Unconventional Take-off and Landing Methods

Wenli Kong , Mehmet Deniz Firat , Till Behler

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1 Introduction

The take-off and landing process is the challenge for an aircraft to start and end the actual flight successfully. It has always been invested a lot of research to make optimization for more comfort, safety, etc.
Next to the conventional take-off and landing methods where the aircraft is started and landed at a long runaway by the execution of the pilot, there are – also because of the variety of applications of modern aircraft - a lot of other take-off and landing methods that are required due to the circumstances or even because of better appropriateness or given technology and design.
This paper gives a short overview of a few unconventional and modern take-off and landing techniques and presents them regarding application fields, potential and challenges and also focuses on future relevant aspects.

2 Unconventional take-off and landing techniques

2.1 CATOBAR

CATOBAR (Catapult Assisted Take-Off But (Barrier) Arrested Recovery) is a horizontal unconventional take-off technique mainly used in aircraft carriers where usually is not much space on the runaway to accelerate. With the assistance of so-called catapultes the aircraft is accelerated to the required launch speed.
The catapult technique was used in 1903 by Samuel Langley for his flying models first. The first successful catapult launch from a ship took place in 1915.[1]
Most modern CATOBAR systems contain of steam catapultes which are commonly used since World War II. The main challenge for launching the aircraft is to provide enough steam pressure. When the aircraft is about to accelerate, the valves of the catapult pressure tanks filled with high pressured steam underneath the short runaway are opened and the steam supports a piston with the necessary force to speed up the aircraft to take-off velocity.
One of the latest advancements for the CATOBAR technique is the Electromagnetic Aircraft Launch System EMALS where the acceleration is achieved by electromagnetic alternating fields. Compared to the steam catapultes, EMALS has more energy capability. Because of the nowadays trend to faster and heavier aircraft this aspect becomes more important. Additionally, EMALS has next to less weight and volume, also the advantage of better controllability, availability and efficiency.[2]
For landing operations, a arresting gear system is used to slow down the speed of aircraft over the short runaway. During the landing process the pilot has to hook into one of the arrestor steel wires that are fixed on the ground. The wire decelerates the aircraft within seconds to a standstill.

Fig. 1 Shenyang J-15 accelerating for take-off, Copyright China's Ministry of National Defense

2.2 STOBAR

In contrast to CATOBAR, STOBAR (Short Take-Off But (Barrier) Arrested Recovery) utilizes inclined ramps to assist take-off. Therefore additional energy generators which cause cost and technical difficulties are not required. The aircraft only uses its own power to take-off. Even if the velocity is not enough to keep constant height in the moments after take-off, the aircraft has time to accelerate further on because the ramp ensure a sufficient climb rate.[3]

2.3 VTOL

A vertical take-off and landing (VTOL) aircraft is a general title for an aircraft that is able to take-off and

land vertically. VTOL includes a variety of types of aircraft including fixed-wing aircraft as well as helicopters and other aircraft with powered rotors, such as cyclocopters and tiltrotors.[4]
In future mobility concepts vertical take-off and landing might play a bigger role for smaller airborne vehicles. As a big advantage the aircraft can take-off and land almost everywhere and has very low space requirement.
There are currently two types of VTOL aircraft in military service: aircraft using a tiltrotor, such as the Bell Boeing V-22 Osprey, and aircraft using directed jet thrust such the Hawker Siddeley Harrier and its successor models. (see figure 2) The basic principle of vertical take-off for a rotary wing airborne vehicles is always the same: Because of the spinning blades, the pressure on the top of the rotor is reduced, and the pressure underneath is increased. Therefore thrust is generated. To move forward, the aircraft tilts slightly to direct some of its thrust forward. In case of directed jet thrust, the jet engine of the aircraft and therefore the thrust vector is aligned vertically to produce a vertical elevating force but is able to change its direction later to move horizontally.[5]

Fig. 2 Hawker Harrier GR1a in hover, Copyright 2019 BAE Systems [6]

2.4 Water landing/ditching

Another technique focused on is landing on water or so-called ditching for aircraft that are not designed for that. This kind of maneuvers only appear in forced and special emergency cases but nevertheless the Federal Aviation Regulations (FAR) prescribe that a regular airplane should also be able to land on water in a preferably secure way.[7]
Those situations are usually not practiced on a flight simulator but there are some things the pilot can pay attention to, e.g. slow down velocity to minimize forces when hitting the water surface or to land parallel to the waves.[8] When the aircraft is not touching down symmetrically the resulting yaw moment can cause immense damage to the aircraft. In order to analyze occurring forces and their effects when the aircraft is hitting the water surface, there were made many numerical simulations with main focus on different pitching angles.[9] It can be concluded that beside the dependency on the aircraft shape and flight approach the pitching angle has mainly impact on the normal load. It is recommended to have a comparatively high initial pitch angle around 10°-12° to prevent the aircraft nose to dip into the water. The chances of leaving the aircraft unscathed and saving the lives of the passengers can therefore be increased. Although the chance success rate of ditching is not estimated very high, there are again and again impressive examples like in 2009 when a pilot managed to land his aircraft on the Hudson River in New York successfully and saved the life of all passengers.(see figure 3)

Fig. 3 Airbus A320 after landing on Hudson River, Copyright Janis Krum

2.5 Development of autonomous take-off and landing

As the importance of autonomous means of transport will increase in the future, also aviation will be affected by this change. New challenges regarding the take-off and landing in particular will occur. Today there are already unmanned aerial vehicles (UAV) like drones and the potential of flying autonomously is not exhausted, at all. This paper will also have a look on the latest trends and approaches for improving the take-off and landing performance of existing autopilots which might be relevant for serial production of larger airliners in the future as well.
Many existing landing support systems as the instrument landing system (ILS) which supports the pilot with the landing when there is bad visibility, require information that are transmitted from the ground.

However, to be independent from the airport system has to be fully on-board.
Latest developed systems mainly focus on vision-based autonomous landing and take advantage of the greatly improved camera techniques in the last years. A research group of the Technical University of Munich (TUM) developed together with the Technical University of Braunschweig a fully automated landing system that extend the usual GPS system with two cameras to prevent disturbances.[10] In figure 4 the detecting of the runaway is depicted. One camera is in the infrared range to be resilient at poor visibility. The optimal landing approach is determined with sensor-fusion which estimates the relative position of the aircraft better than before.

Fig. 4 Visual runaway detecting, Copyright Technische Universität München [10]

To improve the performance of the autopilot recent researches also concentrate on Artificial Neural Networks and Supervised Learning. Training datasets obtained from flight simulators experiments can be used for control models that imitate the behaviour of a human pilot which can be learned and adapted to the autopilot.[11] Therefore the autopilot is be able to perform more take-off and landing tasks without human intervention.
This is only a small insight of the various possibilities to improve autonomous take-off and landing.

3 Conclusion

This paper presented a short abstract of the most common unconventional take-off and landing methods as well as techniques that came up in the last years and are still in their infancy. All of them will become more important in future as the fields of applications for aircraft will definitely be exposed to a huge change. Therefore, the existing methods are continuously refined and enhanced with modern technologies.

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