Expert Conference: Vertical Landing Rockets

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1 Why Vertical Landing Rockets?

There were attempts of landing a rocket propulsion starting at the beginning of the 1960s but there were only attempts by single persons and from a very low height (e.g. Bell Rocket Belt). The main reason to start developing vertical landing rockets professionally was the goal to reduce the cost of space transport by reusing rockets. Historically, rockets flew most of the time only once or they had to be recovered and restored for a lot of money (e.g. SpaceShuttle with landing in salty water). The fuel and oxidizer represent only a very little part of the launch costs while the rocket itself represents the majority. Therefore, the ability to reuse at least the first stage of the rocket is useful to lower the costs even though the vertical landing needs extra fuel and lowers the payload but the future must show how much money the vertical landing of rockets really can save. The two main companies working on vertical landing rockets are SpaceX and Blue Origin. While Blue Origin has the goal to sell trips to the space for civilians, SpaceX mainly offers transportation flights for satellites or supply missions to the ISS.[1] To fulfill these tasks, the rockets have very different designs and requirements for the vertical landing. While the falcon rockets (SpaceX) are thin and tall and the boosters are separated in a higher altitude, the New Shepard rockets (blue Origin) are thicker and smaller because they only should reach about 100km height. Despite these different requirements there are some basic technical designs which are used to land a rocket or rocket-booster smooth and safe on earth. [2]

2 Current Trends

2.1 SpaceX - Falcon 9

Falcon 9's first stage consists nine Merlin engines tanks containing liquid oxygen and rocket-grade kerosene (RP-1) propellant in what they call their proprietary Octaweb arrangement. After ignition, a hold-before-release system ensures that all engines are verified for full-thrust performance before the rocket is released for flight. Then, with thrust greater than five 747s at full power, the Merlin engines launch the rocket to space. Falcon 9 is capable of generating more than 7600 kNs of thrust. The first stage engines are gradually throttled near the end of first-stage flight to limit launch vehicle acceleration as the rocket's mass decreases with the burning of fuel. The engine arrangement can sustain thrust and continue missions even with up to two engine shutdowns providing high reliability to the launch vehicle.

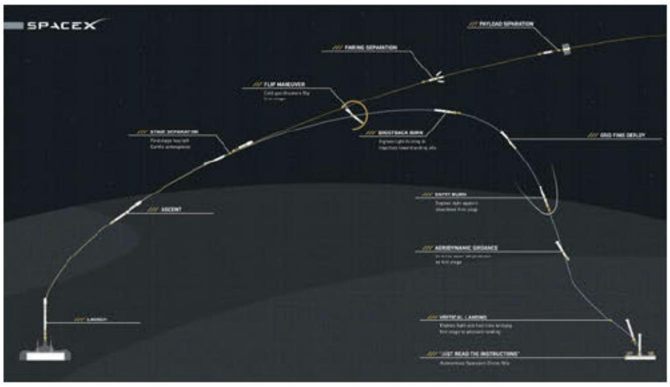

Fig. 1 . SpaceX Falcon 9 Mission Sequence.

The first stage is shutoff at stage separation and the nitrogen thrusters help flip the booster rocket to push back towards the landing pad; this is called the boostback burn. The booster is flipped one more time before the booster enters the atmosphere and the grid fins are deployed and these titanium grid fins carefully control the alignment of the booster as it enters the atmosphere. Once in the atmosphere the booster engine lights up again to create a virtual heat shield and slow the descent of the booster rocket. At this point the grid fins correct the alignment of the booster rocket and correct its flight path. As the rocket enters the final phase of its descent the engines light up in a 1-3-1 pattern to further reduce the approach speed of the booster and the gimbal in the central engine to have the right alignment and the landing legs are deployed close to touch down and the booster is shutoff upon touchdown at either the landing zones on land or the drone ships out at sea. Stage two later inserts the satellite into orbit to complete the mission. [3]

2.2 Blue Origin - New Glenn and New Shepard

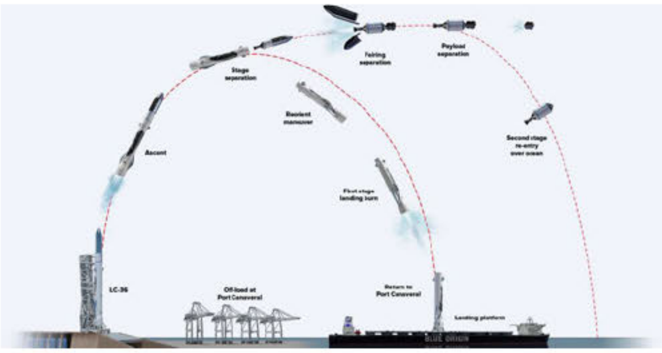

Fig. 2 . Blue Origin Mission Sequence.

The flight path seems to be planned in a fashion similar to the SpaceX mission and is yet to be tested. It is designed to be much larger than the Falcon 9 carrying much more powerful engines called the BE – 4. The main difference is the design of the landing gear and its use of aerodynamically shaped fins to be used for alignment during re entry similar to the grid fins on the SpaceX booster rockets. The New Glenn also will have 7 of their BE-4 engines while the SpaceX Falcon 9 uses 9 Merlin 1D engines to power their rocket.[4][5]

3 Performance

There are a few things a rocket/stage of a rocket must have to be able for vertical landing. The biggest difference in comparison to rockets without vertical landing is that you need extra fuel for the landing. Most rockets use all their fuel to bring their payload to space or the required place but for vertical landing rockets extra fuel is required to reignite the engines to slow down the rocket for a smooth touchdown. This effects the payload the rocket can carry to space because the extra fuel is a part of the payload which else could be used for other things. Additionally, there are a few other features a rocket needs to land vertical and these parts are all extra weight which lowers the payload. The rocket needs extra grid fins for steering the rocket while flying through the earth's atmosphere. They must be movable and very heat-resistant to resist the high temperature created by the friction of the atmosphere. Depending of the usage of the rocket extra thrusters are required at the stage which shall land vertical to flip the rocket to the right position at the beginning of the way back to earth. For the landing itself the rocket also needs landing legs to secure a stable standing after the landing. Additionally, the rocket needs a regulation which processes all the real-time data and controls all the parts necessary for the landing. [2] [6]

4 Future Prospects

The development of reusable rockets will initially lead to an improved access to the low earth orbit satellites. This means that deployment and maintenance of satellites will not only be cheaper but easier too. SpaceX aims to take these rockets further with the proposed private lunar mission and a slightly more ambitious mission to Mars using the BFR Rocket.[7] These inter-planetary missions will be open to the public for the first time in history.

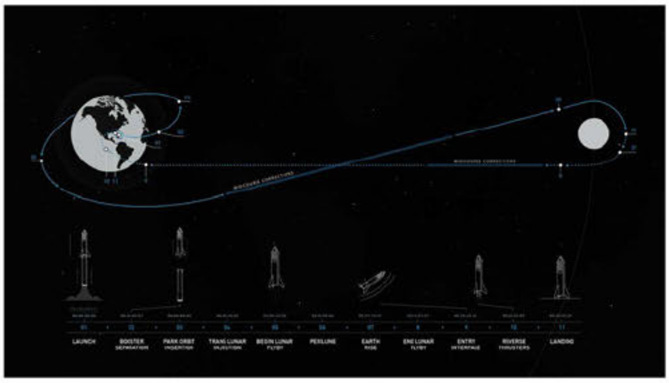

Fig. 3 . SpaceX Lunar Mission Sequence.

Apart from space travel, these rockets could also replace long distance commercial aircrafts someday. Taking advantage of the high operating velocity and service ceiling, these rockets can cut down inter-continental travel time exponentially. With more research efforts put into reusable rockets, we might be able to witness inter-continental rocket travel which can operate just like an aircraft with the airport turn around times within 60 minutes.

5 Environmental Impact

Vertical landing rockets can cut down the use of expendable components by more than 70 percent. This directly affects the carbon footprint during manufacturing and operations.
Additionally, since most of the components return back to earth, these rockets significantly reduce the contribution to the existing space debris crisis.

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