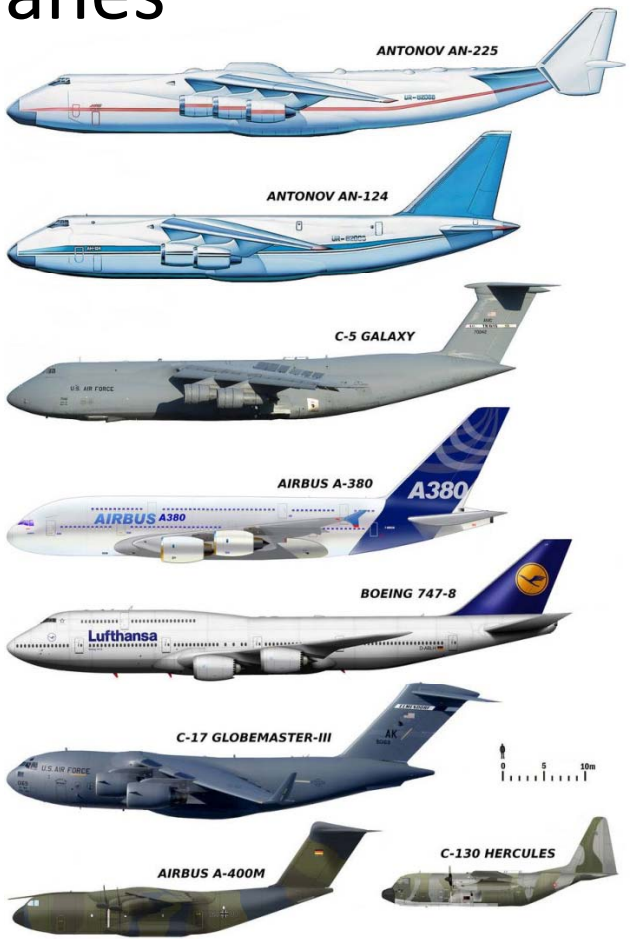
Record-Breaking Airplanes

Record-Breaking Airplanes

- Since the pre-history of aviation, many projects have been motivated by being “the first”, “the largest”, “the fastest”, “the highest”.
- Some records were broken incidentally in the pursuits of other capabilities. (The missions of the X-15 and SR-71 required them to be the fastest and highest-flying airplanes ever. In the case of the F-104, it was an accidental side-effect of developing a fighter with good climbing ability and low supersonic drag. The Helios altitude record was also not an intentional part of the design).
- Many people with a budding interest in aviation will naturally want to know just how high and how fast airplanes can go, and the exciting stories behind these extreme machines and the people who designed and flew them.

The Largest Airplanes





Model:	C-5	747-8	A380	An-124	An-225	Spruce Goose
Length:	247 ft	250 ft	239 ft	226 ft	275 ft	218 Ft
Wingspan:	223 ft	225 ft	262 ft	240 ft	290 ft	320 ft
MTOW:	840 K lbs	987 K lbs	1268 K lbs	893 K lbs	1411 K lbs	400 K lbs
Payload:	270 K lbs	308 K lbs	197 K lbs	330 K lbs	560 K lbs	<150 K lbs

The Largest Airplanes

- Howard Hughes' massive 1945 seaplane, which he called the H-4 Hercules (and the rest of the world calls the "Spruce Goose") is still today the largest airplane ever flown, by measure of wingspan. It only flew once.
- Lockheed's C-5 was the world's largest operational airplane for decades (starting in 1968). It is still the world's largest military airplane.
- Boeing's 747 was the largest airliner for decades. The original 747 was only a little smaller than the C-5 (and the 747-8 is only a little bigger).
- The Antonov 124, which first flew in the 1980s, was designed by the Soviet Union to slightly exceed the C-5's specs.
- The Airbus A380, which first flew in 2005, has the largest wingspan and max weight of any commercial airplane, but does not have a very high payload.
- The Antonov 225 was built to ferry the soviet space shuttle Buran. Only one has ever flown, but it still in commercial service carrying oversize payloads. It is the largest airplane in the world by most reasonable criteria.
- Scaled Composites is currently building the Stratolaunch carrier, a mothership to carry spacecraft launch vehicles. It will have a greater wingspan than the Spruce Goose.

The Smallest Airplanes

SKY BABY

BABY BIRD

BUMBLE BEE

CRI CRI

BD-5J

The Smallest Airplanes

- Donald Stits (son of famous airplane designer Ray Stits) and Robert Starr built and flew the Sky Baby in 1952. It was then the world's smallest airplane.
- Stits got most of the credit/press, leading Starr to design and build the Bumble Bee, which took the record in 1984.
- Less than a year later, Stits tried taking the record back by designing an even smaller airplane, the Baby Bird. Starr tried taking it back again by building an even smaller airplane, the Bumble Bee 2, in 1988… which crashed, nearly killing him. In retrospect, all these tiny airplanes were very short-coupled (control surfaces very close to the center of gravity), making them very difficult to fly. The Guiness Book determined that this record was overly dangerous to pursue further, and deemed the Bumble Bee 2 "the world's smallest biplane" and the Baby Bird "the world's smallest monoplane" to discourage their creators from continuing to compete for a single prize.
- The world's smallest jet is Jim Bede's BD-5J, a kitplane. Many are flying, and some are still being built. FLS Microjet in Oregon offers the latest version.
- The world's smallest twin is the Cri Cri, created by Michel Colomban in France. It was developed to be inexpensive to build and operate, fun and easy and safe to fly: aerobatic, slow, two engines. The record was a side-benefit. Many are flying, some still being built. A few have been converted to jet power and one is electric!

The Fastest Airplanes


BLACKBIRD


CONCORDE

X-15


X-43


F-104

MiG-25

The Fastest Airplanes

- The official airspeed record is held by the Lockheed SR-71 Blackbird. It is the only manned aircraft capable of exceeding 2000 mph (Mach 3.5), and the only airplane capable of cruising at anywhere near such speeds.
- The X-15 could exceed 4500 mph (Mach 6.7). However, it could not take off on its own, and had to be dropped from a mothership. Therefore, the record is unofficial.
- The F-104 remains the only aircraft to have been flown faster than 1000 mph at low altitude. The flight was done by Lockheed test pilot Darryl Greenamyer in an F-104 he built out of parts he had collected.
  (Three years later, the airplane was lost when the landing gear failed after an attempt at an altitude record. Greenamyer ejected safely).
- The X-43 UAV reached 6600 mph (Mach 9.7). However, like the X-15, the record is unofficial because the airplane needed a mothership, and also a booster rocket which was subsequently dropped. The scramjet engine in the X-43 could only be operated for 11 seconds (enough time for the airplane to cover ~15 miles).
- The Concorde was the world's fastest commercial airplane,
  and the MiG-25 is the fastest armed airplane.

The Highest-Flying Airplanes

BLACKBIRD

HELIOS

PERLAN 2

NF-104

X-15

SPACE SHIP ONE

The Highest-Flying Airplanes

- The Blackbird held the world altitude record(90,000 feet) for about 40 years…
- … until the unmanned, solar-powered Helios climbed to 97,000 feet.
- The Blackbird's manned altitude record may soon be stolen by the Perlan 2 glider. (The original Perlan was flown by Steve Fosset to the current glider altitude record).
- Other airplanes have flown even higher, such as the X-43 to 110,000 feet and the NF-104 (an F-104 with an added rocket engine, used to train astronauts) to 120,000 feet. However, these were "zoom" flights: The airplanes could not sustain flight at those altitudes for more than several seconds.
- The ultimate "zoom flights" were those performed by the X-15 (354,000 feet) and since exceeded by SpaceShip One (367,000 feet). However, these too were unofficial due to requiring a mothership.
- Due to the low air density at an altitude of about 100km (328K feet), the speed required to sustain aerodynamic lift roughly matches the speed required for orbit. This is known as the Kármán Line and is generally agreed upon as the "edge of space": To fly any higher, orbiting is easier than using lift. SpaceShip One and X-15 pilots who exceeded this altitude earned astronaut wings from NASA.
- Of course, space rockets fly even higher, but these too are unofficial records because they cannot take off from a conventional runway and most of the craft is jettisoned before the end of the mission.

The Farthest-Flying Airplanes

"Lucky Lady" B-50

Cessna 172 modified for endurance record flight, refuels from truck

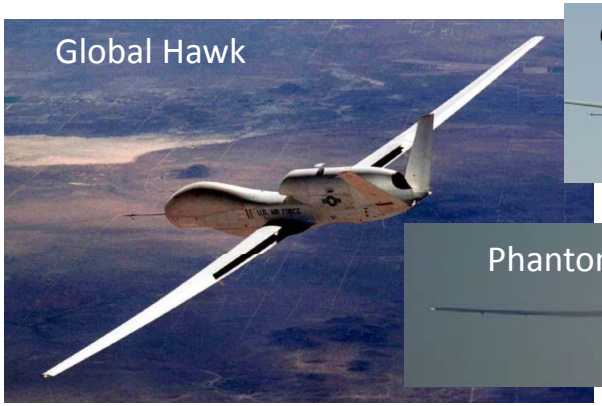
Voyager

Global Flyer

The Farthest-Flying Airplanes

- Development of bombers throughout the 20th century – including World War I, World War II, and the Cold War – encouraged manufacturers to work on technologies allowing for long range flight. The B-36 could fly for 10,000 miles (40 hours!) unrefueled. In-flight refueling was developed for the same purpose.
- In 1949, a USAF B-50 "Lucky Lady" was flown all the way around the world non-stop, taking 94 hours. The record was unofficial because it used in-flight refueling. In 1957, three B-52s replicated the feat, in only 45 hours. In 1995, four B-1s did it in 36 hours.
- Burt Rutan's Voyager, flown by Dick Rutan and Jeanna Yeager, became the first airplane to fly around the world unrefueled, in 1986. The flight took 9 days.
- Rutan's Global Flyer was flown by Steve Fosset all the way around the world in 2 days 19 hours in 2005, becoming the first jet and the first solo airplane to circumnavigate the globe unrefueled. It was then flown from the US around the world and on to England for a record distance of 25,766 miles.
- Various HALE and solar-powered aircraft are being developed that might possibly beat these distance records. However, they fly so slowly that it would take weeks to fly around the world. Even the Solar Impulse will make multiple stops during its months-long flight around the world.
- The longest non-stop commercial flights in the world are about 8500 miles and take a little under 17 hours. These are typically flown in A340-500s / -600s, 777-200LRs /-300ERs, A380s, or 747s. Of these airplanes, the 777-200LR and A340-500HGW have the longest range, but no commercial flights currently make use of the unique twenty-hour endurance of these two airliner models. (And it's no wonder…)
- The longest-endurance flight (would also have been the longest-range flight, if the 150,000 miles had not been flown in circles) took place from December 1958 to February 1959. Robert Timm and John Cook modified a Cessna 172 so that engine oil could be replenished in flight, and added a belly tank that could be refueled while flying over a truck on a highway. They flew around Las Vegas for 64 days without landing!

The Most Efficient Airplanes



The Most Efficient Airplanes

- Fuel efficiency was not as important for most of the 20th century as it is today.
- The 747 was the start of a new era of fuel-efficient airliners: Less fuel burn means cheaper tickets, which means more travelers. Since then, each new airliner gets more seat-miles-per-gallon than the previous.
- As with cars, it was only in the 1970s that society realized that fossil fuels are in limited supply & should not be wasted.
- NASA made funding available in the 1970s for airplane manufacturers to explore high-efficiency technologies: ACEE (aircraft energy efficiency). The result: Winglets, wider turbofans (including on smaller airplanes), and the first uses of composite materials on primary structure in commercial airplanes. Modern airliners all fly with technologies that resulted from this.
- Paul MacCready, a glider pilot, was always fascinated with low-power flight and high efficiency. His motto was "doing more with less". He pioneered human-powered flying and solar-powered flying. (Also worked on the EV-1 electric car that GM "killed", and on projects such as solar car races and speed-record bicycles). His company, AeroVironment, created the Helios and still makes fuel-cell-powered UAVs that can fly for days.
- HALE – high-altitude long-endurance – is now an entire class of aircraft, including the Global Hawk and Predator UAVs, and prototypes such as the QinetiQ Zephyr, the Boeing Condor and Phantom Eye, and the AeroVironment Helios and Global Observer. These can fly for at least a day, some for a few days, holding various endurance records. The Boeing A160/MQ-18 is the first helicopter with this kind of capability. The Solar Impulse is also in this category, capable of flying for over five days (theoretically indefinitely, limited by the pilot).
- In 1980, the CAFE (comparative aircraft flight efficiency) foundation was created to encourage the development of high-efficiency technologies in recreational flying. They held a 400-mile "race" every year until 1990 for airplanes to compete not just on speed but on speed times MPG times payload. In other words, a winning airplane must be both efficient and have practical speed and load-carrying capabilities. More recently, CAFE and NASA have organized the Green Flight Challenge: The airplane must fly 200 miles in under 2 hours, using less than one gallon of fuel per occupant. CAFE now organizes symposia and competitions for electric airplanes, trying to encourage the development of technologies to make them more practical. Along with Google, it sponsors a 1.35 million dollar prize for a four-seat electric aircraft to fly 200 miles. Pipistrel has been winning many of the latest CAFE competitions and prizes, including CAFÉ Green Flight with their ***Pipistrel G4***.
- Burt Rutan is another "superstar" of airplane efficiency. He set out to make airplanes that are fast, safe, easy to build, and cheap to own, so he designs them small, uses a canard configuration and composite construction, and incorporates a unique mix of efficient glider-like features with high-speed streamlined curves. His designs' efficiency was unparalleled until recently, and dominated the 1980s CAFE competitions: ***EZ*** (2-seater, almost 200mph on ~100hp, ~40MPG), ***Quickie*** (1-seater, only 18hp, 70-100 MPG. More HP gives ~200mph), ***Cozy*** (four-seater, almost 200mph on 160hp, ~20MPG), ***Catbird*** (five seater, well over 200 mph on 180hp, ~20MPG), and ***Boomerang*** (only 13 to 17 MPG, but: five seats, can go almost 3000 miles at ~300mph) – not to mention, of course, the Voyager and Global Flyer distance-record airplanes, the Beech Starship and Triumph executive transports, the Solitaire motor-glider, the Proteus and White Knight, and many UAVs.
- Only recently are competitors catching up, such as the ***Pipistrel Panthera*** (four seater, ~200mph at ~20MPG) and various LSAs (two-seaters, ~138mph at ~40MPG. The ***Pipistrel Virus*** cruises at 46 MPG).