LINKÖPING UNIVERSITY

Aircraft Based Rocket Launch

Yeswanth Raghavesh Maddela, Adrian Aruștei, Ibrahim Shariff Mohammed Dawood and Soumen Ghosh

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1 Introduction

Space launching has the disadvantage of being costly. Also, there is a large fuel consumption and difficulties in fuel storage (due to boil-off phenomenon). Air launching is a possible alternative. Launching the rocket in air at a higher altitude skips the most dense portion of the atmosphere where drag has the biggest influence on performance. Although the reduction of the escape velocity is not big, the flexibility and reusability this technique provides will lower the overall costs of space missions.

The purpose of this paper is to review the main concepts of rocket air launches.

2 History

The first case of air launching was when bi-plane fighters were secured under airships (dirigible balloons). This system was used to boost the range of the bi-planes, but as the technology improved this method was abandoned. The historic event of traveling faster than speed of sound was accomplished by launching the rocket powered Bell X-1 from B-29 Superfortress bomber, followed by X-15 being launched by B-52 bomber. The inquisitive nature of humans and the technological advancement led to the development of programs to launch rockets to space from an aircraft.

3 Methods of Air Launch

As the name says itself, the rocket is carried by an aircraft to a particular altitude where air is thinner and launched. Based on the configuration of the rocket and carrier aircraft, the following classification can be made:

- Direct Carry
  - Top Carried
  - Bottom Carried
  - Internally carried
- Towed Glider

3.1 Direct Carry

The simplest way to bring a rocket to the launch altitude is to mount it directly on an aircraft. This method might help the development of space industry in parts of the world where there are no common launching options (for example launching pads). The direct carry can be divided in 3 parts as follows.

3.1.1 Top Carried

The main advantage of this method is that the ground clearance issues are avoided. However, the heavy payload on top creates stability and control problems. The position of the center of gravity changes significantly between take-off and landing. Also additional drag is created which limits the launching altitude (for example the launch altitude for Boeing AirLaunch is 7300 m [1]).

3.1.2 Bottom Carried

The launch vehicle in this method is attached at the bottom of the carrier aircraft. This idea of direct launch has proven to increase the stability and ease of separation from the carrier aircraft. Stratolaunch is an example for this method of direct carry. It is said to be functional by the end of this decade [2]. Stratolaunch is a twin fuselage airplane which presently has the largest wings span from all aircraft. It carries the rocket between the fuselages. It has six Boeing 747 engines for a payload capacity of over 226 700 kg. The main drawbacks of Stratolaunch are the limited payload size and the lateral forces on the rocket created by the carrier aircraft.

3.1.3 Internally carried

The SwiftLaunch Reusable Launch Vehicle (RLV) is one of the feasible concepts when it comes to internally carried method. In this case the rocket is carried within the fuselage of a large cargo plane like Antonov An-124 Ruslan or C-5 Galaxy. At the launch altitude the aft door opens, a parachute is released which in turn pulls the rocket out of the fuselage. The rocket falls with the parachute approximately 600 m until the rocket engines starts. Some of the advantages can be:

- no permanent modification of aircraft needed;
- it saves 1000 m - 3000 m of lost altitude in comparison to horizontal oriented launch.

The biggest 2 limitations are:

- size of fuselage limits the size of rocket;
- cryogenic fueled rockets pose a great risk of explosions.

3.2 Towed Glider Air-Launch System

In this method a jet aircraft will tow a special built glider that carries the payload and booster. Once they reach the launch altitude, the glider is released. Using a small rocket engine the unmanned glider performs a pull-up maneuver such that the payload launches almost vertically. Then both glider and airplane return to the ground.

Fig. 1 Illustration of towed glider air-launch system.[3]

According to [4] and [5] the main advantages of this technique are:

- *reduced costs* due to reusability of glider and jet airplane, less demanding maintenance;
- *increased flexibility* regarding launching areas, weather or propagated delays in launch schedule;
- *increased safety* because the crew is not in the proximity of a rocket (in contrast with the other air-launched methods);
- *better payload capacity* as the reorientation of rocket is done by the glider, which saves a lot of energy compared to the horizontal launch. This means that less fuel is needed and useful payload can be added.

Towing is more efficient than direct carry mainly because the excess thrust is used in a better way. The launch vehicle has its own high performance wing (the glider) and the extra drag produced is far less little than the extra drag produced in the conventional top or bottom carried configurations. In article [5] a nice analogy is made with a pickup truck that pulls a heavy trailer: it would transport much more weight than it could directly carry itself.

Concerns in this topic include carrier airplane take-off abort and heating of the fuel tank during the ascent for liquid propellant rockets. As the temperature of the tank increases (due to solar radiation and air convection) the pressure inside starts to build up and it has to be released. When the vapors escape and pressure drops the liquid oxygen starts to boil, phenomenon known as boil-off [6].

4 Conclusions

Conventional rocket launches tend to be expensive because the rocket stages currently used are not reusable. In this paper a short review of an alternative solution (air launch) has been made. These ideas provide a better performance only if the launch attitude is near vertical. The concepts generally require more advanced technologies and they are still under development.

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