OPEN ACCESS Freely available online

Journal of Aeronautics & Aerospace Engineering

Commentary

Hybrid Air-Breathing Rocket-Cycle Engines Improving Space Propulsion with Reduced Costs and Emissions

Takashi Watanabe*

Department of Aeronautics and Astronautics, The University of Tokyo, Tokyo, Japan

ABOUT THE STUDY

In the evolving landscape of space exploration and travel, one of the key challenges is developing propulsion systems that are both cost-effective and environmentally friendly. Traditional rocket propulsion systems, while powerful, are notoriously expensive and contribute significantly to carbon emissions, making it crucial for the space industry to explore sustainable alternatives.

Space propulsion

Currently, space missions rely heavily on chemical rockets, which carry both fuel and oxidizer for combustion in space. While this technology has been essential for reaching outer space since the dawn of the space age, it has several limitations. Chemical rockets are extremely costly due to the high energy required to overcome Earth's gravity. Additionally, these rockets generate substantial amounts of greenhouse gases, contributing to global warming and environmental degradation.

Enter hybrid air-breathing rocket-cycle engines

Hybrid air-breathing rocket-cycle engines represent a breakthrough in the effort to reduce both the cost and environmental impact of space propulsion. These systems combine the best of both worlds: The high efficiency of air-breathing engines for atmospheric flight and the power of traditional rocket engines for space travel. Essentially, hybrid air-breathing engines operate by using atmospheric oxygen to combust fuel while the vehicle is still within the Earth's atmosphere, switching to rocket propellants once it enters the vacuum of space.

Key advantages of hybrid air-breathing rocket-cycle engines

Cost reduction: One of the most significant benefits of hybrid air-breathing rocket-cycle engines is their potential to dramatically reduce the cost of space launches. By utilizing atmospheric oxygen during the initial phase of flight, these engines can significantly reduce the amount of fuel and oxidizer that needs to be carried into space. This results in a lighter vehicle, lower manufacturing costs, and a reduction in the overall launch cost. These savings could make space travel more affordable for both private companies and government agencies, enabling more frequent launches and expanding access to space.

Environmental impact: Another key advantage of hybrid engines is their ability to reduce the environmental footprint of space missions. Traditional chemical rockets emit large quantities of greenhouse gases and black carbon particles, both of which contribute to climate change. Hybrid engines, on the other hand, could significantly decrease emissions by relying on air-breathing engines during the early stages of flight, which would reduce the amount of fuel required to reach space. Additionally, research is underway to make the fuel used in these hybrid systems more sustainable, including exploring the use of biofuels and other low-emission alternatives.

Improved efficiency: Hybrid engines have the potential to be more efficient than traditional rocket engines. By using atmospheric oxygen for combustion during the first part of the flight, the engine can operate at higher efficiency levels. This efficiency boost can be attributed to the fact that air-breathing engines generally have a higher specific impulse than rocket engines when operating within the atmosphere. The combination of an air-breathing cycle for atmospheric flight and a rocket cycle for space travel could provide an optimized propulsion system that balances fuel use and power output.

Simplicity and versatility: Hybrid air-breathing rocket-cycle engines are simpler in design than many other propulsion systems. By utilizing a single engine that can operate in both air-breathing and rocket modes, engineers can streamline the design process and reduce the complexity of space vehicles. This simplicity also translates into fewer components that could fail, which enhances the safety and reliability of space missions. Additionally, these engines could be adapted for a range of applications, from launching small satellites to powering crewed missions to the Moon and Mars.

Correspondence to: Takashi Watanabe, Department of Aeronautics and Astronautics, The University of Tokyo, Tokyo, Japan; E-mail: watanakashi@yahoo.com

Received: 27-Dec-2024, Manuscript No. JAAE-25-36524; **Editor assigned:** 30-Dec-2024, PreQC No. JAAE-25-36524 (PQ); **Reviewed:** 01-Jan-2025, QC No. JAAE-25-36524; **Revised:** 26-May-2025, Manuscript No. JAAE-25-36524 (R); **Published:** 02-Jun-2025, DOI: 10.35248/2168-9792.25.14.378

Citation: Watanabe T (2025) Hybrid Air-Breathing Rocket-Cycle Engines Improving Space Propulsion with Reduced Costs and Emissions. J Aeronaut Aerospace Eng. 14:378.

Copyright: © 2025 Watanabe T. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Longer mission durability: Hybrid engines can offer longer operational lifespans, as their modular design allows for easier maintenance and upgrades. This could be especially beneficial for missions that require extended periods of travel, such as crewed missions to the Moon or Mars. With a hybrid propulsion system, spacecraft could efficiently travel through different phases of spaceflight, with the option to switch between engine modes to maximize efficiency and minimize wear and tear on the vehicle's components.

Hybrid air-breathing rocket-cycle engines represent a transformative leap forward in the field of space propulsion. By combining the best aspects of air-breathing and rocket propulsion, these systems promise to reduce the cost, emissions, and environmental impact of space missions, while improving efficiency and versatility.