Feasibility Study: Two-Phase Rocket for Reaching Low Earth Orbit

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Abstract

This study evaluates the feasibility of a two-phase launch system combining an aerodynamic phase, inspired by hypersonic aircraft such as the X-15, and a space phase powered by air-independent rocket engines. The objective is to achieve low Earth orbit (LEO) by leveraging the Earth's atmosphere for initial lift, thereby reducing costs and complexity. The technical foundations, structural limitations, and potential benefits of this hybrid approach are examined.

1 Introduction

Access to space remains one of the most significant challenges in aerospace engineering. Current orbital launch systems rely entirely on rockets, which are expensive and complex. This study proposes an alternative approach inspired by aerospace planes like the X-15, which achieved altitudes beyond the Kármán line (100 km). The concept combines an aerodynamic phase to reach the stratosphere and a space phase to achieve orbital velocity and a stable LEO orbit (200–2,000 km).

2 State of the Art

2.1 Aerodynamic Phase

The X-15 aircraft, developed by NASA and the USAF in the 1960s, demonstrated the ability to reach altitudes of up to 107.8 km using rocket propulsion independent of atmospheric oxygen [1]. These missions revealed limitations such as thermal stress and the need for advanced materials.

2.2 Space Phase

Traditional space systems rely on chemical rockets operating in a vacuum. Programs like the Space Shuttle and SpaceX have developed reusable technologies, albeit with significant costs. This work proposes a hybrid system combining the advantages of both approaches.

3 Methodology

3.1 Conceptual Design

The vehicle comprises two main stages:

- **Aerodynamic Phase:** A hypersonic aircraft capable of conventional runway takeoff. It uses jet engines in initial stages and rocket propulsion to reach the Kármán line.
- **Space Phase:** Powered by liquid-fueled rockets designed for vacuum operations, achieving an orbital velocity of approximately 7.8 km/s.

3.2 Feasibility Analysis

Key considerations include:

1. **Materials:** Use of advanced alloys such as titanium and ceramic composites for heat resistance.
2. **Propulsion:** Scramjet engines for the aerodynamic phase and bipropellant rockets for the space phase.
3. **Energy Efficiency:** Analysis of thrust-to-weight ratios and optimized trajectories to minimize fuel consumption.

3.3 Computational Modeling

Simulations using computational fluid dynamics (CFD) and structural analysis tools like ANSYS evaluate aerodynamic and thermal loads.

4 Expected Outcomes

- Cost reduction per kilogram to LEO through terrestrial launch infrastructure.
- Improved payload-to-weight ratio due to the hybrid design.
- Increased component reusability, reducing space debris.

5 Conclusion and Future Work

This hybrid approach offers a promising advancement for space access. Future research will focus on integrating propulsion systems and certifying materials for orbital missions.

References

[1] NASA, *X-15 Hypersonic Research Program*, 1960.

[2] SpaceX, *Reusability in Space Exploration*, 2020.

[3] Theodore von Kármán, *Aerodynamics*, 1947.