Expert Conference: Unconventional Takeoff and Landing methods

Simon Reinberth, Amanda Eriksson, Rajesh D R and *Kristjan Möller*
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1 Introduction

To understand the subject of unconventional take off and landing methods, the first question is, what defines a conventional landing and take off method (hereafter CTOL). CTOL can be defined as a method which uses the length of a runway to build up aerodynamic lift from the speed at which the aircraft is moving. The landing sequence is the opposite of takeoff and also demands a runway to control the speed and therefore the lift.

In some sense the unconventional landing and take off was envisioned before the conventional method. Leonardo da Vinci (1452-1591) had an idea to use vertical takeoff to get off the ground with his early aircraft concept called the Helical Air Screw [1]. The benefits of not using a runway and be able to hover above the ground, just like Leonardo da Vinci's ideas, triggered different research projects. Most of the projects were carried out in between 1950 and 1970, with the aim to find a solution for vertical take off and landing (hereafter VTOL) [2]. The goal was to combine the take off and landing benefits from a helicopter and combine them with the speed and range of an aircraft. Many of the experiments failed, but some succeeded. One of the early aircrafts was the Lockheed XFV-1 which took of vertically on its tail, flew like an airplane and landed on its tail again [2]. A decade later the first widely used VTOL airplane, the Harrier Jump Jet, which is still used today, was introduced. Today the new F-35B is planned to replace the Harrier in the U.S marine corps.

2 Classifications

Different types of takeoff and landing methods were listed, figure 2. All the methods have been used on different aircrafts. The methods for takeoff and landing for spacecrafts will not be further developed in this report.

Abbreviation	Explanation
CTOL	Conventional takeoff and landing
STOL	Short takeoff and landing
CATOBAR	Catapult launch and arrested recovery
STOBAR	Short takeoff but arrested recovery
HTHL	Horizontal takeoff and horizontal landing (spacecraft)
VTOL	Vertical takeoff and landing
VTVL	Vertical takeoff and landing (spacecraft)
VTOHL	Vertical takeoff and horizontal landning
ZLL	Zero length launch systems
VTHL	Vertical takeoff and horizontal landning (spacecraft)
HTVL	Horizontal takeoff and vertical landing (spacecraft)
V/STOL	Vertical and/or short takeoff and landing

Fig. 1 . Different classifications of unconventional landing methods with a brief explanation.

3 Technologies

There have been numerous technologies to achieve the aforementioned takeoff and landing methods. The different technologies have a high impact on the aircraft performance in hover and flight. When comparing VTOL/STOL airplanes to the CTOL contemporary ones, aircraft performance (flight speed, payload capacity, range) in all aspects is usually sacrificed in order to achieve vertical flight capabilities.
Some of the technologies used for unconventional takeoff and landing are discussed in this chapter.

3.1 Thrust vectoring

3.1.1 Tilt rotor

Technology, where the thrust and lift are provided by the same rotors. Vectoring of the thrust is achieved by tilting the rotor axis relative to the rest of the aircraft. Usual placement of the rotors is on the tips of the wings. Most of the aircraft built using this method utilize two turboprop engines (V-22 Osprey) but tests have also been done with up to four rotors. This method of VTOL has the highest hover lift efficiency for it's disk loading [1].

3.1.2 Tilt wing

Similar to the tilt rotor but with a difference of the rotors being fixed to the wing and the wing inclination angle is used for the thrust vectoring. The main advantage for tilt rotor is the smaller down load on the wing thus smaller required power for hovering. However, the disadvantages are a more complex tilt mechanism and difficulties with wing mounted fuel tanks [3].

3.1.3 Nozzled jet

The most prevalent method for fighter aircraft to achieve VTOL capabilities. The exhaust of the jet turbine is directed through movable nozzles that allow for vectoring the thrust between vertical and horizontal. For additional roll and yaw control, bleed nozzles on wingtips and nose are needed. If older nozzled fighters used a shared exhaust from a single lift turbine, like the Harrier, then the newer generation F-35B gets its lift thrust from the turbine exhaust and a seperate fan, that is shaft-connected to the turbine.

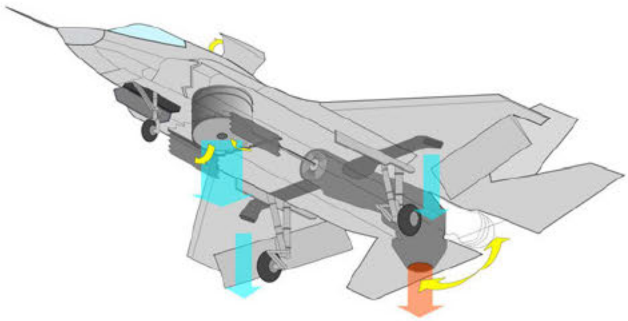

Fig. 2 . Figure of F-35B. The aircraft has a nozzle that can be rotated from horizontal to vertical (By Tosaka [CC BY 3.0 (https://creativecommons.org/licenses/by/3.0)], from Wikimedia Commons).

3.2 Tail sitter

Method for takeoff and landing, where a horizontally mounted engine brings the plane up vertically. The aircraft will also land vertically. In the air, the plane works just like a regular airplane.

The Lockheed XFV-1 had its first flight in 1954. The purpose for the design was to use VTOL for start and landing on ships. By the use of a powerful turboprop engine and two counter-rotating propellers in the front of the plain, the aim was to start the aircraft vertically on its tail and like a helicopter, take off and fly like an ordinary airplane. However, the project was delayed due to reliability problems and later canceled in 1955 [4].

Vertijet is an airplane which starts vertically, but instead of an engine with propellers it uses a jet engine. When landing vertically, the aircraft uses a “hook” to attach it self to a mobile trailer. The trailer is also used for take off. This method, compared to the XFV-1 which started and landed from the ground, did not have to be designed with a robust tail, with the purpose of carrying the load of the aircraft on the ground [5].

3.3 Assisted

3.3.1 Catapult launch and Cable arrested landing

This type of takeoff method is typically used in aircraft carriers, where runways are short. The aircraft is accelerated along a track to achieve takeoff-speed with a catapult action. The catapult action can be achieved by different means like pressurized steam cylinder, hydraulic chambers, electromagnetic motor rails. Initial technologies include flywheel, gunpowder [6] and weight and derrick methods. The catapult tracks are built into flight decks and a release bar is used to attach the nose gear to the catapult mechanism. At the time of launch, the release bar is propelled along the track, pushing the airplane at high speed. Velocity attained by catapult action and the apparent wind speed is enough for the aircraft to takeoff in a short distance [7]. In the same way, aircrafts are brought into rest in short distance by attaching a cable to the arrester hook present on the underbelly of the vehicle. The tension provided by the cable helps reducing the velocity and hence landing distance.

3.3.2 Parachute landing

This technology is commonly used for UAVs. Some UAVs are not provided with landing gear to avoid complicated structure and to save up on cost and weight. In general for UAVs this method is used for landing in tough terrains and during emergency landings.

4 Future

Different solutions to make takeoff and landing more fuel efficient are being evaluated. One of the projects is GABRIEL, created by the European Union. The GABRIEL project evaluated the possibility to use Magnetic Levitation (MAGLEV) to assist airplanes at taxiing, takeoff and landing [8]. The use of MAGLEV at takeoff and landing would reduce the fuel consumption and emissions [9]. Airplanes could also be rebuilt to reduce weight. A small prototype of a MAGLEV track has been built and tested. Since the velocities are much lower on the prototype than a full scale model the results can not be transferred directly, however the tests shows that the prototype did fulfill the requirements [8].

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