A large percentage of the population of the Western world has at least one experience of having flown inside a conventional (e.g. non-Vertical Take-Off and Landing) airplane, but only a small percentage of this population has ever been in a helicopter. And while airplanes dominate the aviation world, helicopters only fill small and often unseen niches. Other VTOL airplanes and machines are even less visible.

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does not have to be as bad as a helicopter. Helicopters hover all the time. If the aircraft is only required to hover during take-off and landing, while during cruise the thrust can be directed forwards for conventional flight, the aircraft can fly faster, further, and longer, without the need for much more fuel. If this kind of dual-mode VTOL technology could be developed, most of the disadvantages of the helicopter would be abolished.

When turboprops were first being introduced right after World War 2, some people noticed that these engines could provide more thrust than the total weight of a conventional airplane. Some airplanes could climb vertically up like a rocket. These airplanes are called ‘tail-sitters’. In the end, the reason why the tail-sitter concept was abandoned was that any commercial application is obviously non-viable. Just try and imagine how passengers would get in and out of a vertical tube in which they are laying flat down. Furthermore, military pilots stated it would be very difficult to land such an airplane on an aircraft carrier.

Now that the thrust issues were solved, engineers focussed their attention on control. But how is a VTOL aircraft controlled?

In order to control any given airplane, the aircraft needs airflow over the control surfaces on the wing and tail, something a VTOL aircraft does not experience during vertical take-off and landing. All VTOL airplanes face this problem and there are a handful of standard solutions.

One could place control surfaces in the downwash airflow of the propeller, eject high-pressure air from little holes in the wingtips, nose and tail or change the angles of the blades on the propeller so that it pulls the airplane in different directions.

A solution found often is to turn the orientation of the engines instead of turning the orientation of the whole aircraft. In a so-called tilt-engine design the engines are tilted forward to enable forward flight and control. This was not possible for a long time since the engines were not powerful enough to keep the plane in the air and accelerate it forwards at the same time. The tilt-engine approach was tried in many variations, including some aircraft where the wings turn upwards along with the engines. Eventually, after many accidents and failures spread over several decades, this concept became operational in 1989 in the form of the V-22 Osprey (See cover visual).

Instead of moving the orientation of the entire engine, one could also direct the airflow. This was tried in propeller airplanes where the propellers were tilted up into a helicopter configuration and in jets where the engine nozzles could similarly be turned downwards instead of backwards. This thrust-vectoring approach became operational in the infamous Harrier jump jet.

Instead of turning the airflow at all, one could also deflect the air downward after the engines have expelled it. This involves placing bucket flaps behind the engines. While some experimental VTOL aircraft could take-off and land vertically with this system, the system was found most useful in short take-off and landing (STOL) aircraft like the C-17.

A fan mounted inside a duct can be made much more efficient than a prop, since there are fewer blade-tip losses, and since the duct itself can act like a diffuser and nozzle, sucking air in the front and accelerating it out the back. Many VTOL airplanes use ducted fans. However, the only successful design up until this day is the Joint Strike Fighter produced by Lockheed Martin.

One last approach involves having dedicated engines to produce lift. These engines turn off while flying forwards during cruise. Instead of having one massive engine and a mechanism to rotate it, the aircraft could also have one big engine or a few small ones directed vertically and a small engine mounted horizontally. This may sound like a good idea, but in practice this concept has been proven to be unsuccessful.

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