

Types of Aircraft Takeoff and Landing Phases

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Chapter- 1

Takeoff



An F/A-18 Hornet takes off from the USS Kitty Hawk (CV-63).



An EasyJet Airbus A319 takes off.

Takeoff is the phase of flight in which an aircraft goes through a transition from moving along the ground (taxiing) to flying in the air, usually starting on a runway. For balloons, helicopters and some specialized fixed-wing aircraft (VTOL aircraft such as the Harrier), no runway is needed. Takeoff is the opposite of landing.



Takeoff of the Shuttle Carrier Aircraft carrying the Space Shuttle Enterprise

Power settings



A hot air balloon takes off from Royal Victoria Park, Bath, England.

For light aircraft, usually full power is used during takeoff. Large transport category (airliner) aircraft may use a reduced power for takeoff, where less than full power is applied in order to prolong engine life, reduce maintenance costs and reduce noise emissions. In some emergency cases, the power used can then be increased to increase the aircraft's performance. Before takeoff, the engines, particularly piston engines, are routinely run up at high power to check for engine-related problems. The aircraft is

permitted to accelerate to rotation speed (often referred to as V_r). The term *rotation* is used because the aircraft pivots around the axis of its main landing gear while still on the ground, usually because of manipulation of the flight controls to make this change in aircraft attitude.

The nose is raised to a nominal 5° – 15° nose up pitch attitude to increase lift from the wings and effect liftoff. For most aircraft, attempting a takeoff without a pitch-up would require cruise speeds while still on the runway.

Fixed-wing aircraft designed for high-speed operation (such as commercial jet aircraft) have difficulty generating enough lift at the low speeds encountered during takeoff. These are therefore fitted with high-lift devices, often including slats and usually flaps, which increase the camber of the wing, making it more effective at low speed, thus creating more lift. These are deployed from the wing before takeoff, and retracted during the climb. They can also be deployed at other times, such as before landing.

The speeds needed for takeoff are relative to the motion of the air (indicated airspeed). A headwind will reduce the ground speed needed for takeoff, as there is a greater flow of air over the wings. Typical takeoff air speeds for jetliners are in the 130–155 knot range (150–180 mph, 240–285 km/h). Light aircraft, such as a Cessna 150, take off at around 55 knots (63 mph, 100 km/h). Ultralights have even lower takeoff speeds. For a given aircraft, the takeoff speed is usually directly proportional to the aircraft weight; the heavier the weight, the greater the speed needed. Some aircraft specifically designed for short takeoff and landing can take off at speeds below 40 knots (74 km/h), and can even become airborne from a standing start when pointed into a sufficiently strong wind.



Virgin Atlantic Boeing 747-400 takes off from Manchester Airport, England.

Speed required

The takeoff speed required varies with air density, aircraft gross weight, and aircraft configuration (flap and/or slat position, as applicable). Air density is affected by factors such as field elevation and air temperature. This relationship between temperature, altitude, and air density can be expressed as a density altitude, or the altitude in the International Standard Atmosphere at which the air density would be equal to the actual air density.

Operations with transport category aircraft employ the concept of the takeoff V-Speeds, V_1 , V_R and V_2 . These speeds are determined not only by the above factors affecting takeoff performance, but also by the length and slope of the runway and any peculiar conditions, such as obstacles off the end of the runway. Below V_1 , in case of critical failures, the takeoff should be aborted; above V_1 the pilot continues the takeoff and returns for landing. After the co-pilot calls V_1 , he/she will call V_r or "rotate," marking speed at which to rotate the aircraft. The V_R for transport category aircraft is calculated such as to allow the aircraft to reach the regulatory screen height at V_2 with one engine failed. Then, V_2 (the safe takeoff speed) is called. This speed must be maintained after an engine failure to meet performance targets for rate of climb and angle of climb.



The Airbus A380 at takeoff. The main and nose undercarriage doors have not yet retracted.

In a single-engine or light twin-engine aircraft, the pilot calculates the length of runway required to take off and clear any obstacles, to ensure sufficient runway to use for takeoff. A safety margin can be added to provide the option to stop on the runway in case of a rejected takeoff. In most such aircraft, any engine failure results in a rejected takeoff as a matter of course, since even overrunning the end of the runway is preferable to lifting off with insufficient power to maintain flight.

If an obstacle needs to be cleared, the pilot climbs at the speed for maximum climb angle (V_x), which results in the greatest altitude gain per unit of horizontal distance travelled. If no obstacle needs to be cleared, or after an obstacle is cleared, the pilot can accelerate to the best rate of climb speed (V_y), where the aircraft will gain the most altitude in the least amount of time. Generally speaking, V_x is a lower speed than V_y , and requires a higher pitch attitude to achieve.



Beechcraft 1900 lifting off from Nelson Airport in New Zealand.

Gliders

Gliders use several launch methods, but the most common is winch-launching or towing behind a light aircraft. Hang gliders can be towed and like paragliders can use winches but are also often foot-launched from a hill.

Chapter- 2

Assisted Takeoff and Balanced Field Takeoff

Assisted Takeoff



Tow line and towing aircraft seen from the cockpit of a glider.

Assisted take off is any system for helping aircraft into the air (as opposed to strictly under its own power). The reason it might be needed is due to the aircraft's weight exceeding the normal maximum take off weight, insufficient power, or the available

runway length may be insufficient, or a combination of all three factors. Assisted take off is also required for gliders, which do not have an engine and are unable to take off by themselves.

Catapults (CATO)



F/A-18 attached to steam catapult preparatory to launch. Note shuttle attached in front of the nose wheel gear and red hold-back bar designed to release at a specified pressure.

A well-known type of assisted take off is that using the aircraft catapult. In modern systems fitted on aircraft carriers, a piston, known as a *shuttle*, is propelled down a long cylinder under steam pressure. The aircraft is attached to the shuttle using a tow bar or launch bar mounted to the nose landing gear (an older system used a steel cable called a catapult bridle; the forward ramps on older carrier bows were used to catch these cables), and is flung off the deck at about 15 knots above minimum flying speed, achieved by the catapult in a 4 second run.

The United States is replacing carrier steam catapults with linear induction motors. The system is called the Electromagnetic Aircraft Launch System (EMALS). An electromagnetic wave travelling through the motor propels the armature along its length, pulling the plane with it. With this system, it will be possible to match launch power and aircraft weight more closely than with the steam system, causing less wear on the aircraft.

The catapult approach is also used for towing gliders into the air. This can be accomplished using an elastic bungee cord arrangement, or more commonly using a cable wound onto a winch, powered by a large diesel engine. The bungee approach is rarely used for man-carrying gliders, as the acceleration is uncontrolled and can yield very high G-forces. It is commonly used to launch model gliders however. Manned gliders are commonly launched simply by towing them aloft behind a powered aircraft.



Photo showing the NMUSAF B-36's starboard pair of J 47 turbojets.

JATO and RATO

JATO stands for 'Jet-assisted take off' (and the similar **RATO** for 'Rocket-assisted take off'). In the **JATO** and **RATO** systems, additional engines are mounted on the airframe which are used only during take off. After that the engines are usually jettisoned, or else they just add to the parasitic weight and drag of the aircraft. However some aircraft such as the Avro Shackleton MR.3 Phase 2, had permanently attached **JATO** engines. The four J-47 turbojet engines on the B-36 were not considered **JATO** systems; they were an integral part of the aircraft's powerplants, and were used during takeoff, climb, and cruise at altitude.

During WW2 the German Arado 234 and the Messerschmitt 323 "Gigant" used rocket units beneath the wings for assisted take off. Such systems were popular during the 1950s, when heavy bombers started to require two or more miles of runways to take off fully laden. This was exacerbated by the relatively low power available from jet engines at the time - for example the B-52 Stratofortress required 8 turbojet engines to yield the required performance, and still needed RATO for very heavy payloads (a proposed update of the B-52 replaces these with half the number of much more powerful engines).



A rocket assisted Boeing B-47B take off.

In a Cold War context, RATO and JATO bottles were seen as a way for fighter aircraft to utilize the undamaged sections of runways of airfields which had been attacked.

Gravity assistance

Early pioneers in powered and unpowered flight used gravity to accelerate their aircraft to a speed which allowed its wings to generate enough lift to achieve independent flight. These included attempts to achieve flight from towers, city walls and cliffs. Generally more successful were attempts in which speed was built up by accelerating down hill and mountain slopes, sometimes on rails or ramps.

Carrier aircraft

Probably the ultimate form of gravity assistance is when an aircraft is released from a larger mother ship or mother craft. This may be because the daughter craft is incapable of taking off normally e.g. the atmospheric flight tests of the Space Shuttle.



A X-15 pictured just after release by a B-52 carrier aircraft.

Usually the rationale for such a system is to free the daughter craft from the need to climb to its release height on its own devices. This allows the daughter craft to be designed with fewer weight and aerodynamic restrictions allowing for exotic configurations to be used or tested, for example the recent SpaceShipOne, and previously the Bell X-1 and other X-planes.

In the interwar years in order to achieve long ranges with the technology of the time, trials were undertaken with float planes piggy backed atop flying boats. With the float plane carried part of the way to its destination and freed from having to use any of its own fuel in the initial climb these combinations could deliver light but time critical cargos faster and farther than a single individual aircraft.

Hot air balloons have acted as "motherships" to hang gliders and para gliders in altitude and distance record attempts.

"Jet Donkeys"

An unusual assisted take off scheme was partially developed during the 1950s which consisted of a jet powered truck or dolly which ran either on rubber tires or rails, used to push a heavy aircraft into the air. Once airborne, the dolly would instantly detach. Because the dolly did not need to fly itself, it was not constrained by the need for low weight, and so could be fitted with very large and powerful engines. The system only reached the early stages of development. The same company was also drawing up plans for a flyable version of the dolly launch system, which it called "jet donkeys". The idea was that a small powerful secondary aircraft could push the heavy main aircraft into the air, detach in flight and return to the airfield to be reused. Sketches of the proposed system show a strange canard-layout aircraft with its cockpit in the tail, pushing the main aircraft via a long extended nose. The system was never developed, it was not long before the further development of the jet engine meant that most of these assisted take off schemes became unnecessary.

Balanced field takeoff

A **balanced field takeoff** is a condition where the accelerate-stop distance required (ASDR) is equal to the takeoff distance required (TODR) for the aircraft weight, engine thrust, aircraft configuration and runway condition. For a given aircraft weight, engine thrust, aircraft configuration and runway condition the shortest runway length that complies with safety regulations is the *balanced field length*.

The takeoff decision speed V_1 , or critical engine-failure recognition speed (V_{cef}), is the fastest speed at which the pilot can decide to reject the takeoff. At speeds below V_1/V_{cef} the aircraft may be brought to a halt before the end of the runway. Above V_1/V_{cef} the pilot must continue the takeoff even if an emergency is recognized.

To achieve a balanced field takeoff, engine power is selected to provide enough acceleration so that at the lowest possible speed to continue the takeoff the remaining necessary takeoff distance with one engine not working is equal to the remaining & necessary accelerate-stop distance.

The **balanced field length** is the shortest field length at which a balanced field takeoff can be performed.

Factors affecting the balanced field length include:

- the mass of the aircraft - higher mass results in slower acceleration and higher takeoff speed

- engine thrust - effected by temperature and air pressure but reduced thrust can also be deliberately selected by the pilot
- density altitude - reduced air pressure or increased temperature increases minimum take off speed
- aircraft configuration such as wing flap position
- runway slope and runway wind component
- runway conditions - a rough or soft field slows acceleration, a wet or icy field reduces braking

Regulatory Background

Aviation regulations, especially FAR 25 and CS-25 (for large passenger aircraft) require the takeoff distance and the accelerate-stop distance to be less than or equal to the available runway length, both with and without an engine failure assumed. The speed below which takeoff must be aborted upon engine failure is called V_1 . On longer runways a pilot can nominate a V_1 within a range, but where the runway length is no longer than the **balanced field length** only one value for V_1 will exist.

Landing and Takeoff Performance Monitoring Systems are devices aimed at providing to the pilot information on the validity of the performance computation, and averting runway overruns that occur in situations not adequately addressed by the takeoff V-speeds concept.

Using the balanced field takeoff concept, V_1 is the maximum speed in the takeoff at which the pilot must take the first action (e.g. reduce thrust, apply brakes, deploy speed brakes) to stop the airplane within the accelerate-stop distance and the minimum speed at which the takeoff can be continued and achieve the required height above the takeoff surface within the takeoff distance.

Chapter- 3

JATO



America's first "rocket-assisted" take-off, an ERCO Ercoupe fitted with a GALCIT booster, in 1941, performed at March Field, California.

JATO is an acronym for **jet-fuel assisted take off**. It is a system for helping overloaded aircraft into the air by providing additional thrust in the form of small rockets.

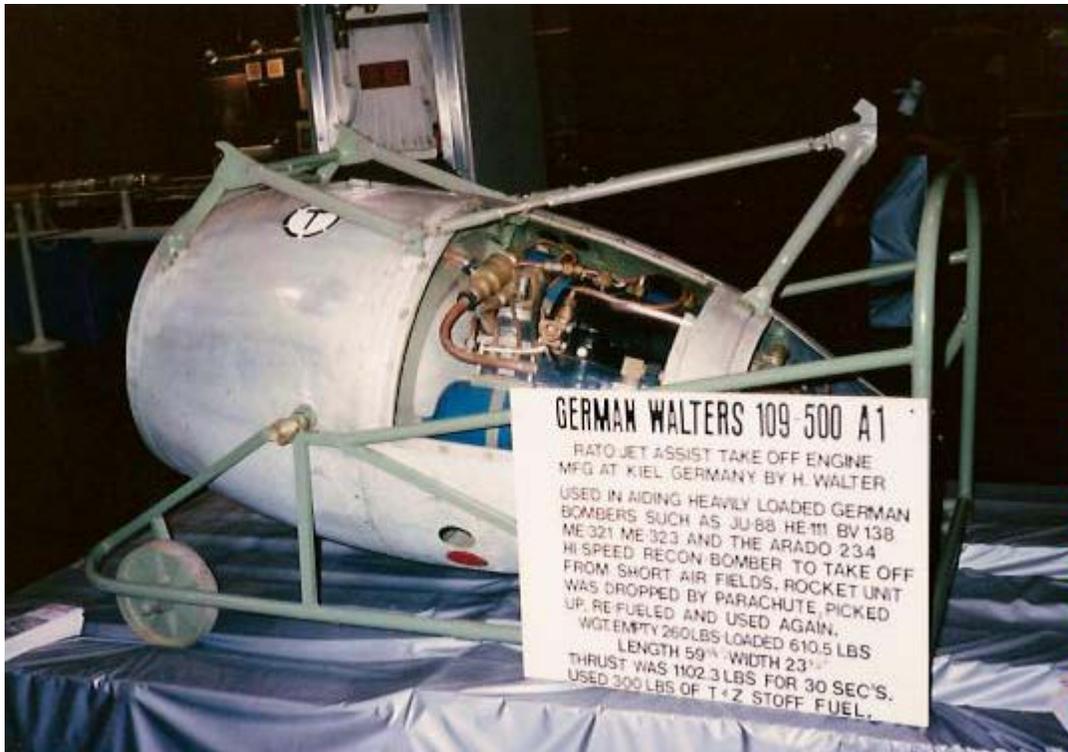
The term is used interchangeably with the (more specific) term **RATO**, for *Rocket-Assisted Take Off* (or in RAF parlance **RATOG** for *Rocket-Assisted Take Off Gear*).



A Lockheed P-2 Neptune launches with "Jet-assisted take-off (JATO)" from the aircraft carrier USS Franklin D. Roosevelt (CV-42), 2 July 1951.

Early experiments and World War II

Early experiments using rockets to boost gliders into the air were conducted in Germany in the 1920s (Lippisch Ente), and later both the Royal Air Force and the Luftwaffe introduced such systems in World War II. The British system used fairly large solid fuel rockets to shoot planes (typically the Hawker Hurricane) off a small ramp fitted to the fronts of merchant ships, known in service as Catapult armed merchantment (or CAM Ships), in order to provide some cover against German reconnaissance planes. After firing, the rocket was released from the back of the plane to fall into the water and sink. The task done, the pilot would fly to friendly territory if possible or parachute from the plane, hopefully to be picked up by one of the escort vessels. Over two years the system was only employed nine times to attack German aircraft with 8 kills recorded for the loss of a single pilot.



A German Walter liquid-fueled RATO pod

The *Luftwaffe* also used the technique in order to help their small bombers, and the enormous *Gigant*, Messerschmitt Me 321 glider, conceived in 1940 for the invasion of Britain, and used to supply the Russian front which also had air tow assistance from up to three bombers, into the air with loads that would have made the takeoff run too long otherwise. This became especially important late in the war when the lengths of usable runways were severely curtailed due to the results of Allied bombing. Their system typically used Walter HWK 500 *Starthilfe* ("start-help") rocket engines driven by breaking down T-Stoff, essentially almost pure hydrogen peroxide. A parachute pack at the front of the motor was used to slow its fall after being released from the plane, so the system could be re-used. First experiments were held in 1937 on an Heinkel He 111, piloted by test-pilot Erich Warsitz at Neuhardenberg, a large field about 70 kilometres east of Berlin, listed as a reserve airfield in the event of war. Other German experiments with JATO were aimed at assisting the launch of interceptor aircraft such as the Messerschmitt Me 262, in their *Heimatschützer* special versions so that they could reach enemy bomber formations sooner, with differing formats of RATO assist rocket motors used on each of the three versions proposed, all liquid fueled. Two prototypes of the *Heimatschützer* versions of the Me 262 were built and test flown, of the three designs proposed.

In early 1939, the United States National Academy of Sciences provided \$1,000 to Theodore von Kármán and the Rocket Research Group at the Guggenheim Aeronautical Laboratory to research rocket-assisted take-off of aircraft. This JATO research was the first rocket research to receive financial assistance from the U.S. government.

Post WWII



C-130 cargo plane RATO takeoff from snow

After World War II JATO became particularly common owing to the low slow-speed thrust of then-current jet engines or for assisting heavy aircraft; the prop-engined Avro Shackleton used Armstrong Siddeley Viper turbojets for takeoff. As the take-off thrust of jet engines has grown, JATO has fallen from favor. It is still used, however, when heavily-laden aircraft need to take off from short runways or when operating in "high and hot" conditions.

Two similar zero-length launch experimental programs were carried out by the US Air Force and by the Soviet VVS at around the same time in the late 1950s. The US Air Force used a modified Republic F-84, designated EF-84G, which used the MGM-1 Matador cruise missile's solid fuel booster. The Soviet VVS used a modified MiG-19 fighter, designated SM-30, launched from a special launcher, and using a nearly identical solid fueled rocket booster design to that of the EF-84G. The F-100 and F-104 were also used for zero-length launch experiments.



C-130 Hercules using RATO during takeoff



Swiss Air Force's Dassault Mirage IIIs in Payerne



BQM-74E Chukar target drone using JATO

Operation Credible Sport was a United States military operation plan in late 1980 to rescue hostages held by Iran using C-130 cargo planes modified with rocket engines to enable a very short take off and landing. The plan was canceled after an accident during the test landing when JATO units designed to cushion the landing fired too soon, causing the aircraft to crash-land.

In all of these cases the term "jet" is correct but the system is more accurately called *RATO*. However *JATO* remains the most popular version, apparently due to its US origin.

JATO urban legend

The JATO Rocket Car is a famous urban legend that relates the story of a car equipped with JATO units that is later found smashed into a mountainside. This story is often given as an example of a Darwin Award; however it appears to be apocryphal, with no basis in fact. The legend has been examined twice on the Discovery Channel show *MythBusters*. For the first attempt, in a 2003 pilot episode, the crew replicated the scene and the thrust of the JATO with some commercially-available amateur rocket motors. The car did go very fast, outrunning the chase helicopter, but nowhere near the 300 mph (500 km/h)

reported in the original story, and failed to become airborne. The myth was revisited in 2007, using a different configuration of rockets in an attempt to make the car fly; however, it exploded before reaching the end of its launch ramp.



BS.605 as used by the Buccaneer S.50



A RATO bottle



Expended RATO bottles being used as ashtrays in Kangerlussuaq, Greenland

Chapter- 4

Non-rocket Spacelaunch

Non-rocket spacelaunch (NRS) is the idea of reaching outer space specifically from the Earth's surface predominantly without the use of conventional chemical rockets, which today is the only method in use.

Transportation to orbit is one factor in the expense of space endeavors; if it can be made more efficient the total cost of space flight can be reduced. Present-day launch costs are very high — \$10,000 to \$25,000 per kilogram from Earth to low Earth orbit, though some countries subsidize launches to prices nearer \$4,000. To settle space, e.g. space exploration and space colonization, much cheaper launch methods are required, as well as a way to avoid serious damage to the atmosphere from the thousands, perhaps millions, of launches required. Another benefit may be increased safety and reliability of launches, which, in addition to lower cost, would avail for space disposal of radioactive waste. Once having overcome the Earth gravity barrier, vehicles may instead use other, non-rocket-based methods of propulsion, e.g. ion thrusters, which have a higher propellant efficiency (specific impulse) and potential maximum velocity than conventional rockets, but are not suitable for spacelaunch.

Several alternatives to conventional chemical rockets have been proposed. In some systems a rocket *is* involved, but it ignites after reaching space in another manner.

Comparison

Comparison of non-rocket spacelaunch methods
Initial operating condition for new systems

Method ^(a)	Publication year	Estimated build-cost US\$ ^(b)	Payload Size kg	Estimated cost to LEO US\$/kg ^(b)	Capacity metric tons per year	Technology readiness level
Conventional rocket			118,000	3,273	200~	9
Space elevator	2004	6.2-40	18,000+	220-400	2,000	2-4
Hypersonic Skyhook	1993	<1 ^(c)	1,500 ^(d)		30 ^(e)	2

Rotovator	1977					2
HASTOL,	2000		15,000 ^(f)			2
Space fountain						2+
Orbital ring	1980	15		<0.05		2
Launch loop (small)	1985	10	5,000	300	40,000	2+
Launch loop (large)	1985	30	5,000	3	6,000,000	2+
KITE Launcher	2005					2
StarTram		60		20~	2,000~	2
Mass driver						4
Ram accelerator	2004			<500		6
Space gun	1865 ^(g)	0.5	450	500		6
Slingatron			100			2
Spaceplane	1992	10-15	12,000	3,000		7
Laser propulsion						up to 4

(a) References in this column apply to entire row unless specifically replaced

(b) All monetary values in un-inflated dollars based on reference publication date except as noted

(c) CY2008 estimate from description in 1993 reference system

(d) Requires first stage to ~5 km/s

(e) Subject to very rapid increase via bootstrapping

(f) Requires Boeing proposed DF-9 vehicle first stage to ~4 km/s

(g) Jules Verne's novel, *From the Earth to the Moon*. Newton's cannonball in the 1728 book *A Treatise of the System of the World* was considered a thought experiment.

Static structures

In this usage, the term "static" is intended to convey the understanding that the structural portion of the system has no internal moving parts. The structure as a whole, often being on orbit, will move at high velocities, but the parts of the structure do not move relative to other nearby parts.

Compressive structures

Compressive structures for non-rocket spacelaunch are proposals to use long, very strong structures like guyed antenna towers or artificial mountains up which payloads can be raised.

Space Tower

A *space tower* is a tower that would reach outer space. To fully replace rocket power and attain orbit, a tower would have to extend beyond the 100 km Kármán line (a common definition of outer space) to at least 237 km above the Earth's surface. Release from this height will result in an elliptical orbit with the lowest altitude just high enough to prevent reentry. If the tower went all the way to geosynchronous orbit at approximately 36,000 km, objects released at this height could then drift away with minimal power and would be in a circular orbit at that height. The concept of a structure reaching to geosynchronous orbit was first conceived by Konstantin Tsiolkovsky, who proposed a compression structure, or "Tsiolkovsky tower."

A parallel-sided structure made of conventional brick and stone cannot reach past 2000 meters as bricks at the bottom would be crushed under the weight. Imaginary materials would allow the tower to reach a usable height. A tapered structure could reach higher, but cost increases exponentially with construction height. A tower could form one component of a successful launch system, such as being the base station of a space elevator, or a support pillar for the distal part of a mass driver or the "gun barrel" of a space gun.

There are a number of other options to consider for building space towers: rigid, inflatable, kinetic, electrostatic and electronic structures.

Tensile structures

Tensile structures for non-rocket spacelaunch are proposals to use long, very strong cables (known as tethers) to drag a payload into, or fling it toward, space. Tethers can also be used for changing orbit once in space.

Orbital tethers can be tidally locked (skyhooks) or rotating (rotovators). They can be designed (in theory) to pick up the payload when the payload is stationary or when the payload is hypersonic (has a high but not orbital velocity).

Endo-atmospheric tethers can be used to transfer kinetics (energy and momentum) between large conventional aircraft (subsonic or low supersonic) or other motive force and smaller aerodynamic vehicles, propelling them to hypersonic velocities without exotic propulsion systems.

Skyhooks

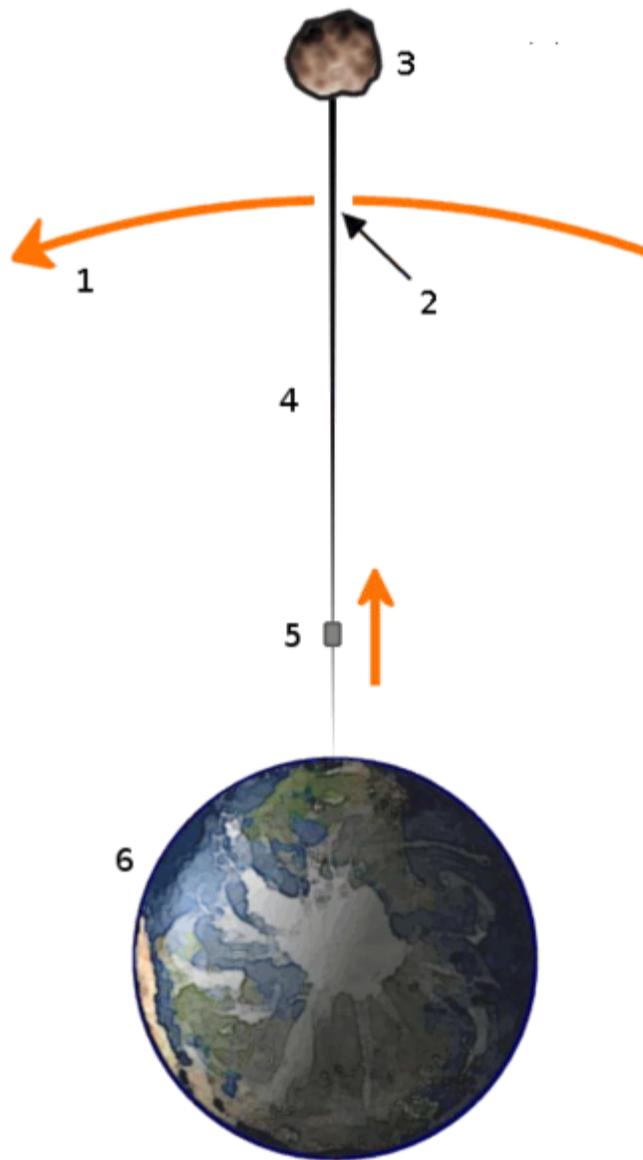
A *skyhook* is a tidally locked tether, i.e., it rotates once each time it orbits around a planet or moon.

An example use of a skyhook is that a payload, launched from the ground, can be attached to the base of the skyhook, which is then carried to orbit. This means that a single stage to skyhook approach can be employed, and a high-specific-impulse drive or

propellantless electromagnetic tether can be used to make up the momentum debt of the payload- or payload flow can be balanced from the moon.

Most skyhook designs require tapering of the cable towards the tips; this permits the cable material to be under constant stress throughout, and allows potentially indefinite tip speeds and length. However, in practice the cable taper ratios required can be too large for affordable systems to be able to handle desirable sizes of payloads above tip speeds of perhaps 2.5-3.5 km/s with current engineering materials.

Space elevator



A space elevator would consist of a cable anchored to the Earth's surface, reaching into space.

A *space elevator* a.k.a. *beanstalk* or "synchronous skyhook" is a stationary skyhook. It focuses on tensile structures (tethers) reaching from the ground to geosynchronous orbit.

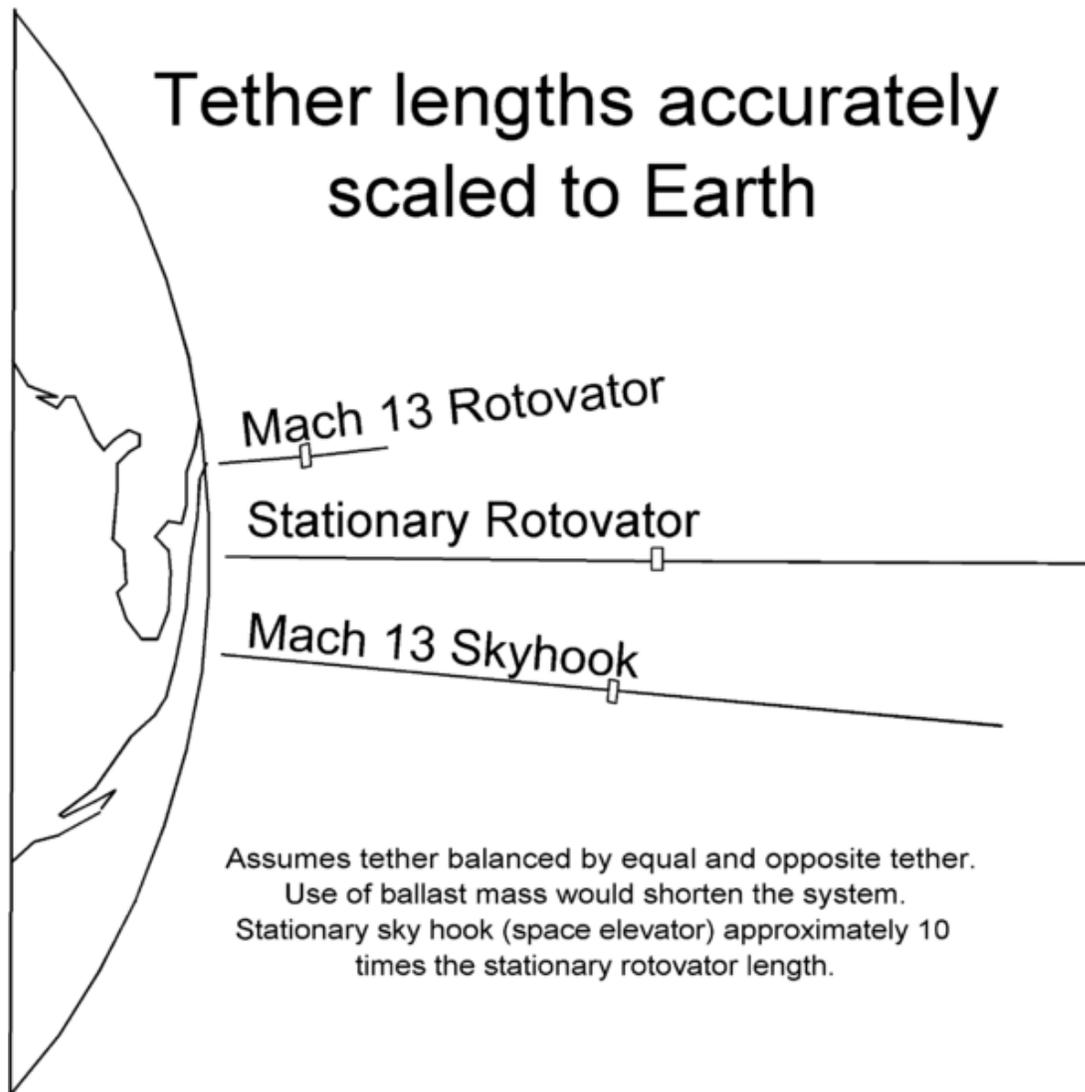
The most common proposal is a tether, usually in the form of a cable or ribbon, spanning from the surface near the equator to a point beyond geosynchronous orbit. Neglecting perturbations, it would be possible to design such a tether to barely touch the ground while remaining in orbit. All proposals however have additional ballast placed at the two ends to provide stability. As the planet rotates, the inertia at the upper end of the tether counteracts gravity, and keeps the cable taut. Vehicles can then climb the tether and reach orbit without the use of rocket propulsion. Such a structure could hypothetically permit delivery of cargo and people to orbit at a fraction of the cost of launching payloads by rocket.

Current technology is not capable of manufacturing materials that are sufficiently strong and light enough to build an Earth-based space elevator as the total mass of conventional materials needed to construct such a structure would be far too great. Recent proposals for a space elevator are notable in their plans to use carbon nanotube-based materials as the tensile element in the tether design, since the theoretical strength of carbon nanotubes appears great enough to make this practical.

Another difficulty includes shielding the passengers from the Van Allen belts which would require extremely heavy and comprehensive shielding to prevent significant health issues such as cancer and may prevent manned launch for quite some time irrespective of the other issues.

Current technology may be able to support elevators in other locations in the solar system however, and other designs for space elevators exist that use current materials.

A partial space elevator can also be less than the full length from orbit to the surface. Subsystems for an orbiting space elevator have been demonstrated with the X-43 and TIPS flights.



Orbital tether lengths compared.

A *hypersonic skyhook* is a relatively short tether that reaches from just above the edge of space to its design length.

Without the two end ballasts, a space elevator would still be in geosynchronous orbit, and thus stationary relative to the ground. If that tether were to be shorter and still reach the surface, the center of gravity would need to drop also. This would cause the lower tip to have a velocity in the orbital direction. The shorter the tether is, the faster becomes the lower tip velocity. With higher tip velocity, lower material properties are needed to make a practical design but the less benefit is obtained from this method. Eventually, any such design becomes a balance between the expense of providing the velocity to the payload at pick-up and the expense of launching the mass of the tether and power plant as dictated

by available materials. Also, the lower tip is raised out of the atmosphere to avoid heating problems.

A reference design was published using materials similar to Spectra 2000 and relying on one Titan IV launch to orbit a fully functional hypersonic skyhook. To keep the tether weight within the launch capacity, a payload pick-up velocity of 5 km/s was assumed. Though the reference design was limited to an Initial Operating Condition of 1,500 kg payload size, at a maximum rate of about one payload each 17 days, the prime limitation to higher capacity was power plant size. One launch of additional power plant would almost double the available power and capacity.

The problem is getting the payload to the altitude (100 km) and velocity (5 km/s) required for pick-up.

Rotovators

A *rotovator* is a tether that rotates more than once each time it orbits around a planet or moon. Rotovators rotate in the same sense as they orbit such that the lower tip has a retrograde motion relative to the center of gravity.

Rotovators in almost all ways have the same benefits as skyhooks. However, due to the retrograde velocity, the lower tip can achieve a specified Mach number with a shorter tether. This, despite the rotational forces, produces lower stresses in the tether so that lower strength to weight ratio materials can be used for the same results.

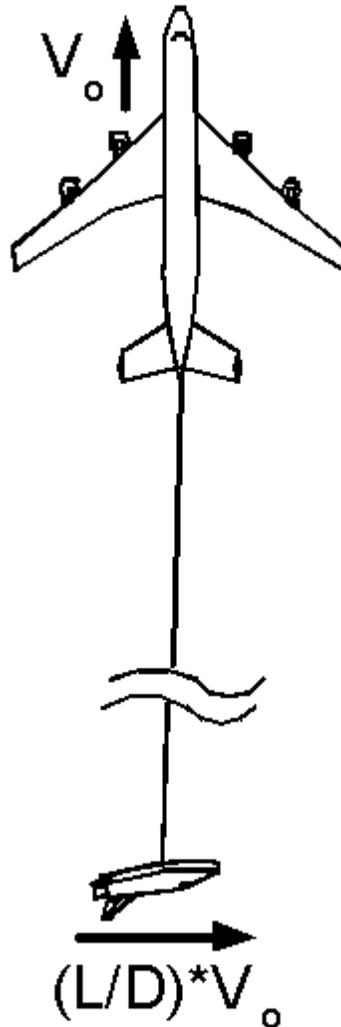
Stationary rotovators

A *stationary rotovator* implies only that the retrograde velocity of the tip fully cancels the orbital velocity. To a stationary payload, it appears as though the tether tip decelerates as it drops straight down from the sky, and then accelerates back upward. The payload must grapple the tip of the tether during that short duration when the tip has come to a stop. Hans Moravec's description of this was "a satellite that rotates like a wheel." With current materials a stationary rotovator to reach Earth's surface is impractical however; but is possible on other interplanetary bodies such as Mars and the Moon.

Hypersonic rotovator (HASTOL)

Similar to a hypersonic skyhook, a *hypersonic rotovator* uses a much shorter tether than its stationary equivalent and picks up its payload at hypersonic speeds. The Hypersonic Airplane, Space Tether, Orbital Launch (HASTOL) is one design for a hypersonic rotovator.

Endo-atmospheric tethers

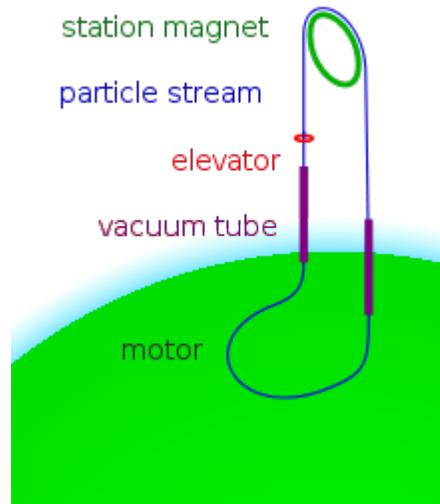


KITE Launcher - transferring momentum to the vehicle

An *endo-atmospheric tether* uses the long cable within the atmosphere to provide some or all of the velocity needed to reach orbit. The tether is used to transfer kinetics (energy and momentum) from a massive, slow end (typically a large subsonic or low supersonic aircraft) to a hypersonic end through aerodynamics or centripetal action. The *Kinetics Interchange TETHER (KITE) Launcher* is one proposed endo-atmospheric tether.

Dynamic structures

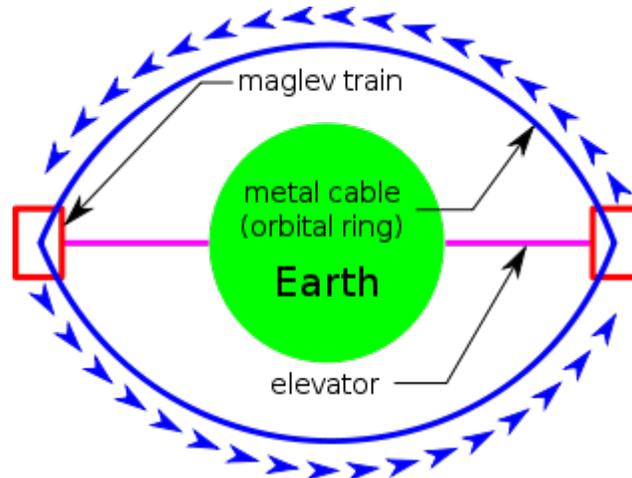
Space fountain



Hyde design

A *space fountain* is a proposed form of space elevator that does not require the structure to be in geosynchronous orbit, and does not rely on tensile strength for support. In contrast to the original space elevator design (a tethered satellite), a space fountain is a tremendously tall tower extending up from the ground. Since such a tall tower could not support its own weight using traditional materials, massive pellets are projected upward from the bottom of the tower and redirected back down once they reach the top, so that the force of redirection holds the top of the tower aloft. Satellite payloads ascend or descend by coupling with this stream of pellets or by climbing up the side of the tower. The space fountain has several key advantages over a space elevator in that it doesn't require materials with extreme strength, can be located at any point on a planet's surface instead of just the lower latitudes, and can be raised to any height required. Its major disadvantage is that it is an active structure, and so requires constant power input to balance its internal friction to remain aloft.

Orbital ring

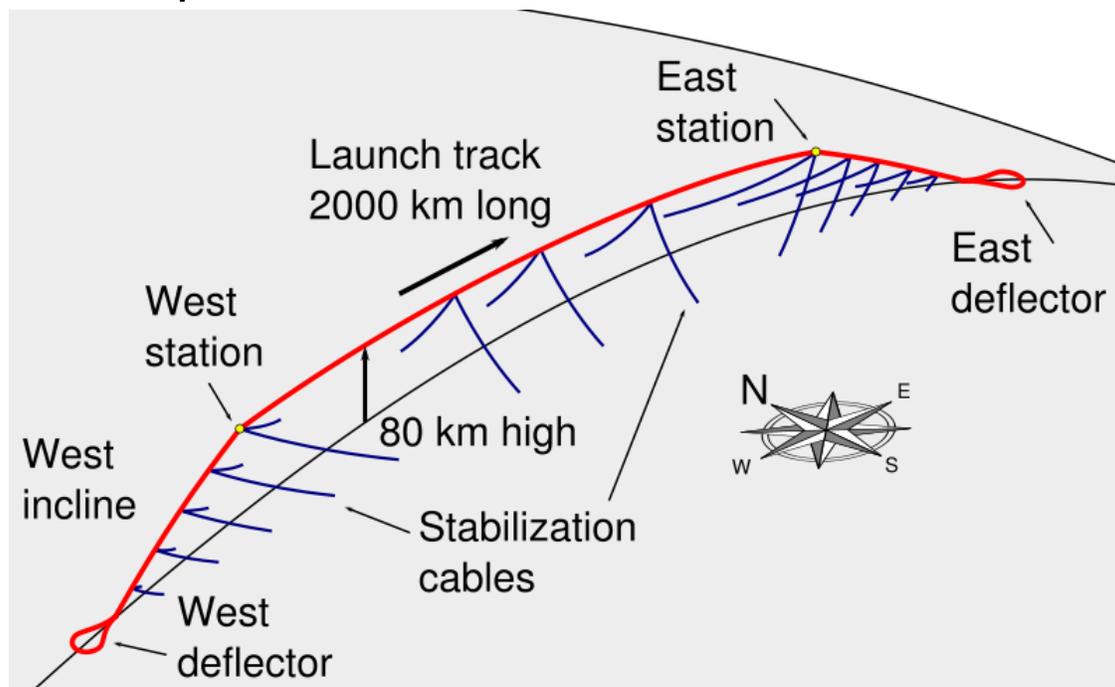


An *Orbital Ring* is a concept for a space elevator that consists of a ring in low earth orbit that rotates at slightly above orbital speed, and has fixed tethers hanging down to the ground.

The first design of an orbital ring offered by A. Yunitsky in 1982 .

In the 1982 Paul Birch JBIS design of an orbital ring system, a rotating cable is placed in a low Earth orbit, rotating at slightly faster than orbital speed. Not in orbit, but riding on this ring, supported electromagnetically on superconducting magnets, are Ring Stations that stay in one place above some designated point on Earth. Hanging down from these Ring Stations are short space elevators made from cables with high tensile strength to mass ratio. Paul Birch found that since the Ring Station can be used to accelerate the orbital ring eastwards as well as hold the tether, it is possible to deliberately cause the orbital ring to precess around Earth instead of staying fixed in inertial space while the Earth rotates beneath it. By making the precession rate large enough, the Orbital Ring can be made to precess once per day at the rate of rotation of the Earth. The ring is now "geostationary" without having to be either at the normal geostationary altitude or even in the equatorial plane. This means that using the orbital ring concept, a Ring Station can be positioned above any point on Earth that is desired, and anywhere on the globe can be served by a space elevator instead of just the equator. A network of orbital ring systems crossing, for example, at the poles, could cover the whole planet with an array of elevators and geostationary ring stations.

Launch loop



Launch Loop (with thanks to Keith Lofstrom-1985)

A *launch loop* or *Lofstrom loop* is a design for a belt-based maglev orbital launch system that would be around 2000 km long and maintained at an altitude of up to 80 km (50 mi). Vehicles weighing 5 metric tons would be electromagnetically accelerated on top of the cable which forms an acceleration track, from which they would be projected into Earth orbit or even beyond. The structure would constantly need around 200 MW of power to keep it in place.

The system is designed to be suitable for launching humans for space tourism, space exploration and space colonization with a maximum of 3g acceleration .

Pneumatic freestanding tower

One proposed design is a freestanding tower composed of high strength material (e.g. kevlar) tubular columns inflated with a low density gas mix, and with dynamic stabilization systems including gyroscopes and "pressure balancing". Suggested benefits in contrast to other space elevator designs include avoiding working with the great lengths of structure involved in some other designs, construction from the ground instead of orbit, and functional access to the entire range of altitudes within the design's practical reach. The design presented is "at 5 km altitude and extending to 20 km above sea level", and the authors suggest that "The approach may be further scaled to provide direct access to altitudes above 200 km".

Projectile launchers

With any of these projectile launchers, the launcher gives a high velocity at, or near, ground level. In order to achieve orbit, the projectile must be given enough extra velocity to punch through the atmosphere. Also, the projectile needs either an internal or external means to perform orbital insertion. The designs below fall into three categories, electrically driven, chemically driven, and mechanically driven.

Electrical

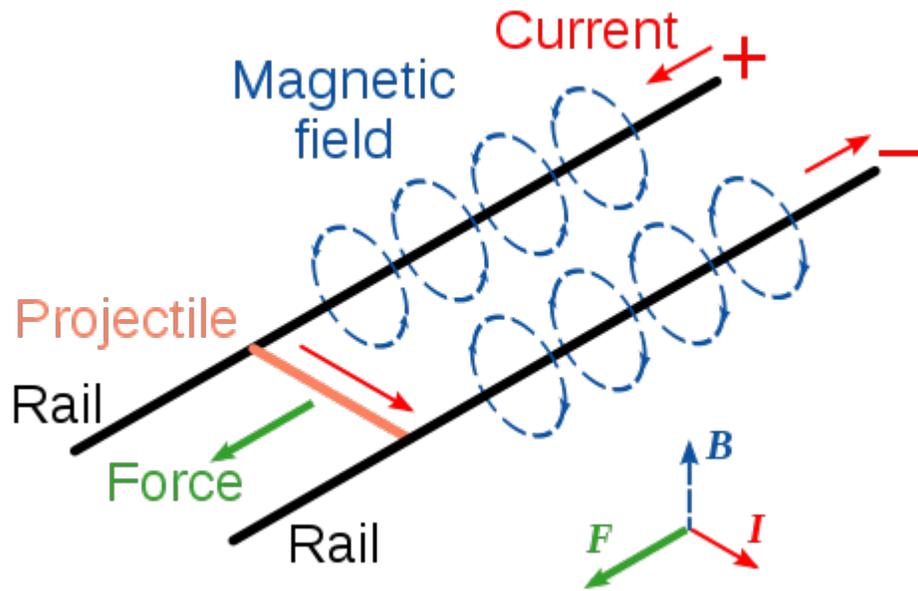
Mass driver



A mass driver for lunar launch (artist's conception)

A *mass driver* is basically a very long and mainly horizontally aligned launch track for spacelaunch, targeted upwards at the end.

It would use a linear motor to accelerate payloads up to high speeds. All existing and contemplated mass drivers use coils of wire energized by electricity to make electromagnets. Sequential firing of a row of electromagnets accelerates the payload along a path. After leaving the path, the payload continues to move due to inertia.



Electo-dynamic interactions in a rail gun

Rail gun

A *rail gun* is a pair of conductive rails with a projectile between them. A high current passes to and from the projectile through the rails, and through an armature at the back of the projectile between the parallel rails. The interactions between the electrical and magnetic fields accelerate the projectile.

StarTram

StarTram is a proposal for an evacuated tube at 22 km for launching vehicles into space, held up by a large current in superconducting cables that repels another set of cables on the ground with an opposing current flow.

Chemical

Space gun

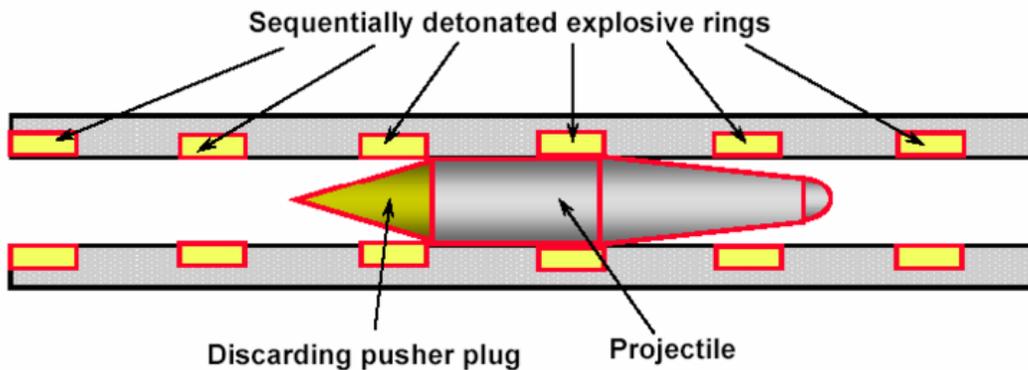


Project HARP, a prototype of a space gun.

A *space gun* is a method of launching an object into outer space using a large gun, or cannon.

However, even with a "gun barrel" through both the Earth's crust and troposphere, the g-forces required to generate escape velocity would still be more than what a human tolerates. Therefore, the space gun would be restricted to freight and ruggedized satellites. Also, the projectile needs either an internal or external means to stabilize on orbit.

Blast wave accelerator



Sequenced explosions keep acceleration high

A *blast wave accelerator* is similar to a *space gun* but it differs in that rings of explosive along the length of the barrel are detonated in sequence to keep the accelerations high. Also, rather than just relying on the pressure behind the projectile, the blast wave accelerator specifically times the explosions to squeeze on a tail cone on the projectile, as one might shoot a pumpkin seed by squeezing the tapered end.

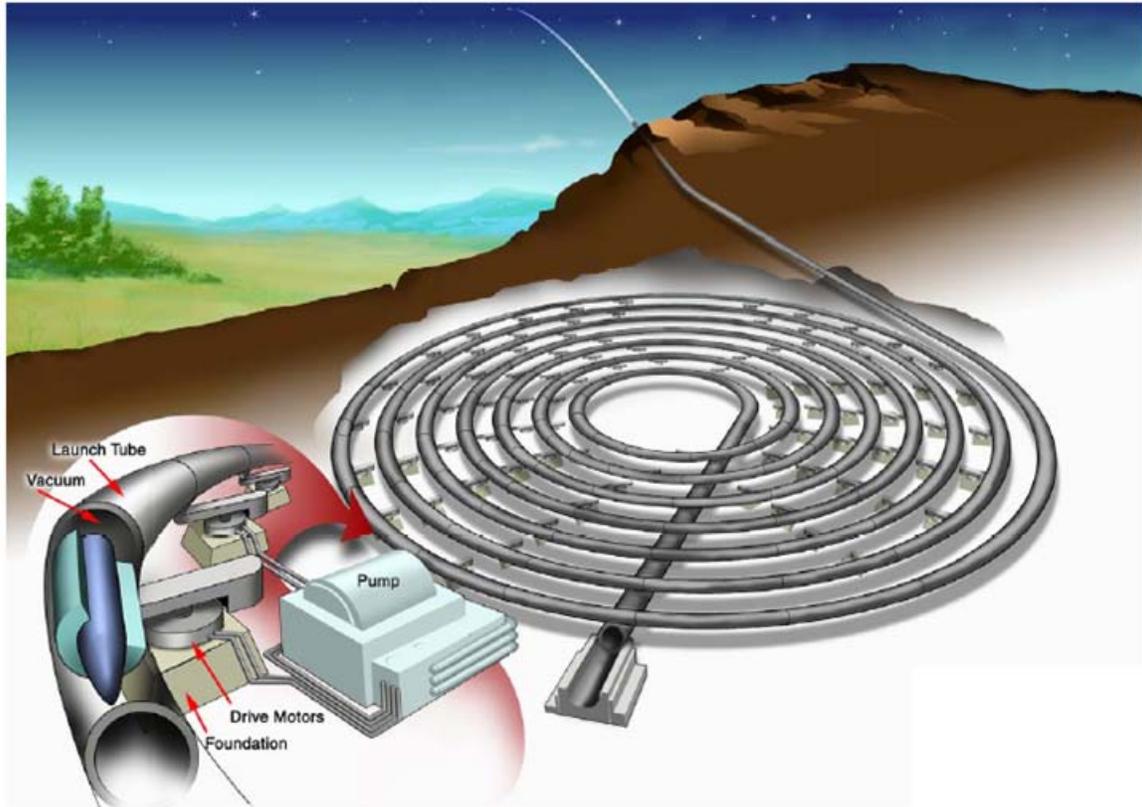
Ram Accelerator

A *ram accelerator* also uses chemical energy like the *space gun* but it is entirely different in that it relies on a jet-engine-like propulsion cycle utilizing ramjet and/or scramjet combustion processes to accelerate the projectile to extremely high speeds.

It is a long tube filled with a mixture of combustible gasses with a frangible diaphragm at either end to contain the gasses. The projectile, which is shaped like a ram jet core, is fired by another means (e.g., a light gas gun) supersonically through the first diaphragm into the end of the tube. It then burns the gasses as fuel, accelerating down the tube under jet propulsion. Other physics come into play at higher velocities.

Mechanical

Slingatron



Slingatron concept

In a *slingatron*, projectiles are accelerated along a rigid tube or track that typically has circular or spiral turns, or combinations of these geometries in two or three dimensions. A projectile is accelerated in the curved tube by propelling the entire tube in a small-amplitude circular motion of constant or increasing frequency without changing the orientation of the tube, i.e., the entire tube gyrates but does not spin.

This gyration continually displaces the tube with a component along the direction of the centripetal force acting on the projectile, so that work is continually done on the projectile as it advances through the machine. The centripetal force experienced by the projectile is the accelerating force, and is proportional to the projectile mass.

Reaction drives (jets and unconventional rockets)

Spaceplanes



X-43A with scramjet attached to the underside

A *spaceplane* is an aircraft designed to pass the edge of space. It combines some features of an aircraft with some of a spacecraft. Typically, it takes the form of a spacecraft equipped with aerodynamic surfaces, one or more rocket engines, and sometimes additional airbreathing propulsion as well.

Early spaceplanes were used to explore hypersonic flight (e.g. X-15).

Some air-breathing engine-based designs (c.f. X-30) such as aircraft based on scramjets or pulse detonation engines could potentially achieve orbital velocity or go some useful way to doing so; however, these designs still must perform a final rocket burn at their apogee to circularize their trajectory to avoid returning to the atmosphere.

Other, reusable turbojet-like designs like Skylon which uses precooled jet engines up to Mach 5.5 before employing rockets to enter orbit appears to have a mass budget that permits a larger payload than pure rockets while achieving it in a single stage.

Laser propulsion

Laser propulsion is a form of Beam-powered propulsion where the energy source is a remote (usually ground-based) laser system. This form of propulsion differs from a conventional chemical rocket where both energy and reaction mass come from the solid or liquid propellants carried on board the vehicle.

The concept of laser propelled vehicles was first introduced by Arthur Kantrowitz in 1972.

Buoyant lifting

Balloon

Balloons can raise the initial altitude of rockets.

However, balloons have relatively low payload, and this decreases even more with increasing altitude.

The lifting gas is usually helium, which is expensive in large quantities. This makes balloons an expensive launch assist technique. Hydrogen could be used, but is highly flammable; although the Hindenburg Disaster may not have been caused by the use of hydrogen, there is still debate upon the matter.

Buoyant space port

By using big balloons it is possible to construct a space port in the stratosphere. Rockets can start from it or a mass driver can accelerate payloads into the orbit. This has the advantage that most (about 90%) of the atmosphere is below the space port and that you start really high. *As a rough estimate, a rocket that reaches an altitude of 20 km when launched from the ground will reach 100 km if launched at an altitude of 20 km from a balloon.*

Chapter- 5

STOL and CATOBAR

STOL



A Zenair CH 701 STOL light aircraft.

Short take-off and landing or STOL is an acronym for *short take-off and landing*, a term used to describe aircraft with very short runway requirements.

Definitions

There is no one accepted definition of STOL and many different definitions have been used by different authorities and nations at various times and for a myriad of regulatory and military purposes. Some accepted definitions of STOL include:

short takeoff and landing: (DOD/NATO) The ability of an aircraft to clear a 50-foot (15 meters) obstacle within 1,500 feet (450 meters) of commencing takeoff or in landing, to stop within 1,500 feet (450 meters) after passing over a 50-foot (15 meters) obstacle. Also called STOL.

Department of Defense Dictionary of Military and Associated Terms (JP 1-02)

"STOL (Short Take Off and Landing). STOL performance of an aircraft is the ability of aircraft to take off and clear a 50-foot obstruction in a distance of 1,500 feet from beginning the takeoff run. It must also be able to stop within 1,500 feet after crossing a 50-foot obstacle on landing."

Dictionary of Aeronautical Terms

"An aircraft that, at some weight within its approved operating weight, is capable of operating from a STOL runway in compliance with the applicable STOL characteristics and airworthiness, operations, noise, and pollution standards" and "'aircraft" means any machine capable of deriving support in the atmosphere"

Transport Canada and Arizona Department of Transportation

"A STOL aircraft is an aircraft with a certified performance capability to execute approaches along a glideslope of 6 degrees or steeper and to execute missed approaches at a climb gradient sufficient to clear a 15:1 missed approach surface at sea level... A STOL runway is one which is specifically designated and marked for STOL aircraft operations, and designed and maintained to specified standards."

US Federal Aviation Administration

"Heavier-than-air craft that cannot take off and land vertically, but can operate within areas substantially more confined than those normally required by aircraft of the same size. Derived from short takeoff and landing aircraft."

McGraw-Hill Dictionary of Scientific & Technical Terms

"short takeoff and landing aircraft (STOL), heavier-than-air craft, capable of rising from and descending to the ground with only a short length of runway, but incapable of doing so vertically. The precise definition of an STOL aircraft has not been universally agreed upon. However, it has been tentatively defined as an aircraft that upon taking off needs only 1,000 ft (305 m) of runway to clear a 50-ft (15-m) obstacle at the end of that distance and upon landing can clear the same obstacle and then land within 1,000 ft."

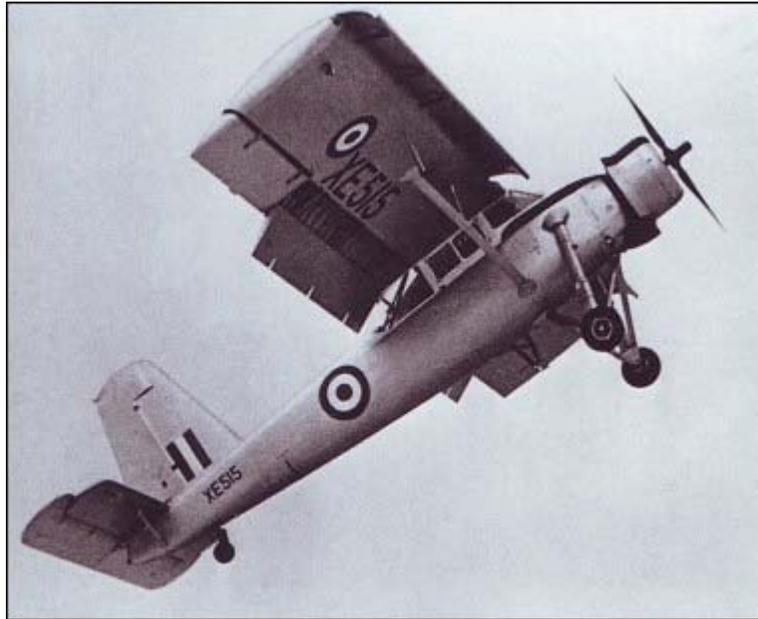
Columbia Encyclopedia

"The STOL mode of flight is one during which an airplane taking off or landing is operated at climb-out and approach speeds lower than the conventionally accepted margins of airspeed above the power-off stalling speed of the airplane."

Lieutenant Colonel Walter P. Maiersperger, USAF (Ret)

Additionally some aircraft manufacturers market their products as STOL, without providing evidence that the aircraft meets any accepted definition.

Design considerations



Scottish Aviation Pioneer in flight showing aerodynamic devices on wing



GAF Nomad VH-ATO

Many fixed-wing STOL aircraft are bush planes, though some, like the de Havilland Dash-7, are designed for use on prepared airstrips; likewise, many STOL aircraft are taildraggers, though there are exceptions like the Quest Kodiak, de Havilland Twin Otter and the Peterson 260SE. Autogyros also have STOL capability, needing a short ground roll to get airborne, but capable of a near-zero ground roll when landing.

Runway length requirement is a function of the square of the minimum flying speed (stall speed), and most design effort is spent on reducing this number. For takeoff, large power/weight ratios and low drag help the plane to accelerate for flight. The landing run is minimized by strong brakes, low landing speed, thrust reversers or spoilers (less common). Overall STOL performance is set by the length of runway needed to land or take off, whichever is longer.

Of equal importance to short ground run is the ability to clear obstacles, such as trees, on both take off and landing. For takeoff, large power/weight ratios and low drag result in a high rate of climb required to clear obstacles. For landing, high drag allows the aeroplane to descend steeply to the runway without building excess speed resulting in a longer ground run. Drag is increased by use of flaps (devices on the wings) and by a forward slip (causing the aeroplane to fly somewhat sideways though the air to increase drag).

Normally, a STOL aircraft will have a large wing for its weight. These wings often use aerodynamic devices like flaps, slots, slats, and vortex generators. Typically, designing an aircraft for excellent STOL performance reduces maximum speed, but does not reduce payload lifting ability. The payload is critical, because many small, isolated communities rely on STOL aircraft as their only transportation link to the outside world for passengers or cargo; examples include many communities in the Canadian north and Alaska.

Most STOL aircraft can land either on- or off-airport. Typical off-airport landing areas include snow or ice (using skis), fields or gravel riverbanks (often using special fat, low-pressure tundra tires), and water (using floats): these areas are often extremely short and obstructed by tall trees or hills. Wheel skis and amphibious floats combine wheels with skis or floats, allowing the choice of landing on snow/water or a prepared runway.

STOL kits



Micro Dynamics vortex generators mounted on the wing of a Cessna 182K

A number of aircraft modification companies offer STOL kits that can be installed on aircraft to improve their short field performance.

- Crosswinds STOL of Wasilla, Alaska sells STOL kits for light aircraft, including leading edge cuffs, tip spill plates, inboard flap extensions and STOL fences. The company offers kits for Piper PA-12, PA-14, PA-18, PA-20 and 22, Bellanca Champion Model 7 series, Cessna 170B, 180 and 185.
- Horton, Inc of Wellington, Kansas offers STOL kits under the brand name *Horton STOL-Craft*, emphasizing that the modifications increase safety by allowing forced landings to occur at lower speeds and thus improve survivability. The Horton modifications include a drooped leading edge cuff, conical cambered wingtips, control surface gap seals and wing fences. The company says: "On an average you can expect to get a 4-7 knot reduction in stall speeds. Flying at these lower stall speeds you can reduce the take-off and landing distances by 10%". Horton STOL kits are available for the Cessna 150, 170, 172, 177, 188, 205, 206, 207, 210, 336, 337 and the Piper PA-28.

- Micro AeroDynamics markets vortex generator modification kits for "STOL benefits". The Micro kits consist of small VGs that are glued to the wing leading edge, as well as the underside of the elevator and on the fin. The VG kits are available for a large number of light aircraft types.
- Sierra Industries sells Robertson STOL kits, marketed under the name R/STOL, incorporate a drooped leading edge cuff, wing fences, drooping ailerons and an automatic trim system. The company says that installation "allows 15 to 25 MPH slower approaches and requires up to 40% less runway distance". R/STOL kits are available for the Cessna 150, 152, 172, 182, 185, 206, 207, 210, T210, P210, 310, 337, 340, 401, 402, 414 and 421.

STOLport

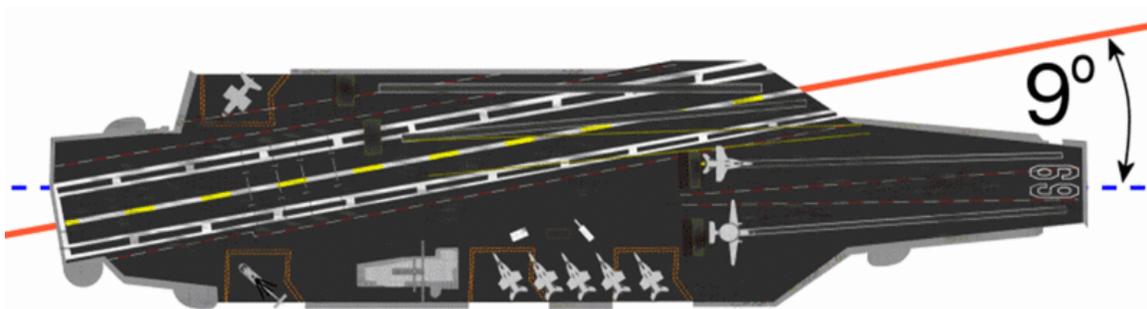
A STOLport is an airport designed with STOL operations in mind, normally having a short single runway.

STOLports are not common but can be found, for example, at London City Airport in England.

CESTOL

CESTOL or Cruise Efficient Short Takeoff and Landing, is sometimes used to describe aircraft with both very short runway requirements and high cruise speeds (greater than mach 0.8).

CATOBAR



Flight deck of USS Dwight D. Eisenhower, showing catapult layout.



Catapult start on USS Nimitz

CATOBAR (catapult assisted take off but arrested recovery) is a system used for the launch and recovery of aircraft from the deck of an aircraft carrier. Under this technique, aircraft launch using a catapult assisted take off and land on the ship (the recovery phase) using arrestor wires. Although this system is more costly than alternative methods, it provides greater flexibility in carrier operations, since it allows the vessel to support conventional aircraft. Alternate methods of launch and recovery can only use aircraft with STOVL or STOBAR capability. Only three countries still operate carriers that use the CATOBAR system; the U.S. *Nimitz* class, and USS *Enterprise* (CVN-65), France's *Charles De Gaulle*, and Brazil's *Naé São Paulo*. The Future French aircraft carrier is planned to be built as CATOBAR. In order to save money, the British *Queen Elizabeth* class aircraft carriers were originally to be built as STOVL carriers operating the F-35B

Lightning II, but subsequent to the Strategic Defence and Security Review they are now to be CATOBAR carriers capable of supporting the non-STOVL F-35C variant. India's second aircraft carrier of Vikrant class is planned to be of 65,000 tons and to utilise steam catapults.

Chapter- 6

VTOL and Zero Length Launch

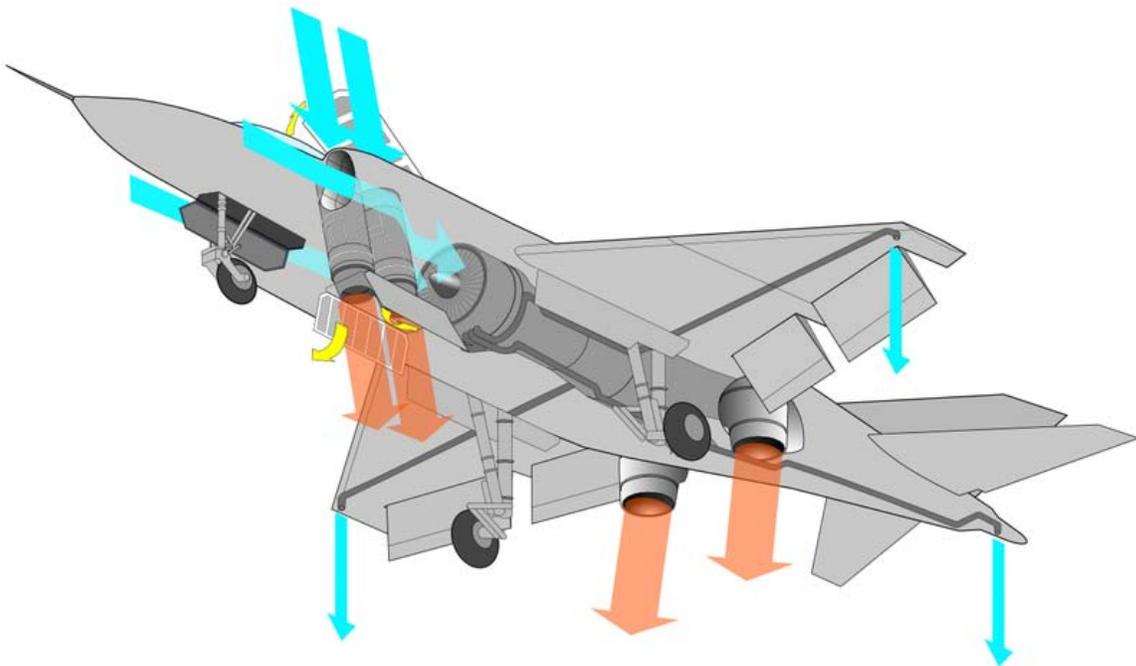
VTOL



The Harrier Jump Jet, one of the most famous fixed-wing single-engine VTOL aircraft



A Camcopter S-100, a modern VTOL unmanned aerial vehicle



Air forces on Soviet Union's VTOL aircraft: the twin-engine Yak-38

VTOL is an acronym for **vertical take-off and landing** aircraft. This classification includes fixed-wing aircraft that can hover, take off and land vertically as well as helicopters and other aircraft with powered rotors, such as tiltrotors. The terminology for

spacecraft and rockets is *VTVL* (vertical takeoff with vertical landing). Some VTOL aircraft can operate in other modes as well, such as CTOL (conventional take-off and landing), STOL (short take-off and landing), and/or STOVL (short take-off and vertical landing). Others, such as some helicopters, can only operate by VTOL, due to the aircraft lacking landing gear that can handle horizontal motion. VTOL is a subset of V/STOL (vertical and/or short take-off and landing).

Besides the ubiquitous helicopter, there are currently two types of VTOL aircraft in military service: craft using a tiltrotor, such as the Bell Boeing V-22 Osprey, and aircraft using directed jet thrust such as the Harrier family.

History

In addition to the helicopter, many approaches have been tried to develop practical aircraft with vertical take-off and landing capabilities. Nikola Tesla patented a vertical take-off and landing vehicle concept in 1928. An early functional contribution to VTOL was Rolls-Royce's Thrust Measuring Rig ("flying bedstead") of 1953. This led to the first VTOL engines as used in the first British VTOL aircraft, the Short SC.1 (1957) which used 4 vertical lift engines with a horizontal one for forward thrust.

Another British VTOL project was the gyrodyne, where a rotor is powered during take-off and landing but which then freewheels during flight, with separate propulsion engines providing forward thrust. Starting with the Fairey Gyrodyne, this type of aircraft later evolved into the much larger twin-engined Fairey Rotodyne, that used tipjets to power the rotor on take-off and landing but which then used two Napier Eland turboprops driving conventional propellers mounted on substantial wings to provide propulsion, the wings serving to unload the rotor during horizontal flight. The Rotodyne was developed to combine the efficiency of a fixed-wing aircraft at cruise with the VTOL capability of a helicopter to provide short haul airliner service from city centres to airports.

The use of vertical fans driven by engines was investigated in the 1950s. The US built an aircraft where the jet exhaust drove the fans, while British projects not built included fans driven by mechanical drives from the jet engines.

The idea of using the same engine for vertical and horizontal flight by altering the path of the thrust led to the Bristol Siddeley Pegasus engine which used rotating ducts to direct thrust over a range of angles. This was developed side by side with an airframe, the Hawker P.1127, which became subsequently the Kestrel and then entered production as the Hawker Siddeley Harrier, though the supersonic Hawker Siddeley P.1154 was canceled in 1965. The French in competition with the P.1154 had developed a version of the Dassault Mirage III capable of attaining Mach 1. The Dassault Mirage IIIV achieved transition from vertical to horizontal flight in March 1966, reaching Mach 1.3 in level flight a short time later.

The Harrier is often flown in STOVL mode which enables it to carry a higher fuel or weapon load over a given distance. Now retired from British Royal Navy service, the

Indian Navy operates Sea Harriers mainly from its aircraft carrier INS Viraat. The latest version of the Harrier, the BAE Harrier II is operated by the British Royal Air Force and Royal Navy. The United States Marine Corps, and the Italian and Spanish Navies use the AV-8B Harrier II, an equivalent derivative of the Harrier II. The Harrier II/AV-8 will be replaced in the air arms of the US and UK by a STOVL variant of the F-35 Lightning II.

NASA has flown other VTOL craft such as the Bell XV-15 research craft (1977), as have the Soviet Navy and *Luftwaffe*. Sikorsky tested an aircraft dubbed the X-Wing, which took off in the manner of a helicopter. The rotors would become stationary in mid-flight, and function as wings, providing lift in addition to the static wings. Boeing X-50 is a Canard Rotor/Wing prototype that utilizes a similar concept.



Do 31 E3 on display at the Deutsches Museum, Germany

The Yakovlev Yak-38 was the Soviet Navy's VTOL aircraft for their light carriers, cargoships, and capital ships. It was developed from the Yakovlev Yak-36 experimental aircraft. Before the Soviet Union collapsed, a supersonic VTOL aircraft was developed as the Yak-38's successor, the Yak-141, which never went into production.



A German V/STOL VJ101 on display at the Deutsches Museum, Munich, Germany

In the 1960s and early 70s Germany planned three different VTOL planes. One used the F-104 as a base for research for a V/STOL aircraft. Although two models (X1 and X2) were built, the project was canceled due to high costs and political problems as well as changed needs in the Luftwaffe and NATO. The EWR VJ 101C did perform free VTOL take-offs and landings, as well as test flights beyond mach 1 in the mid- and late 60s. One of the test-aircraft is preserved in the Deutsches Museum in Munich, Germany. The others were the VFW-Fokker VAK 191B light fighter and reconnaissance plane, and the Dornier Do 31E-3 (troop) transport.

Canadair CL-84 Dynavert



CL-84-1 (CX8402) on display at the Canada Aviation and Space Museum in Ottawa, Ontario

The CL-84 was a Canadian V/STOL turbine tilt-wing monoplane designed and manufactured by Canadair between 1964 and 1972. The Canadian government ordered three updated CL-84s for military evaluation in 1968, designated the CL-84-1. From 1972 to 1974, this version was demonstrated and evaluated in the United States aboard the aircraft carriers USS *Guam* and USS *Guadalcanal*, and at various other centres. These trials involved military pilots from the United States, the United Kingdom and Canada. Two of the CL-84s crashed due to mechanical failures, but no loss of life occurred as a result of these accidents. No production contracts resulted.

Aircraft designed to operate in extraterrestrial environments often utilize VTOL. An example of this type of aircraft is the LLRV. Spacecraft typically operate in environments where runways or even a suitably flat surface for skids is nonexistent.

V-22



U.S. Marines jump from a V-22 Osprey, the first production tiltrotor aircraft.

The V-22 Osprey is the world's first production tiltrotor aircraft, with one three-bladed proprotor, turboprop engine, and transmission nacelle mounted on each wingtip. The Osprey is a multi-mission aircraft with both a vertical takeoff and landing (VTOL) and short takeoff and landing capability (STOL). It is designed to perform missions like a conventional helicopter with the long-range, high-speed cruise performance of a turboprop aircraft. The FAA classifies the Osprey as a model of powered lift aircraft.

Zero length launch



F-100D-60-NA (sn 56-2904) in trial of zero-length-launch system. Pilot is Maj. R. Titus (USAF photo).

The **zero length launch system** or **zero length take-off system** (ZLL, ZLTO, ZEL, ZELL) was a system whereby jet fighters and attack aircraft were intended to be placed upon rockets attached to mobile launch platforms. Most zero length launch experiments took place in the 1950s, during the Cold War.

History

The primary advantage of a zero length launch system is the elimination of the need for a vulnerable airfield for takeoffs. In the event of a sudden attack, air forces could field effective air defenses and launch airstrikes even with their own airbases destroyed. Although launching aircraft using rocket boosters proved to be relatively trouble-free, zero length launch systems still required a conventional runway if the aircraft was expected to land. Bulky mobile launching platforms also proved to be expensive to operate and difficult to transport. Security would also have been an issue with mobile launchers, especially if equipped with nuclear-armed strike fighters.

The United States Air Force, *Luftwaffe*, and the Soviet Air Force all conducted experiments in zero length launching. All works upon ZELL aircraft were abandoned due to logistical concerns and the increasing efficiency of guided missiles.

Manned aircraft involved in ZELL Testing



F-104G ZLL at Luftwaffenmuseum der Bundeswehr, Berlin Gatow.

- F-84G Thunderjet
- North American F-100D Super Sabre
- Lockheed F-104 Starfighter
- Mikoyan-Gurevich MiG-19 "Farmer"
- North American XF-108 Rapier - (aircraft program cancelled)

The desire to field combat aircraft without depending on vulnerable landing strips also motivated development of aircraft capable of vertical (VTOL) or short (STOL) takeoffs or landings. Examples of these include British Hawker Siddeley Harrier, Soviet Yak-38 (both serially produced) and American McDonnell Douglas F-15S/MTD.

Chapter- 7

Rocket Launch



Launching of Mercury-Redstone 2.

A **rocket launch** is the first phase of the flight of a rocket. Launches for orbital spaceflights, or launches into interplanetary space, are usually from a fixed location on the ground, but may also be from a floating platform such as the San Marco platform, or the Sea Launch launch vessel.

Launches of suborbital flights (including missile launches), can also be from:

- a missile silo
- a mobile launcher vehicle
- a submarine
- air launch:
 - from a plane (e.g. Scaled Composites SpaceShipOne, Pegasus Rocket, X-15)
 - from a balloon (Rockoon, da Vinci Project (under development))
- a surface ship (Aegis Ballistic Missile Defense System)
- an inclined rail

Launches not into space can also be from:

- the shoulder

"Rocket launch technologies" generally refers to the entire set of systems needed to successfully launch a vehicle, not just the vehicle itself, but also the firing control systems, ground control station, launch pad, and tracking stations needed for a successful launch and/or recovery.

Commercial launches

Commercial launch service providers include:

- Boeing Launch Services Inc. (BLS) - Delta rocket
 - Sea Launch - Zenit-3SL (Zenit rocket stages 1 and 2 with Energia Block DM-SL upper stage)
- EADS SPACE Transportation / Arianespace - Ariane rocket
- International Launch Services (ILS) - Proton rocket
- United Launch Alliance (ULA) - Delta IV And Atlas V
- Starsem - Soyuz rocket
- ISRO - PSLV, GSLV

Viewing rocket launches

In the United States, dates for commercial and manned space launches are matters of public record, and are available months ahead of time. The exact dates of military launches remain confidential until only days before, but the months are public as well.

With the exception of the Space Shuttle, the visitor complex of the John F. Kennedy Space Center in Florida is open to the general public (with a \$38 admission fee) for viewing rocket launches from the Space Center and from Cape Canaveral Air Force Station. Viewing Space Shuttle launches from the visitor center requires special reservations. The visitor center is generally 10 km (6 miles) from the launch pads. Special reservations for the Space Shuttle are required because it is a much more powerful

vehicle than the expendable launch vehicles currently in use, as well as the possibility of a disaster that would result in immediate death for the astronauts, such as the explosion of *Challenger* at the launch of mission STS-51-L. Outside the center itself, the best launch viewing sites are along the beaches within the vicinity.

Launches from Vandenberg Air Force Base in California can best be seen from the cities of Santa Maria or Lompoc, or the surrounding beaches.

Launches by Russia from the Baikonur Cosmodrome in Kazakhstan can best be viewed from the city of Baikonur.

Launches by the European Space Agency from Guiana Space Centre in French Guiana can best be viewed from Kourou or the surrounding beaches.

Launch vehicles

If a rocket is launched to deliver a payload from a planetary surface into space it is called a launch vehicle.

There are several broad categories that launch vehicles fall under, including:

- Expendable launch system
- Reusable launch system
- Single stage to orbit
- Two stage to orbit
- Three stage to orbit

There were over 70 orbital launches in 2010.

Orbital launches

Orbital launch vehicles take off vertically, and then begin to progressively lean over, usually following a gravity turn trajectory.

Once above the majority of the atmosphere the vehicle then angles the rocket jet, pointing it largely horizontally but somewhat downwards, this permits the vehicle to gain and then maintain altitude while increasing horizontal speed. As the speed grows the vehicle will become more and more horizontal until at orbital speed, the engine will cut off.

All current vehicles will *stage*- jettison hardware on the way to orbit.

When launching a spacecraft to orbit, a "dogleg" is a guided, powered turn during ascent phase that causes a rocket's flight path to deviate from a "straight" path. A dogleg is necessary if the desired launch azimuth, to reach a desired orbital inclination, would take the ground track over land (or over a populated area, e.g. Russia usually does launch over land, but over unpopulated areas), or if the rocket is trying to reach an orbital plane that

does not reach the latitude of the launch site. Doglegs are undesirable due to extra onboard fuel required, causing heavier load, and a reduction of vehicle performance.

Chapter- 8

Launch Vehicle



A Russian Soyuz lifts off from the Baikonur Cosmodrome in Kazakhstan heading for the ISS

Launch vehicle

Performance class	payload lift capacity to LEO (kg)
Small	less than 2,000
Medium	2,000 — 10,000
Mid-heavy	10,000 — 20,000
Heavy	20,000 — 50,000
Super-heavy	50,000 or more

In spaceflight, a **launch vehicle** or **carrier rocket** is a rocket used to carry a payload from the Earth's surface into outer space. A **launch system** includes the launch vehicle, the launch pad and other infrastructure. Usually the payload is an artificial satellite placed into orbit, but some spaceflights are sub-orbital while others enable spacecraft to escape Earth orbit entirely. A launch vehicle which carries its payload on a suborbital trajectory is often called a sounding rocket.

Types of launch vehicles



Ukrainian LV Zenit-2 is prepared for launch

Expendable launch vehicles are designed for one-time use. They usually separate from their payload, and may break up during atmospheric reentry. Reusable launch vehicles, on the other hand, are designed to be recovered intact and used again for subsequent

launches. For orbital spaceflights, the Space Shuttle is currently the only launch vehicle with components which have been used for multiple flights. Non-rocket spacelaunch alternatives are at the planning stage.

Launch vehicles are often characterized by the amount of mass they can lift into orbit. For example, a Proton rocket has a launch capacity of 22,000 kilograms (49,000 lb) into low Earth orbit (LEO). Launch vehicles are also characterized by the number of stages they employ. Rockets with as many as five stages have been successfully launched, and there have been designs for several single-stage-to-orbit vehicles. Additionally, launch vehicles are very often supplied with boosters, which supply high thrust early on in the flight, and normally in parallel with other engines on the vehicle. Boosters allow the remaining engines to be smaller, which reduces the burnout mass of later stages, and thus allows for larger payloads.

Other frequently-reported characteristics of launch vehicles are the nation or space agency responsible for the launch, and the company or consortium that manufactures and launches the vehicle. For example, the European Space Agency is responsible for the Ariane V, and the United Launch Alliance manufactures and launches the Delta IV. Many launch vehicles are considered part of an historical line of vehicles which share the same or similar names such as the Atlas V being the latest member of the Atlas rocket family.

By launch platform

- Land: Spaceport and fixed missile silo (Strela) for converted ICBMs
- Sea: fixed platform (San Marco), mobile platform (Sea Launch), submarine (Shtil', Volna) for converted SLBMs
- Air: aircraft (Pegasus, AirLaunch LLC), balloon (ARCASPACE), proposal for permanent Buoyant space port

Vehicle assembly

Various methods are used to move an assembled launch vehicle onto its launch pad, each method with its own specialized equipment. These assembly activities take place as part of the overall launch campaign for the vehicle. In some launch systems, like the Delta II, the vehicle is assembled vertically on the pad, using a crane to hoist each stage into place. The Space Shuttle orbiter, including its external tank, and solid rocket boosters, are assembled vertically in NASA's Vehicle Assembly Building, and then a special crawler-transporter moves the entire stack to the launch pad while it is in an upright position. In contrast, the Soyuz rocket is assembled horizontally in a processing hangar, transported horizontally, and then brought upright once at the pad.

Derivation and related terms

In the English language, the phrase carrier rocket was used earlier, and still is occasionally, in Britain. A translation of that phrase is used in German, Russian, and

Chinese. In the 1950s, the US Air Force disliked the term *carrier* due to the competitive nature of their relationship with the US Navy and their high profile operation of aircraft carriers. As an alternative, Project Vanguard provided a contraction of the phrase "Satellite Launching Vehicle" abbreviated to "SLV". This provided a term in the list of what the rockets were allocated for: flight test, or actually launching a satellite. The contraction would also apply to rockets which send probes to other worlds or the interplanetary medium.

Orbital launch vehicles



A Saturn V launch vehicle sends Apollo 15 on its way to the moon.

Sounding rockets are normally used for brief, inexpensive space and microgravity experiments. Current human-rated suborbital launch vehicles include SpaceShipOne and the upcoming SpaceShipTwo, among others. The delta-v needed for orbital launch is generally between 7,600 and 8,000 metres per second (25,000 and 26,000 ft/s), although there is no upper limit. How much delta-v is needed can be determined by using a combination of air-drag, which is determined by ballistic coefficient, gravity losses, altitude gain and the horizontal speed necessary to give a suitable perigee. The delta-v required for altitude gain varies, but is around 2 kilometres per second (1.2 mi/s) for 200 kilometres (120 mi) altitude.

Minimising air-drag entails having a reasonably high ballistic coefficient, which generally means having a launch vehicle that is at least 20 metres (66 ft) long, or a ratio of length to diameter greater than ten. Leaving the atmosphere as early on in the flight as possible provides an air drag of around 300 metres per second (980 ft/s). The horizontal speed necessary to achieve low earth orbit is around 7,800 metres per second (26,000 ft/s).

The calculation of the total delta-v for launch is complicated, and in nearly all cases numerical integration is used; adding multiple delta-v values provides a pessimistic result, since the rocket can thrust while at an angle in order to reach orbit, thereby saving fuel as it can gain altitude and horizontal speed simultaneously.

Regulation

Under international law, the nationality of the owner of a launch vehicle determines which country is responsible for any damages resulting from that vehicle. Due to this, some countries require that rocket manufacturers and launchers adhere to specific regulations in order to indemnify and protect the safety of people and property that may be affected by a flight.

In the US, any rocket launch that is not classified as amateur, and also is not "for and by the government," must be approved by the Federal Aviation Administration's Office of Commercial Space Transportation (FAA/AST), located in Washington, DC

Chapter- 9

Other Types of Takeoff

STOBAR

STOBAR (short take off but arrested recovery) is a system used for the launch and recovery of aircraft from the deck of an aircraft carrier, combining elements of both STOVL (Short Take Off and Vertical Landing.) and CATOBAR (Catapult Assisted Take Off But Arrested Recovery). Aircraft launch under their own power using a ski-jump to assist take-off (rather than using a catapult like most carriers). However, these are conventional, rather than STOVL aircraft, and thus require arrestor wires to land on the ship. The Russian Navy aircraft carrier *Admiral Kuznetsov* is the only current example of a STOBAR carrier, another will be the Indian *Vikramaditya* and the future *Vikrant* class aircraft carrier. The STOBAR system is simpler to build than CATOBAR — but it works only with light, and lightly armed, fighter aircraft that have a high thrust to weight ratio.

When the Eurofighter was proposed for the "Future Carrier Borne Aircraft" it was envisaged that it would operate in a STOBAR configuration. The FCBA is to be deployed on the British Royal Navy's next generation carriers, Queen Elizabeth class aircraft carrier. Instead, the Lockheed Martin Lightning II, operating in a CATOBAR configuration, will be the FCBA|.

STOVL

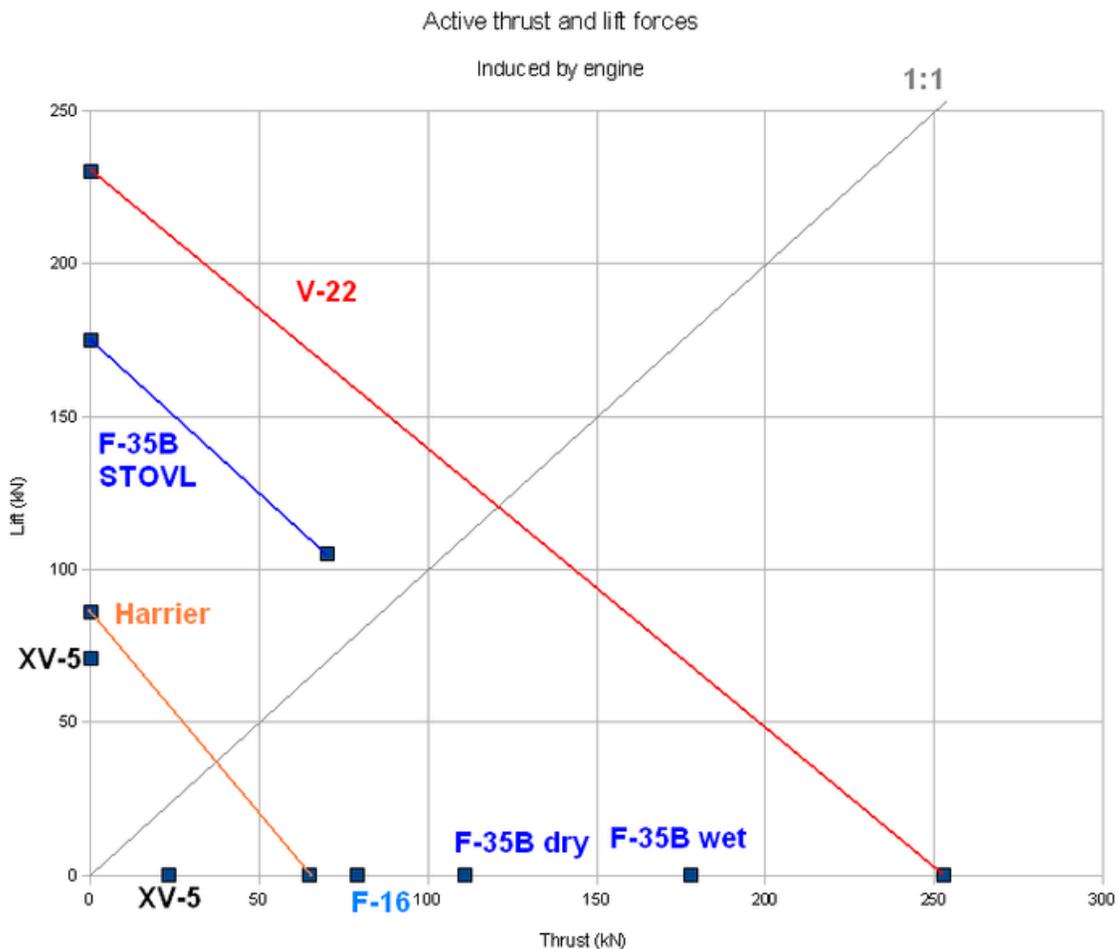
STOVL is an acronym for *short take off and vertical landing*.

This is the ability of some aircraft to take off from a short runway or take off vertically if it does not have a very heavy payload and land vertically (i.e. with no runway). The formal NATO definition (since 1991) is:

A Short Take-Off and Vertical Landing aircraft (*aéronef à décollage court et atterrissage vertical*) is a fixed-wing aircraft capable of clearing a 15 m (50 ft) obstacle within 450 m (1,500 ft) of commencing take-off run, and capable of landing vertically.

This is often accomplished on aircraft carriers through the use of "ski-jump" runways, instead of the conventional catapult system. STOVL use tends to allow aircraft to carry a larger payload as compared to during VTOL use, while still only requiring a short runway. The most famous example is probably the Hawker Siddeley Harrier, which though technically a VTOL aircraft, is operationally a STOVL aircraft due to the extra weight it carries at take off for fuel and armaments. The same is true of the F-35B Lightning II, which demonstrated VTOL capability in test flights but is operationally STOVL.

History



Comparison of lift and thrust for various aircraft

In 1951, the Lockheed XFV-1 and the Convair XFY tailsitters were both designed around the Allison YT40 turboprop engine driving contra-rotating propellers.

The British Hawker P.1127 took off vertically in 1960, and demonstrated conventional take off in 1961. By 1964 the first development aircraft, the Hawker Siddeley Kestrel, were flying. These were flown by a tripartite squadron of British, US and West German pilots. The first Hawker Siddeley Harrier flew in 1967.

In 1962, Lockheed built the XV-4 Hummingbird for the U.S. Army. It sought to "augment" available thrust by injecting the engine exhaust into an ejector pump in the fuselage. First flying vertically in 1963, it suffered a fatal crash in 1964. It was converted into the XV-4B Hummingbird for the U.S. Air Force as a testbed for separate, vertically mounted lift engines, similar to those used in the Yak-38 Forger. That plane flew and later crashed in 1969. The Ryan XV-5 Vertifan, which was also built for the U.S. Army at the same time as the Hummingbird, experimented with gas driven lift fans. That plane used fans in the nose and each wing, covered by doors which resembled half garbage can lids when raised. However, it crashed twice, and proved to generate a disappointing amount of lift, and was difficult to transition to horizontal flight.

Of dozens of VTOL and V/STOL designs tried from the 1950s to 1980s, only the subsonic Hawker Siddeley Harrier and Yak-38 Forger reached operational status, with the Forger being withdrawn after the fall of the Soviet Union.

Boeing had studied another odd-looking supersonic fighter in the 1960s which never made it beyond photos in Aviation Week. Rockwell International built, and then abandoned, the Rockwell XFV-12 supersonic fighter which had an unusual wing which opened up like window blinds to create an ejector pump for vertical flight. It never generated enough lift to get off the ground despite developing 20,000 lbf of thrust. The French had a nominally Mach 2 Dassault Mirage IIIV fitted with no less than 8 lift engines that flew (and crashed), but did not have enough space for fuel or payload for combat missions. The German EWR VJ 101 used swiveling engines mounted on the wingtips with fuselage mounted lift engines, and the VJ 101C X1 reached supersonic flight (Mach 1.08) on July 29, 1964. The supersonic Hawker Siddeley P.1154 which competed with the Mirage IIIV for NATO use was cancelled even as the aircraft were being built.

NASA uses the abbreviation SSTOVL for Supersonic Short Take-Off / Vertical Landing, and as of 2011, the X-35B/F-35B are the only aircraft to conform with this combination within one flight.

The experimental Mach 1.7 Yakovlev Yak-141 did not find an operational customer, but its rotating rear nozzle technology found good use with the F-35B. The F-35 Lightning II is expected to enter service by 2011.

Larger STOVL designs were considered, the Armstrong Whitworth AW.681 cargo aircraft was under development when cancelled in 1965. The Dornier Do 31 got as far as three experimental aircraft before cancellation in 1970.

Although mostly a VTOL design, the V-22 Osprey has increased payload when taking off from a short runway.

V/STOL



RAF Harrier GR9 arrives at RIAT 2008



A U.S. Marine Corps MV-22 Osprey prepares to land aboard a ship

Vertical and/or short take-off and landing (V/STOL) is a term used to describe aircraft that are able to take-off or land vertically or on short runways. Vertical takeoff and landing (VTOL) describes craft which do not require runways at all. Generally, a V/STOL aircraft needs to be able to hover; helicopters are not typically considered under the V/STOL classification.

Most V/STOL aircraft types were experiments or outright failures from the 1950s to 1970s. V/STOL aircraft types that have been produced in large numbers include the Harrier, Yak-38 Forger and V-22 Osprey.

A rolling takeoff, sometimes with a ramp (ski-jump), reduces the amount of thrust required to lift an aircraft from the ground (compared with vertical takeoff), and hence increases the payload and range that can be achieved for a given thrust. For instance, the Harrier is incapable of taking off vertically with a full weapons and fuel load. Hence V/STOL aircraft generally use a runway if it is available. I.e. Short Take Off and Vertical Landing (STOVL) or Conventional Take-off and Landing (CTOL) operation is preferred to VTOL operation.

V/STOL was developed to allow fast jets to be operated from clearings in forests, from very short runways, and from small aircraft carriers that would previously only have been able to carry helicopters.

The main advantage of V/STOL aircraft is closer basing to the enemy, which reduces response time and tanker support requirements. In the case of the Falklands War, it also permitted high performance fighter air cover and ground attack without a large aircraft carrier equipped with a catapult.

The latest V/STOL aircraft is the F-35B, which is expected to enter service in 2016.

Lists of V/STOL aircraft

Vectored thrust

- Ryan XV-5. Ducts in wings with half-trash can lid covers.
- Hawker P.1127/Kestrel/Harrier; four rotating nozzles for vectored thrust of fan and jet exhaust.

Tilt-rotor

- Bell XV-3
- Bell XV-15
- Bell 609
- Bell-Boeing V-22 Osprey (scale up of XV-15)

Tilt-wing

- Fairchild X-19 - four rotating propellers, tilt-wing.
- Canadair CL-84 Dynavert, two turboprop tilt-wing in RCAF service from 1960
- LTV XC-142 four-engine tilt-wing cross-shafted turboprop
- Bell X-22 rotating ducted propellers. Small transport prototype. Slightly smaller than V-22 Osprey.
- Hiller X-18

Separate thrust and lift

- Kamov Ka-22
- Lockheed XV-4 Hummingbird
- Mirage "Balzac" V (V stands for vertical and is a modified Mirage III)
- Mirage III V the first VTOL capable of supersonic flight (Mach 2.03 during tests)
- Yakovlev Yak-141 Flown, but not operational
- Yakovlev Yak-38

Supersonic

Although many aircraft have been proposed, built, and some even tested, the F-35B is expected to be the first supersonic VTOL aircraft in operational service.

- Bell D-188A Mach 2 swivelling engines, mockup stage
- EWR VJ 101 Mach 2 fighter from Germany similar to Bell D-188A, flown to M1.04 but not operational
- Mirage III V the first VTOL capable of supersonic flight (Mach 2.03 during tests), not operational
- Hawker Siddeley P.1154 M1.7 Supersonic Harrier. Never built
- Rockwell XFV-12 Built but could not lift its own weight
- Yakovlev Yak-141 Flown, but not operational
- Lockheed Martin X-35B/F-35B uses a vectored-thrust engine (the Pratt & Whitney F135) plus a lifting fan. First aircraft capable of demonstrating transition from short take-off to supersonic flight to vertical landing on the same sortie.

VTOHL

VTOHL is an acronym for **vertical take-off and horizontal landing**. **VTOHL** describes airplanes that can lift off vertically but land in the traditional manner.

While many VTOL aircraft can operate in this fashion, some planes must land normally after taking off vertically due to a vertical landing either being impossible (requiring a structure to orient it vertically for take off) or impractical (complexities and power requirements in descending on engine power with no horizontal velocity).

Examples include the German rocket plane, the Space Shuttle, and the Buran spacecraft.

Also **VTOSL** which is **Vertical Takeoff Short Landing**, done by Harriers and also with other V/STOL Aircraft.

VTVL

VTVL is an abbreviation for *vertical takeoff, vertical landing*. It is most often used describing reusable rockets. Multiple VTVL craft have flown. The aviation equivalent of this mode of operation is VTOL.

VTVL

The most famous VTVL regime craft was the McDonnell Douglas DC-X in the 1990s.

Presently, Armadillo Aerospace's Scorpius / Super Mod, Masten Space Systems' Xombie and Unreasonable Rocket's Blue Ball are flying VTVL rockets that are competing / have recently competed in the Northrop Grumman / NASA Lunar Lander Challenge.

SpaceX plans to eventually install deployable landing gear on the Dragon spacecraft and use the vehicle's thrusters to perform a land-based landing.

Three VTVL craft have been proffered to NASA in response to NASA's suborbital reusable launch vehicle (sRLV) solicitation under NASA's Flight Operations Program: the Blue Origin New Shepard, the Masten Xaero, and the Armadillo Super Mod.

Other approaches

There are other approaches for reusable rocket configurations, like VTHL (Vertical Takeoff, Horizontal Landing that X-33 would have used) and HTHL (Both takeoff and landing using a runway, like an aeroplane).

VTHL

VTHL — *vertical takeoff, horizontal landing* — is the mode of operation for all current and formerly operational orbital spaceplanes, such as the Boeing X-37, the NASA Space Shuttle, the 1988 Soviet Buran space shuttle, as well as the circa-1960 USAF X-20 Dyna-Soar.

There have also been several VTHL proposals for that never flew including NASA Space Shuttle proposed replacements X-33 and VentureStar. The 1990s NASA concept spaceplane, the HL-20 Personnel Launch System (HL stands for "Horizontal Lander"), was VTHL, as was a circa-2003 derivative of the HL-20, the Orbital Space Plane concept.

As of March 2011, two VTHL commercial spaceplanes are currently in various stages of development. Both are successors to the HL-20 design. The Sierra Nevada Corporation Dream Chaser follows the HL-20 outer mold line while the Orbital Sciences Corporation Prometheus is a blended lifting body spaceplane that follows the outer mold line of the circa-2003 *Orbital Space Plane*, itself a derivative of the HL-20.

While VTHL is the term used in spaceflight systems design, the aviation literature often uses VTOHL (Verticle TakeOff and Horizontal Landing), as well as several VTOHL aviation-specific subtypes: VTOCL, VTOSL, VTOBAR).

HTHL

HTHL or *horizontal takeoff and horizontal landing* is the spaceflight equivalent of aviation HTOL (principally CTOL, but also other subtypes STOCL, CTOSL, STOL, CTOBAR, CATOSL, CATOCL, CATOBAR, STOBAR). This is the mode of operation for the first private commercial spaceplane, the two-stage-to-space Tier One from the Ansari X-Prize SpaceShipOne/WhiteKnightOne combination. It is also used for the upcoming Tier 1b SpaceShipTwo/WhiteKnightTwo combination. A prominent example of its use was the X-15 program. The failed proposals for NASA Space Shuttle replacements, X-30 NASP used this mode of operation.

The Lynx rocketplane is a suborbital HTHL spaceplane that is slated to begin atmospheric flight testing in late 2011. Reaction Engines Skylon, a design descendant of the British HOTOL program, is an HTHL spaceplane currently under development in the UK.

Both the Lynx rocketplane and SpaceShipTwo have been proffered to NASA to carry suborbital research payloads in response to NASA's suborbital reusable launch vehicle (sRLV) solicitation under the NASA Flight Operations Program.

Another example is the 1960s Northrop HL-10 atmospheric test aircraft where the HL stands for "Horizontal Lander".

HTVL

HTVL or *horizontal takeoff and vertical landing* is the spaceflight equivalent of aviation HTOVL (and its subtypes CTOVL, STOVL, CATOVL). This mode of operation has not been used, but has been proposed for some systems that use a two-stage to orbit launch system with a plane based first stage, and a capsule return vehicle. One of the few HTVL vehicles is the 1960s concept spacecraft Hyperion SSTO, designed by Philip Bono.

Chapter- 10

Landing



Piper Cherokee landing sequence from approach to flare



An airliner flaring at London Heathrow Airport (Air Jamaica Airbus A340-300)



A landing Qantas Boeing 747-400 passes close to houses on the boundary of London Heathrow Airport, England



An unusual landing; a Piper J3C-65 Cub lands on a trailer as part of an airshow.



F-18 landing on an aircraft carrier

Landing is the last part of a flight, where a flying animal, aircraft, or spacecraft returns to the ground. When the flying object returns to water, the process is called **alighting**,

although it is commonly called "landing" and "touchdown" as well. A normal aircraft flight would include several parts of flight including taxi, takeoff, climb, cruise, descent and landing.

Aircraft

Aircraft usually land at an airport on a firm runway or helicopter landing pad, generally constructed of asphalt concrete, concrete, gravel or grass. Aircraft equipped with pontoons are able to land on water. Aircraft also sometimes use skis to land on snow or ice.

To land, the airspeed and the rate of descent are reduced to where the object descends at a slow enough rate to allow for a gentle touch down. Landing is accomplished by slowing down and descending to the runway. This speed reduction is accomplished by reducing thrust and/or inducing a greater amount of drag using flaps, landing gear or speed brakes. When a fixed wing aircraft approaches the ground, the pilot will move the control column back to execute a flare or round-out. This increases the angle of attack. Progressive movement of the control column back will allow the aircraft to settle onto the runway at minimum speed, landing on its main wheels first in the case of a tricycle gear aircraft or on all three wheels simultaneously in the case of a conventional landing gear-equipped aircraft.

Light aircraft

In a light aircraft, with little crosswind, the ideal landing is when contact with the ground occurs as the forward speed is reduced to the point where there is no longer sufficient airspeed to remain aloft. The stall warning is often heard just before landing, indicating that this speed and altitude have been reached. The result is very light touch down.

Light aircraft landing situations, and the pilot skills required, can be divided into four types:

- Normal landings
- Crosswind landings - where a significant wind not aligned with the landing area is a factor
- Short field landings - where the length of the landing area is a limiting factor
- Soft and unprepared field landings - where the landing area is wet, soft or has ground obstacles such as furrows or ruts to contend with

Large aircraft

In large transport category (airliner), aircraft pilots land the aircraft by "flying the airplane on to the runway." The airspeed and attitude of the plane are adjusted for landing. The airspeed is kept well above stall speed and at a constant rate of descent. A flare is performed just before landing, and the descent rate is significantly reduced, causing a light touch down. Upon touchdown, spoilers (sometimes called "lift dumpers")

are deployed to dramatically reduce the lift and transfer the aircraft's weight to its wheels, where mechanical braking, such as an autobrake system, can take effect. Reverse thrust is used by many jet aircraft to help slow down just after touch-down, redirecting engine exhaust forward instead of back. Some propeller planes also have this feature, where the blades of the propeller are re-angled to push air forward instead of back.

Environmental factors

Factors such as crosswind where the pilot will use a crab landing or a slip landing will cause pilots to land slightly faster and sometimes with different aircraft attitude to ensure a safe landing.

Other factors affecting a particular landing might include: the plane size, wind, weight, runway length, obstacles, ground effects, weather, runway altitude, air temperature, air pressure, air traffic control, visibility, avionics and the overall situation.

For example, landing a multi-engine turboprop military such as a C-130 Hercules, under fire in a grass field in a war zone, requires different skills and precautions than landing a single engine plane such as a Cessna 150 on a paved runway in uncontrolled airspace, which is different from landing an airliner such as a Airbus A380 at a major airport with air traffic control.

Parachutes

The term "landing" is also applied to people or objects descending to the ground using a parachute. These objects are considered to be in a controlled descent instead of actually flying. A parachute works by capturing air inducing enough drag that the object that is falling hits the ground at a relatively slow speed. There are many examples of parachutes in nature, including the seeds of a dandelion.

Rockets

Sometimes, a safe landing is accomplished by using multiple forms of lift, thrust and dampening systems. The Apollo Lunar Module used a rocket and landing gear to land on the moon. Several Soviet rockets including the Soyuz spacecraft have used parachutes and airbag landing systems to dampen the landing on earth.

Chapter- 11

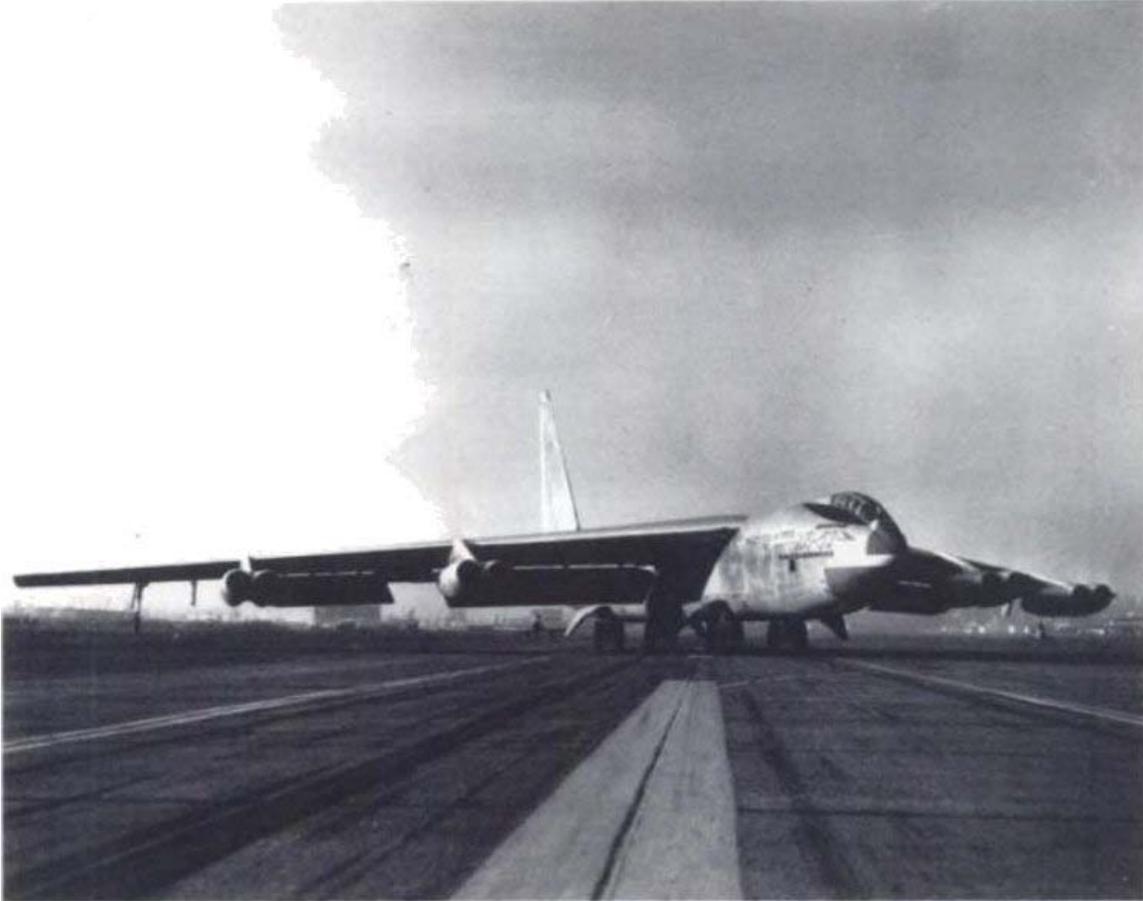
Crosswind Landing and Belly Landing

Crosswind landing

A **crosswind landing** is a landing maneuver in which a significant component of the prevailing wind is perpendicular to the runway center line.

Significance

Aircraft in flight are subject to the direction of the winds in which the aircraft is operating. For example, an aircraft in flight that is pointed directly north along its longitudinal axis will, generally, fly in that northerly direction. However, if there is a west wind in the air in which the aircraft is flying, then the actual trajectory of the aircraft will be slightly to the east of north. If the aircraft was landing on a northbound runway, it would need to compensate for this easterly component of velocity caused by the west crosswind.



XB-52 performing a crab landing having nose pointed toward incoming wind, but undercarriage aligned along the runway

In situations where a crosswind is present, the aircraft will adopt a yaw orientation with respect to the runway and will drift laterally as it approaches the runway. These pose significant safety issues when safe operation of the undercarriage requires the body and the velocity of the aircraft to be aligned with the runway at touch down. The landing gear on the B-52 included an unusual feature to counteract the problem: all landing gear bogies could be steered, allowing the aircraft to land with the wheels facing the direction of travel even if the nose was not pointed in the same direction.

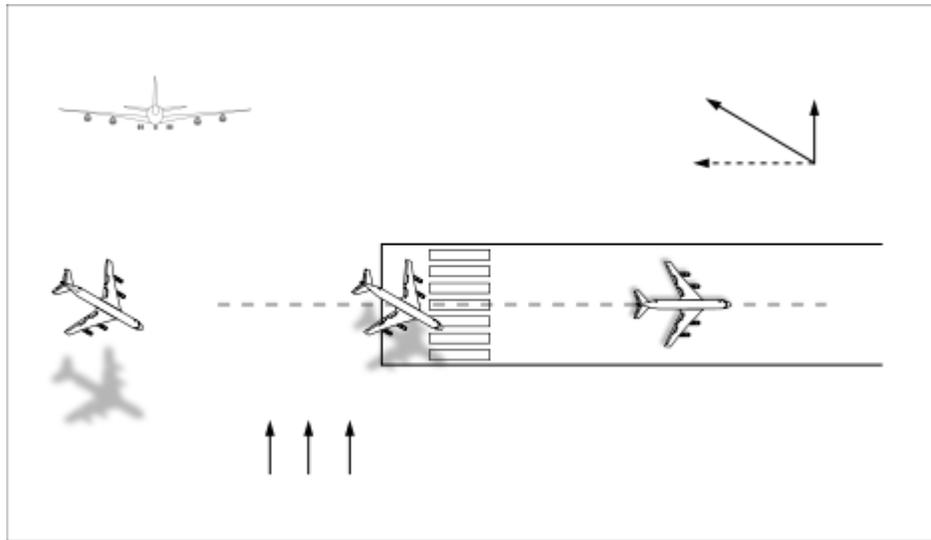
To meet these conflicting requirements, three standard procedures are used for executing a safe landing in a cross wind situation. These landings are called the Crab, De-Crab and Sideslip techniques.

If the crosswind landing is not executed safely, the aircraft may experience wingstrike, where a wing hits the runway.

Techniques

The following guidelines are advised by Boeing for a crosswind landing. These guidelines assume steady wind (no gusting). These winds are measured at 10 m (33 feet) tower height for a runway 45 m (148 feet) in width. Basically, there are 3 landing techniques which may be used to correct for cross winds: De-Crab, Crab, and Sideslip.

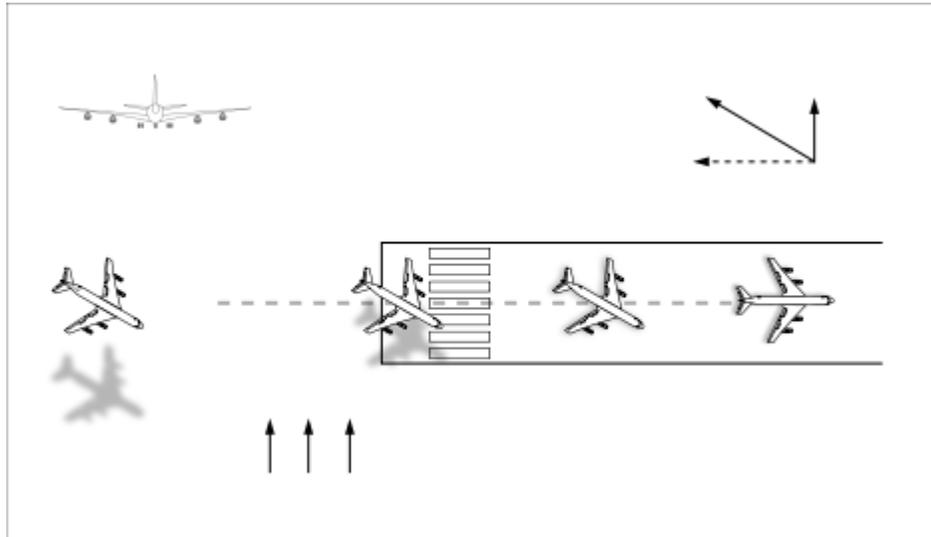
De-Crab



De-crab

The objective of this technique is to maintain wings level and the aircraft position near the runway centerline during approach. The nose points into the wind so that the aircraft approaches the runway slightly skewed with respect to the runway centerline (crabbing). This gives the impression of approaching the runway flying sideways, which can be disorienting for the pilot. Position is maintained by balancing the crosswind component, or more accurately the drag force arising from it, with engine thrust. Wings are maintained level throughout the approach. Just before the flare, opposite rudder (downwind rudder) is applied to eliminate the crab, with a simultaneous application of opposite aileron to maintain a wings-level attitude, so that at touch down, the body, velocity vector, and bank angle are all aligned with the runway, and the aircraft is positioned near the center.

Crab



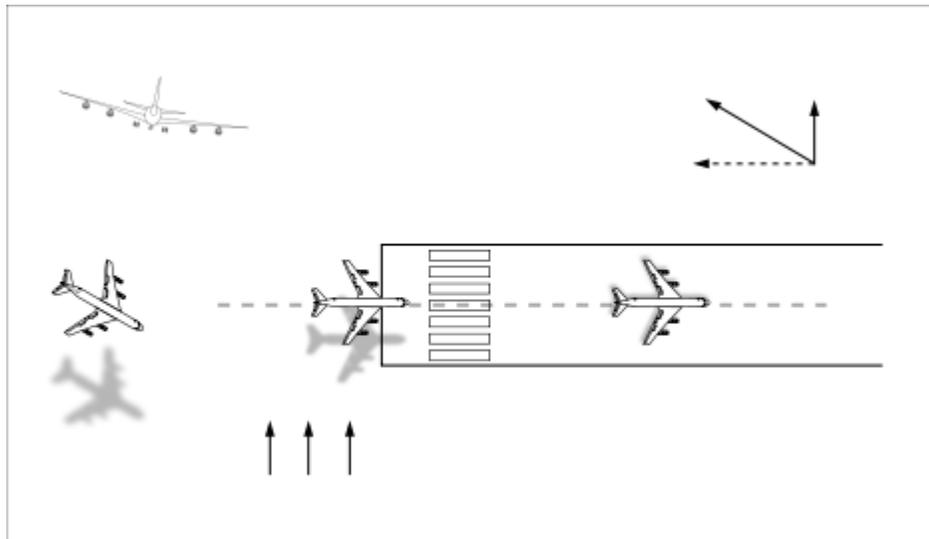
Crab

The airplane can land using crab only (zero side slip) up to the landing crosswind guideline speeds.

On dry runways, upon touchdown the airplane tracks towards the upwind edge of the runway while de-crabbing to align with the runway. Immediate upwind aileron is needed to ensure the wings remain level while rudder is needed to track center line. The greater the amount of crab at touchdown, the larger the lateral deviation from the point of touchdown. For this reason, touchdown in a crab only condition is not recommended when landing on a dry runway.

On very slippery runways, landing the airplane using crab only reduces drift towards the downwind side of a touchdown, and may reduce pilot workload since the airplane does not have to be de-crabbed before touchdown. However, proper rudder and upwind aileron must be applied after touchdown to ensure directional control is maintained.

Sideslip



Sideslip

This sideslip crosswind technique is to maintain the aircraft's heading aligned with the runway centerline. The initial phase of the approach is flown using the Crab technique to correct for drift. The aircraft heading is adjusted using rudder and ailerons to align with the runway. This places the aircraft at a constant sideslip angle, which its natural stability will tend to correct. Sufficient rudder and aileron must be applied continuously to maintain the sideslip at this value. The dihedral action of the wings has a tendency to cause the aircraft to roll, so aileron must be applied to check the bank angle.

With a slight residual bank angle, a touchdown is typically accomplished with the upwind main wheels touching down just before the downwind wheels. Excessive control must be avoided because over-banking could cause the engine nacelle or outboard wing flap to contact the runway/ground.

In strong crosswind conditions, it is sometimes necessary to combine the crab technique with the sideslip technique.

Belly landing



This F-106 made an unmanned belly landing.



This A-10 made a belly landing at Edwards AFB.

A **belly landing** or **gear-up landing** is when an aircraft lands without its landing gear fully extended and uses its underside, or belly, as its primary landing device. Normally the term *gear-up landing* refers to incidents in which the pilot forgets to extend the landing gear, while *belly landing* refers to incidents where a mechanical malfunction prevents the pilot from extending the landing gear.

During a belly landing, there is normally extensive damage to the airplane. Belly landings carry the risk that the aircraft may flip over, disintegrate, or catch fire if it lands too fast or too hard. Extreme precision is needed to ensure that the plane lands as straight and level as possible while maintaining enough airspeed to maintain control. Strong crosswinds, low visibility, damage to the airplane, or unresponsive instruments or controls greatly increase the danger of performing a belly landing. Still, belly landings are one of the most common types of aircraft accidents, and are normally not fatal if executed carefully.

Causes and prevention

Pilot error

The most common cause of gear-up landings is the pilot simply forgetting to extend the landing gear before touchdown. On any retractable gear aircraft, lowering the landing gear is part of the pilot's landing checklist, which also includes items such as setting the flaps, propeller and mixture controls for landing. Pilots who ritually perform such checklists before landing are less likely to land gear-up. However, some pilots neglect

these checklists and perform the tasks by memory, increasing the chances of forgetting to lower the landing gear. Even studious pilots are at risk, for they may be distracted and forget to perform the checklist or be interrupted in the middle of it by other duties such as collision avoidance or another emergency. The common nature of gear-up landings caused by pilot error has led to an adage within the aviation community: *"There are two types of pilots: Those that have landed gear up, and those that will."*

All aircraft with retractable landing gear are required to have a way to indicate the status of the landing gear, which is normally a set of lights that change colors from red to amber to green depending on whether the gear are up, in transit, or down. However, a distracted pilot may forget to look at these lights. This has led to aircraft designers building extra safety systems in the aircraft to reduce the possibility of human error. In small aircraft this most commonly takes the form of a warning light and horn which operate when any of the landing gear is not locked down and any of the engine throttles are retarded below a cruise power setting. However, the horn has been useless in situations when the pilot was unfamiliar with the aircraft and did not know what the horn sounding was meant to indicate. Pilots have sometimes confused the landing gear warning horn with the stall warning horn. In other cases, pilots cannot hear the horn on older aircraft due to wearing a modern noise-canceling headset.

In larger aircraft the warning system usually excludes the engine power setting and instead warns the pilot when the flaps are set for landing but the landing gear is not. An alternative system uses the ground proximity warning system or radar altimeter to engage a warning when the airplane is close to the ground and descending with the gear not down. Most airliners incorporate a voice message system which eliminates the ambiguity of a horn or buzzer and instead gives the pilot a clear verbal indication: *"GEAR NOT DOWN"*. In addition, large aircraft are designed to be operated by two pilots working as a team. One flies the aircraft and handles communications and collision avoidance, while the other operates the aircraft systems. This provides a sort of human redundancy which reduces the workload placed on any one crew member, and provides for one crew member to be able to check the work of the other. The combination of advanced warning systems and effective crew training has made gear-up landing accidents in large aircraft extremely rare.

In some cases the pilot may be warned of an unsafe gear condition by the aircraft's flying characteristics. Often very sleek, high-performance airplanes will be very difficult to slow to a safe landing speed without the aerodynamic drag of the extended landing gear.

Mechanical failure

Mechanical failure is another cause of belly landings. Most landing gear are operated by electric motors or hydraulic actuators. Multiple redundancies are usually provided to prevent a single failure from failing the entire landing gear extension process. Whether electrically or hydraulically operated, the landing gear can usually be powered from multiple sources. In case the power system fails, an emergency extension system is always available. This may take the form of a manually-operated crank or pump, or a

mechanical free-fall mechanism which disengages the uplocks and allows the landing gear to fall due to gravity.

In cases where only one landing gear leg fails to extend, the pilot may choose to retract all the gear and perform a belly landing because he may believe it to be easier to control the aircraft during rollout with no gear at all than with one gear missing.

Some aircraft, like the A-10 Thunderbolt II, are specifically designed to make belly landings safer. In the A-10's case, the retracted main wheels protrude out of their nacelles, so the plane virtually rolls on belly landings.

Examples

In July 2006 an Australian F-111 bomber made an emergency landing after a wheel on the landing gear fell off after take-off. The pilot circled the airfield for three hours burning off fuel before coming in with his landing gear retracted and arrestor hook deployed. The F-111 suffered only superficial damage.

On 4 July 2000 Malév Flight 262, a Tupolev Tu-154, performed a gear-up touchdown during the landing and skidded on the runway, but was able to take off and land normally after a go-around. No injuries were reported.

Chapter- 12

Emergency Landing and Deadstick Landing

Emergency landing



JetBlue Airways Flight 292 making an emergency landing at LAX

An **emergency landing** is a landing made by an aircraft in response to a crisis which either interferes with the operation of the aircraft or involves sudden medical emergencies necessitating diversion to the nearest airport.

Types of emergency landings

There are several different types of emergency landings for powered aircraft: planned landing or unplanned landing

- *Forced landing*, the aircraft is forced to make a landing due to technical problems, medical problems or weather conditions. Landing as soon as possible is a priority, no matter where. A forced landing may be necessary even if the aircraft is still flyable. This can arise to either facilitate emergency medical or police assistance or get the aircraft on the ground before a major system failure occurs which would force a crash landing or ditch situation.
- *Precautionary landing*, may result from a planned landing at a location about which information is limited, from unanticipated changes during the flight, or from abnormal or even emergency situations. The sooner a pilot locates and inspects a potential landing site, the less the chance of additional limitations being imposed by worsening aircraft conditions, deteriorating weather, or other factors.
- *Crash landing*, is caused by the failure of or damage to vital systems such as engines, hydraulics, or landing gear, and so a landing must be attempted where a runway is needed but none is available. The pilot is essentially trying to get the aircraft on the ground in a way which minimizes the possibility of injury or death to the people aboard.
- *Ditching*, is the same as a crash landing, only on water. After the disabled aircraft makes contact with the surface of the water, the aircraft will eventually sink if it is not designed to float, although the craft may well float for hours depending on damage.

Procedures

If there is no engine power available during a forced landing, a fixed-wing aircraft glides, while a rotary winged aircraft (helicopter) autorotates to the ground by trading altitude for airspeed to maintain control. Pilots often practice "simulated forced landings", in which an engine failure is simulated and the pilot has to get the aircraft on the ground safely, by selecting a landing area and then gliding the aircraft at its best gliding speed.

If there is a suitable landing spot within the aircraft's gliding or autorotation distance, an unplanned landing will often result in no injuries or significant damage to the aircraft, since powered aircraft generally use little or no power when they are landing. Light aircraft can often land safely on fields, roads, or gravel river banks (or on the water, if they are float-equipped); but medium and heavy aircraft generally require long, prepared runway surfaces because of their heavier weight and higher landing speeds. Glider pilots routinely land away from their base and so most cross-country pilots are in current practice.

UAV forced landing research

Since 2003, research has been conducted on enabling UAVs to perform a forced landing autonomously.

Notable examples of emergency landings

Large airliners have multiple engines and redundant systems, so forced landings are extremely rare for them, but some notable ones have occurred. The most famous example is the Gimli Glider, an Air Canada Boeing 767 that ran out of fuel and glided to a safe landing in Gimli, Manitoba, Canada on July 23, 1983. On June 1982, British Airways Flight 9, a Boeing 747 en route from Kuala Lumpur to Perth lost power in all four engines, three of which subsequently recovered, eventually diverting to Jakarta. On April 28, 1988, Aloha Airlines Flight 243 experienced an explosive decompression mid-flight, forcing an emergency landing at the Kahului Airport with only one casualty, flight attendant Clarabell "C.B." Lansing. More recently, Air Transat Flight 236 ran out of fuel over the Atlantic Ocean on August 24, 2001 and made a successful forced landing in the Azores.

A less successful crash landing involved Southern Airways Flight 242 on April 4, 1977. The DC-9 lost both of its engines due to hail and heavy rain in a thunderstorm and, unable to glide to an airport, made a forced landing on a highway near New Hope, Georgia, United States. The plane made a hard landing and was still carrying a large amount of fuel, so it burst into flames, killing the majority of the passengers and several people on the ground.

Airliners frequently make emergency landings, and almost all of them are uneventful. However because of their inherent uncertain nature, they can quickly become crash landings or worse. Some notable instances include Swissair Flight 111, which crashed near Halifax, Nova Scotia, Canada on September 2, 1998 while dumping fuel in preparation for a precautionary landing due to fire; United Airlines Flight 232, which broke up while landing at Sioux City, Iowa, U.S.A. on July 19, 1989; and Air Canada Flight 797, which burned after landing at Cincinnati/Northern Kentucky International Airport on June 2, 1983 after a fire started in the cabin.

Emergency water landings



US Airways Flight 1549 after ditching in the Hudson River

Several passenger and cargo aircraft and helicopter ditchings have been documented. These intentional emergency water landings are the result of an in-flight fuel depletion or mechanical malfunction and not an accidental overshoot of a runway or an uncontrolled crash into a body of water. The following figures show survival rates for passengers and crew:

- US Airways Flight 1549, Airbus A320, New York City to Charlotte/Douglas International Airport, 15 January 2009, made a controlled safe water ditch into the Hudson River after losing thrust in both engines due to birdstrike at about 3000 feet altitude three minutes into the flight after a normal takeoff from LaGuardia Airport; 155 passengers and crew made an orderly evacuation as a NYC fireboat towed the floating aircraft with passengers standing on the wing. The survival rate was 100%.
- On 6 August 2005, Tuninter Flight 1153 (an ATR 72) ditched off the Sicilian coast after running out of fuel. Of 39 aboard, 23 survived with injuries including serious burns. The plane's wreck was found in three pieces. The survival rate was 59%.
- On December 4, 2004, Miami Air Lease' N41626, a Convair CV-340 cargo airplane with two pilots on board experienced an engine failure enroute between Opa-locka, Florida and Nassau, Bahamas. Unable to feather the propeller, the airplane rapidly lost altitude and the pilots ditched into Maule Lake, North Miami Beach, Florida. Both occupants were rescued. The survival rate was 100%.

- On 16 January 2002, Garuda Indonesia Flight 421 (a Boeing 737) successfully ditched into the Bengawan Solo River near Yogyakarta, Java Island after experiencing a twin engine flameout during heavy precipitation and hail. The pilots tried to restart the engines several times before making the decision to ditch the aircraft. Photographs taken shortly after evacuation show that the plane came to rest in knee-deep water. Of the 60 occupants, one flight attendant was killed. The survival rate was 98%.
- On 23 November 1996, Ethiopian Airlines Flight 961 (a Boeing 767-260ER), ditched in the Indian Ocean near Comoros after being hijacked and running out of fuel, killing 125 of the 175 passengers and crew on board. Unable to operate flaps, it impacted at high speed, dragging its left wingtip before tumbling and breaking into three pieces. The panicking hijackers were fighting the pilots for the control of the plane at the time of the impact, which caused the plane to roll just before hitting the water, and the subsequent wingtip hitting the water and breakup are a result of this struggle in the cockpit. Some passengers were killed on impact or trapped in the cabin when they inflated their life vests before exiting. Most of the survivors were found hanging onto a section of the fuselage that remained floating. The survival rate was 29%.
- On October 16, 1982, Colombian Air Force C 130 Hercules cargo aircraft ditched in Atlantic Ocean 330 kilometers east of Cape May, New Jersey after running out of fuel. Probably due to the buoyancy of the empty fuel tanks, the hull floated for 56 hours. 8 of the 13 occupants were rescued. The survival rate was 62%.
- On 2 May 1970, ALM Flight 980 (a McDonnell Douglas DC-9-33CF), ditched in mile-deep water after running out of fuel during multiple attempts to land at Princess Juliana International Airport on the island of Saint Maarten in the Netherlands Antilles under low-visibility weather. Insufficient warning to the cabin resulted in several passengers and crew still either standing or with unfastened seat belts as the aircraft struck the water. Of 63 occupants, 40 survivors were recovered by U.S. military helicopters. The survival rate was 63%.
- On 21 August 1963, an Aeroflot Tupolev Tu-124 ditched into the Neva River in Leningrad after running out of fuel. The aircraft floated and was towed to shore by a tugboat which it had nearly hit as it came down on the water. The tug rushed to the floating aircraft and pulled it with its passengers near to the shore where the passengers disembarked onto the tug; all 52 on board escaped without injuries. The survival rate was 100%.
- On 23 September 1962, Flying Tiger Line Flight 923, a Lockheed 1049H-82 Super Constellation passenger aircraft with a crew of 8 and 68 U.S. military (paratrooper) passengers ditched in the North Atlantic about 500 miles west of Shannon, Ireland after losing three engines on a flight from Gander, Newfoundland to Frankfurt, Germany. 45 of the passengers and 3 crew were rescued, with 23 passengers and 5 crew members being lost in the storm-swept

seas. All occupants successfully evacuated the airplane. Those who were lost succumbed in the rough seas. The survival rate for landing and evacuation was 100%. The final survival rate of the accident was 63%.

- On 16 July 1962, a New York Airways Boeing Vertol 107 helicopter made an emergency landing in New York's East River after power failure. All 22 passengers were safely evacuated. The survival rate was 100%.
- In October 1956, Pan Am Flight 6 (a Boeing 377) ditched northeast of Hawaii, after losing two of its four engines. The aircraft was able to circle around USCGC *Pontchartrain* until daybreak, when it ditched; all 31 on board survived. The survival rate was 100%.
- In April 1956, Northwest Orient Airlines Flight 2 (also a Boeing 377) ditched into Puget Sound after what was later decided to be caused by failure of the crew to close the cowl flaps on the plane's engines. All aboard escaped the aircraft after a textbook landing, but four passengers and one flight attendant succumbed either to drowning or to hypothermia before being rescued. The survival rate was 87%.
- On 26 March 1955, Pan Am Flight 845/26 ditched 35 miles from the Oregon coast after an engine tore loose. Despite the tail section breaking off during the impact the aircraft floated for twenty minutes before sinking. Survivors were rescued after a further 90 minutes in the water. The survival rate was 83%.
- On 19 June 1954, Swissair Convair CV-240 HB-IRW ditched into the English Channel because of fuel starvation, which was attributed to pilot error. All three crew and five passengers survived the ditching and could escape the plane. However, three of the passengers could not swim and eventually drowned, because there were no life jackets on board, which was not prescribed at the time. The survival rate was 63%.
- On 3 August 1953, Air France Flight 152, a Lockheed L-749A Constellation ditched 6 miles from Fetiye Point, Turkey, 1,5 miles offshore into the Mediterranean Sea on a flight between Rome, Italy and Beirut, Lebanon. The propeller had failed due to blade fracture. Due to violent vibrations, engine number three broke away and control of engine number four was lost. The crew of eight and all but four of the 34 passengers were rescued. The survival rate was 91%.
- On 16 April 1952, the de Havilland Australia DHA-3 Drover VH-DHA operated by the Australian Department of Civil Aviation with 3 occupants was ditched in the Bismarck Sea between Wewak and Manus Island. The port propeller failed, a propeller blade penetrated the fuselage and the single pilot was rendered unconscious; the ditching was performed by a passenger. The survival rate was 100%.

- On 11 April 1952, Pan Am Flight 526A ditched 11,3 NW of Puerto Rico due to engine failure after take off. Many survived the initial ditching but panicking passengers refused to leave the sinking wreck and drowned. 52 passengers were killed, 17 passengers and crew members were rescued by the USCG. After this accident it was recommended to implement pre-flight safety demonstrations for over-water flights. The survival rate was 25%.

605 of 871 occupants of the above listed ditchings survived. A lot of passengers weren't killed by the impact but drowned because of hypothermia or panic. The average survival rate of the accidents listed above is 69%.

Deadstick landing

A **deadstick landing**, also called a **dead-stick landing** or **forced landing**, occurs when an aircraft loses all of its propulsive power and is forced to land. The term is often misunderstood, as the flight controls in the majority of aircraft are either fully or partially functional, even with no engine power. Instead, the term refers to the wooden propeller (the "stick") being stopped in an engine-out setting.

All fixed-wing aircraft have some capability to glide with no engine power; that is, they do not sink straight down like a stone, but rather continue to glide horizontally while descending. After a loss of power, the pilot's goal is to fly the descending aircraft to the most suitable landing spot within gliding distance, and then land with the least amount of damage possible. The area open for potential landing sites depends on the original altitude, local terrain, and the engine-out gliding capabilities of the aircraft.

The success of the deadstick landing largely depends on the availability of suitable landing areas. A competent pilot gliding a relatively light, slow plane to a flat field or runway should result in an otherwise normal landing. A heavier, faster aircraft or a plane gliding into mountains and/or trees could result in substantial damage.

There have been several instances of large jet airliners successfully executing a deadstick landing:

1. Gimli Glider: An Air Canada Boeing 767, ran out of fuel en route from Montreal to Edmonton. The plane had insufficient glide range to complete a diversion to Winnipeg, but the crew managed to make a successful dead stick landing at an abandoned airfield at Gimli, where a car rally was underway on the runway.
2. Air Transat Flight 236: An Air Transat Airbus A330 also ran out of fuel while flying across the North Atlantic, from Toronto to Lisbon. The crew glided the aircraft over 100 miles and made a deadstick landing at a military air base in the Azores.

3. TACA Flight 110: A Boeing 737-300 traveling from Belize City, Belize to New Orleans, Louisiana, United States that lost power in both engines, but made a successful unpowered landing on a grass levee at NASA's Michoud Assembly Facility in the Michoud area of eastern New Orleans.
4. Hapag-Lloyd Flight 3378: An A310 en route from Greece to Germany experienced a landing gear problem and subsequent fuel depletion, resulting in a deadstick landing in Vienna.
5. US Airways Flight 1549: An A320 en route from New York City's LaGuardia Airport to Charlotte, North Carolina that lost both engines when it struck a flock of Canada Geese on take-off and successfully ditched in the Hudson River adjacent to Manhattan with no loss of life.

With helicopters, a forced landing involves *autorotation*, since the helicopter glides by allowing its rotor to spin freely during the descent thus generating lift.

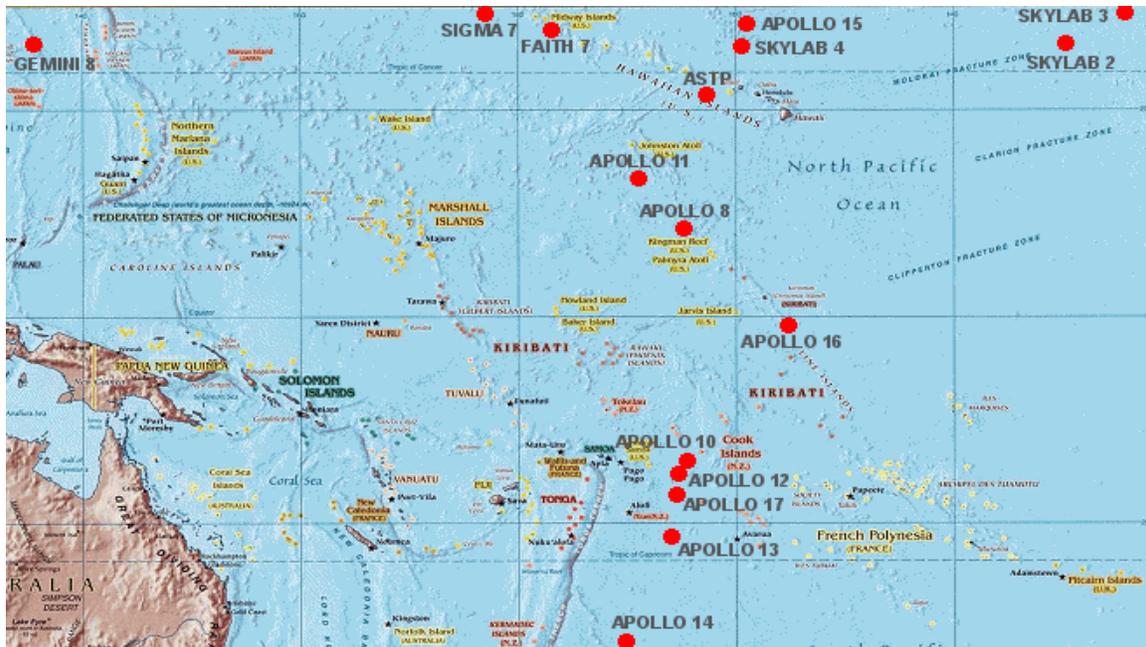
When a pilot makes an emergency landing of an aircraft that has some or all of its propulsive power still available, it is known as a *precautionary landing*. An example of such a landing occurred on April 29, 2007, at Manchester Airport in the United Kingdom, when a bird got sucked into the right engine of a Thomsonfly Boeing 757 just as it rotated off of the runway.

Chapter- 13

Splashdown



Locations of Atlantic Ocean splashdowns of American spacecraft.



Locations of Pacific Ocean splashdowns of American spacecraft.

Splashdown is the method of landing a spacecraft by parachute in a body of water. It was used by American manned spacecraft prior to the Space Shuttle program. It is also possible for the Russian Soyuz spacecraft and Chinese Shenzhou spacecraft to land in water, though this is only a contingency. The only example of an (unintentional) splashdown in Soviet history is the Soyuz 23 landing.

As the name suggests, the capsule parachutes into an ocean or other large body of water. The properties of water cushion the spacecraft enough that there is no need for a braking rocket to slow the final descent as was the case with Russian and Chinese manned space capsules, which returned to Earth over land. The American practice came in part because American launch sites are on the coastline and launch primarily over water. Russian and Chinese launch sites are far inland and most early launch aborts were likely to descend on land.

The splashdown method of landing was utilized for Mercury, Gemini and Apollo (including Skylab, which used Apollo capsules). On one occasion a Soviet spacecraft, Soyuz 23, punched through the ice of a frozen lake (nearly killing the cosmonauts), and this was unintentional.

On early Mercury flights, a helicopter attached a cable to the capsule, lifted it from the water and delivered it to a nearby ship. This was changed after the sinking of *Liberty Bell* 7. All later Mercury, Gemini and Apollo capsules had a flotation collar (similar to a rubber life raft) attached to the spacecraft to increase their buoyancy. The spacecraft would then be brought alongside a ship and lifted onto deck by crane.

After the flotation collar is attached, a hatch on the spacecraft is usually opened. At that time, some astronauts decide to be hoisted aboard a helicopter for a ride to the recovery ship and some decided to stay with the spacecraft and be lifted aboard ship via crane. (Because of his overshoot aboard *Aurora 7*, and mindful of the fate of *Liberty Bell 7*, Scott Carpenter alone egressed through the nose of his capsule instead of through the hatch, waiting for recovery forces in his life raft.) All Gemini and Apollo flights (Apollos 7 to 17) used the former, while Mercury missions from Mercury 6 to Mercury 9, as well as all Skylab missions and Apollo-Soyuz used the latter, especially the Skylab flights as to preserve all medical data. During the Gemini and Apollo programs, NASA used *MV Retriever* for the astronauts to practice water egress.

The early design concept for the new U.S. Orion Crew Exploration Vehicle featured recovery on land using a combination of parachutes and airbags, although it was also designed to make a contingency splashdown (only for an in-flight abort) if needed. Due to weight considerations, the airbag design concept was dropped. The present design concept features landings via splashdown in the Pacific Ocean off the coast of California.



Apollo after splashdown. (NASA)



Apollo hoisted onto ship. (NASA)

Disadvantages

While the water the spacecraft landed on would cushion it to a degree, the impact could still be quite violent for the astronauts.

There are several disadvantages for splashdowns, foremost among them being the danger of the spacecraft flooding and sinking. This happened to Gus Grissom when the hatch of his Mercury-Redstone 4 capsule malfunctioned and blew prematurely. The capsule sank and Grissom nearly drowned.

Another problem associated with splashdown is that if the capsule comes down far from any recovery forces the crew are exposed to greater danger. As an example, Scott Carpenter in Mercury 7 overshot the assigned landing zone by 400 km. These recovery operation mishaps can be mitigated by placing several vessels on standby in several different locations, but this is quite an expensive option.

Locations of splashdowns

Manned spacecraft

Spacecraft	Landing Date	Recovery Ship	Miss Distance (kilometres)
Freedom 7	May 5, 1961	USS <i>Lake Champlain</i> (CVS-39)	5.6
Liberty Bell 7	July 21, 1961	USS <i>Randolph</i> (CVS-15)	9.3

Friendship 7	February 20, 1962	USS <i>Noa</i> (DD-841) (USS <i>Randolph</i> (CVS-15)**)	74
Aurora 7	May 24, 1962	USS <i>Farragut</i> (DLG-6) (USS <i>Intrepid</i> (CVS-11)**)	400
Sigma 7	October 3, 1962	USS <i>Kearsarge</i> (CVS-33)	7.4
Faith 7	May 16, 1963	USS <i>Kearsarge</i> (CVS-33)	8.1
Gemini 3	March 23, 1965	USS <i>Intrepid</i> (CVS-11)	111
Gemini 4	June 7, 1965	USS <i>Wasp</i> (CVS-18)	81
Gemini 5	August 29, 1965	USS <i>Lake Champlain</i> (CVS 39)	270
Gemini 7	December 18, 1965	USS <i>Wasp</i> (CVS-18)	12
Gemini 6A	December 16, 1965	USS <i>Wasp</i> (CVS-18)	13
Gemini 8	March 17, 1966	USS <i>Leonard F. Mason</i> (DD-852) (USS <i>Boxer</i> (LPH-4)**)	2
Gemini 9A	June 6, 1966	USS <i>Wasp</i> (CVS-18)	0.7
Gemini 10	July 21, 1966	USS <i>Guadalcanal</i> (LPH-7)	6
Gemini 11	September 15, 1966	USS <i>Guam</i> (LPH-9)	5
Gemini 12	November 15, 1966	USS <i>Wasp</i> (CVS-18)	5
Apollo 7	October 22, 1968	USS <i>Essex</i> (CVS-9)	3
Apollo 8	December 27, 1968	USS <i>Yorktown</i> (CVS-10)	2
Apollo 9	March 13, 1969	USS <i>Guadalcanal</i> (LPH-7)	5
Apollo 10	May 26, 1969	USS <i>Princeton</i> (CVS-37)	2.4
Apollo 11	July 24, 1969	USS <i>Hornet</i> (CVS-12)	3.13
Apollo 12	November 24, 1969	USS <i>Hornet</i> (CVS-12)	3.7
Apollo 13	April 17, 1970	USS <i>Iwo Jima</i> (LPH-2)	1.85
Apollo 14	February 9, 1971	USS <i>New Orleans</i> (LPH-11)	1.1
Apollo 15	August 7, 1971	USS <i>Okinawa</i> (LPH-3)	1.85
Apollo 16	April 27, 1972	USS <i>Ticonderoga</i> (CVS-14)	0.55
Apollo 17	December 19, 1972	USS <i>Ticonderoga</i> (CVS-14)	1.85

	1972		
Skylab 2	June 22, 1973	USS <i>Ticonderoga</i> (CVS-14)	
Skylab 3	September 25, 1973	USS <i>New Orleans</i> (LPH-11)	
Skylab 4	February 8, 1974	USS <i>New Orleans</i> (LPH-11)	
ASTP Apollo	July 24, 1975	USS <i>New Orleans</i> (LPH-11)	1.3
Soyuz 23	October 16, 1976	Helicopter Mi-8	

*Planned recovery ship ***



Apollo splashdown. (NASA)

Unmanned spacecraft

Spacecraft	Landing Date	Recovery Ship	Miss Distance
Jupiter AM-18	May 28, 1959	USS <i>Kiowa</i> (ATF-72)	16 km
Mercury-Big Joe	September 9, 1959	USS <i>Strong</i> (DD-758)	925 km
Mercury-Little Joe 2	December 4, 1959	USS <i>Borie</i> (DD-704)	? km
Mercury-Redstone 1A	December 19, 1960	USS <i>Valley Forge</i> (CV-45)	12.9 km

Mercury-Redstone 2	January 31, 1961	USS <i>Donner</i> (LSD-20)	209.2 km
Mercury-Atlas 2	February 21, 1961	USS <i>Donner</i> (LSD-20)	20.9 km
Mercury-Atlas 4	September 13, 1961	USS <i>Decatur</i> (DD-936)	64.4 km
Mercury-Atlas 5	November 29, 1961	USS <i>Stormes</i> (DD-780)	? km
Gemini 2	January 19, 1965	USS <i>Lake Champlain</i> (CVS-39)	38.6 km
Apollo 201	February 26, 1966	USS <i>Boxer</i> (LPH-4)	? km
Apollo 202	August 25, 1966	USS <i>Hornet</i> (CVS-12)	? km
Gemini 2-MOL	November 3, 1966	USS <i>La Salle</i> (LPD-3)	11.26 km
Apollo 4	November 9, 1967	USS <i>Bennington</i> (CVS-20)	16 km
Apollo 6	April 4, 1968	USS <i>Okinawa</i> (LPH-3)	? km
Zond 5	September 21, 1968	USSR recovery naval vessel Borovichy & Vasiliy Golovin	105 km
Zond 8	October 27, 1970	USSR recovery ship Taman	24 km
COTS Demo Flight 1	December 8, 2010	?	0.8 km

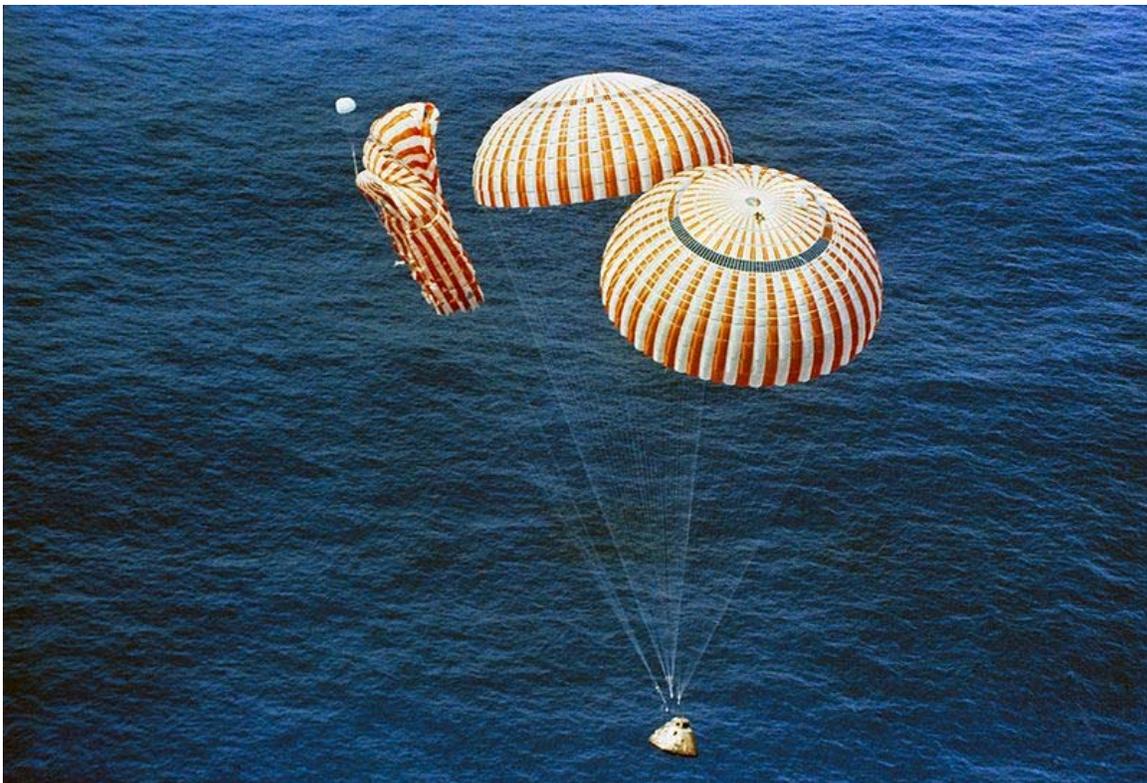
Chapter- 14

Water Landing

A **water landing** is, in the broadest sense, any landing on a body of water. All waterfowl, those seabirds capable of flight, and some human-built vehicles are capable of landing in water as a matter of course.

The phrase "water landing" is also used as a euphemism for crash-landing into water in an aircraft not designed for the purpose. The National Transportation Safety Board of the United States government defines "**ditching**" in its aviation accident coding manual as "a planned event in which a flight crew knowingly makes a controlled emergency landing in water. (Excludes float plane landings in normal water landing areas.)" Such water landings are extremely rare for commercial passenger airlines.

By design



Apollo 15 capsule descends under two of three parachutes

Seaplanes, flying boats, and amphibious aircraft are designed to take off and land on water. Landing can be supported by a hull-shaped fuselage and/or pontoons. The availability of a long effective runway was historically important on lifting size restrictions on aircraft, and their freedom from constructed strips remains useful for transportation to lakes and other remote areas. The ability to loiter on water is also important for marine rescue operations and fire fighting. One disadvantage of water landing is that it is dangerous in the presence of waves. Furthermore, the necessary equipment compromises the craft's aerodynamic efficiency and speed.

Early manned spacecraft launched by the United States were designed to land in water by the splashdown method. The craft would parachute into the water, which acted as a cushion to bring the craft to a stop; the impacts were violent but survivable. Landing over water rather than land made braking rockets unnecessary, but its disadvantages included difficult retrieval and the danger of drowning. The NASA Space Shuttle design was intended to land on a runway instead. NASA's upcoming Constellation Program will use the Orion Spacecraft to carry crew, which will land in the ocean.

In distress

Although extremely uncommon in commercial passenger travel, small aircraft ditchings are common occurrences. According to the National Transportation Safety Board, there are about a dozen ditchings per year.

General aviation

General aviation includes all fields of aviation outside of military or scheduled (commercial) flights. This classification includes small aircraft, e.g., training aircraft, airships, gliders, helicopters, and corporate aircraft, including business jets and other for-hire operations. General aviation has the highest accident and incident rate in aviation, with 16 deaths per million flight hours, compared to 0.74 deaths per million flight hours for commercial flights (North America and Europe) .

Commercial aircraft



US Airways Flight 1549, ditched in the Hudson River in 2009 with all passengers surviving

The FAA does not require commercial pilots to train to ditch but airline cabin personnel must train the evacuation process. In addition, the FAA implemented rules under which circumstances (kind of operator, number of passengers, weight, route) an aircraft has to carry emergency equipment including floating devices such as life jackets and life rafts.

While there have been several 'successful' (survivable) water landings by narrow-body and propeller-driven airliners, few commercial jets have ever touched down 'perfectly' on water. There has been a good deal of popular controversy over the efficiency of life vests and rafts. For example, Ralph Nader's Aviation Consumer Action Project had been quoted as saying that a wide body jet would "shatter like a raw egg dropped on pavement, killing most if not all passengers on impact, even in calm seas with well-trained pilots and good landing trajectories."

Also, in December 2002, *The Economist* had quoted an expert as claiming that "No large airliner has ever made an emergency landing on water" in an article that goes on to charge, "So the life jackets ... have little purpose other than to make passengers feel better." This idea was repeated in *The Economist* in September 2006 in an article which reported that "in the history of aviation the number of wide-bodied aircraft that have made successful landings on water is zero."

Of note is the January 15, 2009, ditching of US Airways Flight 1549, an Airbus A320 narrow-body jet, which successfully ditched in the North River section of the Hudson River mid-river between Manhattan in New York City and Weehawken in New Jersey. All on board survived, showing that inflatable slide-rafts and life jackets can sometimes serve their purposes, although photographs from the incident show that very few passengers were wearing life jackets. After take-off from La Guardia, initial reports cite dual engine failure due to bird strikes at a low altitude. Pilot Chesley B. "Sully" Sullenberger was able to cross the Bronx in a slow turn to the south-west, pass over the George Washington Bridge and ditch the plane in the Hudson River. The left engine broke away on contact with the river. All 155 passengers and crew survived with only one major injury and 77 minor injuries, in part because the plane came to a halt adjacent to the passenger ferry route between NYC and New Jersey.

Survival rates of passenger airplane water ditchings

In all cases where a passenger plane has undergone an intentional water landing or ditching, some or all of the occupants have survived. Examples of water landings in which passengers survived after a planned and intentional water landing after an in-flight emergency are:

- On 15 January 2009, the aforementioned US Airways Flight 1549 (an Airbus A320) successfully ditched into the Hudson River between New York City and New Jersey, after reports of multiple bird strikes. All of the 155 passengers and crew aboard escaped and were rescued by passenger ferries and day-cruise boats, in spite of freezing temperatures (the ditching occurred near the Circle Line Sightseeing Cruises and NY Waterway piers in midtown Manhattan). The survival rate was 100%.
- On 6 August 2005, Tuninter Flight 1153 (an ATR 72) ditched off the Sicilian coast after running out of fuel. Of 39 aboard, 23 survived with injuries. The plane's wreck was found in three pieces. The survival rate was 59%.
- On 16 January 2002, Garuda Indonesia Flight 421 (a Boeing 737) successfully ditched into the Bengawan Solo River near Yogyakarta, Java Island after experiencing a twin engine flameout during heavy precipitation and hail. The pilots tried to restart the engines several times before making the decision to ditch the aircraft. Photographs taken shortly after evacuation show that the plane came to rest in knee-deep water. Of the 60 occupants, one flight attendant was killed. The survival rate was 98%.

- On 23 November 1996, Ethiopian Airlines Flight 961 (a Boeing 767-260ER), ditched in the Indian Ocean near Comoros after being hijacked and running out of fuel, killing 125 of the 175 passengers and crew on board. Unable to operate flaps, it impacted at high speed, dragging its left wingtip before tumbling and breaking into three pieces. The panicking hijackers were fighting the pilots for the control of the plane at the time of the impact, which caused the plane to roll just before hitting the water, and the subsequent wingtip hitting the water and breakup are a result of this struggle in the cockpit. Some passengers were killed on impact or trapped in the cabin when they inflated their life vests before exiting. Most of the survivors were found hanging onto a section of the fuselage that remained floating. The survival rate was 29%.
- On 2 May 1970, ALM Flight 980 (a McDonnell Douglas DC-9-33CF), ditched in mile-deep water after running out of fuel during multiple attempts to land at Princess Juliana International Airport on the island of Saint Maarten in the Netherlands Antilles under low-visibility weather. Insufficient warning to the cabin resulted in several passengers and crew still either standing or with unfastened seat belts as the aircraft struck the water. Of 63 occupants, 40 survivors were recovered by U.S. military helicopters. The survival rate was 63%.
- On 21 August 1963, an Aeroflot Tupolev Tu-124 ditched into the Neva River in Leningrad after running out of fuel. The aircraft floated and was towed to shore by a tugboat which it had nearly hit as it came down on the water. The tug rushed to the floating aircraft and pulled it with its passengers near to the shore where the passengers disembarked onto the tug; all 52 on board escaped without injuries. The survival rate was 100%.
- On 23 September 1962, Flying Tiger Line Flight 923, a Lockheed 1049H-82 Super Constellation N6923C, passenger aircraft, on a military (MATS) charter flight, with a crew of 8 and 68 U.S. civilian and military (paratrooper) passengers ditched in the North Atlantic about 500 miles west of Shannon, Ireland after losing three engines on a flight from Gander, Newfoundland to Frankfurt, Germany. 45 of the passengers and 3 crew were rescued, with 23 passengers and 5 crew members being lost in the storm-swept seas. All occupants successfully evacuated the airplane. Those who were lost succumbed in the rough seas. The survival rate for landing and evacuation was 100%. The final survival rate of the accident was 63%.
- In October 1956, Pan Am Flight 6 (a Boeing 377) ditched northeast of Hawaii, after losing two of its four engines. The aircraft was able to circle around USCGC *Pontchartrain* until daybreak, when it ditched; all 31 on board survived. The survival rate was 100%.
- In April 1956, Northwest Orient Airlines Flight 2 (also a Boeing 377) ditched into Puget Sound after what was later decided to be caused by failure of the crew to close the cowl flaps on the plane's engines. All aboard escaped the aircraft after a

textbook landing, but four passengers and one flight attendant succumbed either to drowning or to hypothermia before being rescued. The survival rate was 87%.

- On 26 March 1955, Pan Am Flight 845/26 ditched 35 miles from the Oregon coast after an engine tore loose. Despite the tail section breaking off during the impact the aircraft floated for twenty minutes before sinking. Survivors were rescued after a further 90 minutes in the water. The survival rate was 83%.
- On 19 June 1954, Swissair Convair CV-240 HB-IRW ditched into the English Channel because of fuel starvation, which was attributed to pilot error. All three crew and five passengers survived the ditching and could escape the plane. However, three of the passengers could not swim and eventually drowned, because there were no life jackets on board, which was not prescribed at the time. The survival rate was 63%.
- On 3 August 1953, Air France Flight 152, a Lockheed L-749A Constellation ditched 6 miles from Fetiye Point, Turkey 1,5 miles offshore into the Mediterranean Sea on a flight between Rome, Italy and Beirut, Lebanon. The propeller had failed due to blade fracture. Due to violent vibrations, engine number three broke away and control of engine number four was lost. The crew of eight and all but four of the 34 passengers were rescued. The survival rate was 91%.
- On 16 April 1952, the de Havilland Australia DHA-3 Drover VH-DHA operated by the Australian Department of Civil Aviation with 3 occupants was ditched in the Bismarck Sea between Wewak and Manus Island. The port propeller failed, a propeller blade penetrated the fuselage and the single pilot was rendered unconscious; the ditching was performed by a passenger. The survival rate was 100%.
- On 11 April 1952, Pan Am Flight 526A ditched 11,3 NW of Puerto Rico due to engine failure after take off. Many survived the initial ditching but panicking passengers refused to leave the sinking wreck and drowned. 52 passengers were killed, 17 passengers and crew members were rescued by the USCG. After this accident it was recommended to implement pre-flight safety demonstrations for over-water flights. The survival rate was 25%.

573 of 834 occupants of the above listed emergency water landings survived. A lot of passengers weren't killed by the impact but drowned because of hypothermia or panic. The average survival rate is 69%.

Aircraft landing on water for other reasons

Aircraft also sometimes end up in water by running off the end of runways, landing in water short of the end of a runway, or even being forcibly flown into the water during

suicidal/homicidal events. Twice at LaGuardia Airport, aircraft have rolled into the East River.

- On 30 April 2002, DAS Air Cargo DC-10-30F freighter N800WR approached Entebbe, Uganda runway 35 following a flight from London-Gatwick carrying over 50 tons of cargo. The airplane landed long: 4000–5000 feet down the 12000-foot runway. The nosegear touched down 13 seconds after the main undercarriage. The DC-10 could not be brought to a halt and slid off the runway into Lake Victoria about 100 meters from the southern end of the runway. The DC-10 ended up with the no. 1 and 3 engines submerged and cockpit section separated from the fuselage. The crew members were rescued with a life raft within just 10 minutes of the accident.
- On 3 February 2000, Trans Arabian Air Transport Flight 310, a Boeing 707-351(C) carrying cargo, grossly overshot the landing strip at Mwanza Airport after a first attempt failed and eventually landed in the middle of Lake Victoria. The plane continued floating after the landing and all five crew survived, some with light injuries.
- On 12 September 1993, while landing in poor weather conditions at Faa'a International Airport, Papeete, Tahiti, an Air France Boeing 747 registered F-GITA hydroplaned, overshot the runway and ended in a lagoon. All 272 passengers and crew evacuated successfully, even though the engines were still running and there was a risk of ingestion. The survival rate was 100%.
- In 1993, China Airlines Flight 605, a Boeing 747-409, ended up in water after it overran runway 13 at Kai Tak International Airport on landing during a typhoon with wind gusting to gale force. All of the 396 occupants donned life-vests, boarded the eight slide/rafts and no fatalities resulted. The airframe remained above water even after the aircraft was evacuated.
- In 1989, USAir 5050, a Boeing 737-401 with 63 people aboard, overran the runway, landing in the East River and breaking into three pieces, sustained two deaths.
- In 1985, a DC-10 of American Airlines taking off from Muñoz Marín Airport in Puerto Rico to Dallas-Fort Worth International Airport in Texas overran the runway and nosedived into a nearby lake. No one was injured.
- On 9 February 1982, Japan Airlines Flight 350 landed in shallow water of Tokyo Bay short of the runway on approach to Tokyo International Airport after the captain engaged thrust-reversers in an attempted suicide. Crew members tried to stop him but were not fully successful. 24 of the 166 passengers and (ironically) none of the eight crew members died. The captain was found not guilty of any crime due to insanity.

- On 23 January 1982, World Airways Flight 30, landing at Boston Logan International Airport after a flight from Newark, New Jersey, slid off the runway due to ice and landed in Boston Harbor. The cockpit area separated from the remainder of the fuselage at first row of seats. Two passengers in the first row disappeared and were presumed dead, but the other 210 people aboard survived (99% survival).
- In 1982, Air Florida Flight 90 went down in the icy Potomac river after taking off from Washington National Airport during a snowstorm without proper de-icing. Only 6 out of 79 passengers and crew survived the initial crash, with one of the survivors eventually drowning after helping others to safety. The plane also hit a bridge, killing four and injuring another four motorists. The survival rate from the plane was 6%.
- On 7 August 1980, a Tupolev 154B-1 operated by Taron Romanian Airlines ditched in the water, 300m short of the runway at Nouadhibou Airport (NDB/GQPP), Mauritania. 1 passenger out of 168 passengers and crew died. The survival rate was 99%.
- In 1978, National Airlines Flight 193, a Boeing 727 Trijet, unintentionally landed in the waters of Escambia Bay near Pensacola, Florida after coming down short of the runway during a foggy approach. There were 3 fatalities among 52 passengers and 6 crewmembers, a 95% survival rate.
- On 22 November 1968, Japan Airlines Flight 2, a DC-8-62, landed short of the runway in San Francisco Bay on approach to San Francisco International Airport. There were no fatalities, and the aircraft itself was in good enough condition to be removed from the water, rebuilt, and flown again.

Crashing

There is a distinction between a controlled ditching and simply crashing (not even crash-landing) into the water; the latter is capable of killing everyone upon impact and disintegrating the plane. For example:

- Yemenia Flight 626 killed 152 out of 153 aboard after crashing in the Indian Ocean. Only One Survived.
- Air France Flight 447 killed all 228 aboard in 2009 after crashing in the Atlantic Ocean.
- Adam Air Flight 574 killed all 102 aboard in 2007.
- Armavia Flight 967 killed all 113 aboard in 2006.
- Alaska Airlines Flight 261 killed all 88 aboard in 2000.
- Kenya Airways Flight 431: 10 of 179 (6%) survived in a sea crash off Côte d'Ivoire in 2000.
- EgyptAir Flight 990 killed all 217 aboard in 1999.
- Swissair Flight 111 killed all 229 aboard in 1998.

- SilkAir Flight 185 killed all 104 aboard in 1997.
- Eastern Air Lines Flight 375: 10 of 72 (14%) survived the crash into Winthrop Bay shortly after take off. It remains the most deadly crash in US history involving a bird strike.
- American Airlines Flight 320: 8 of 73 (11%) survived in a landing in New York City's East River in 1959.

On a smaller scale, John F. Kennedy, Jr. and his two passengers died in a water crash. As pilot and columnist, Patrick Smith comments that these crashes tend to be more memorable than controlled water landings, perhaps fueling the public's suspicions of the survivability of aircraft that hit water.