Higher-Efficiency Altitude-Adaptive Dynamic Rocket Engine Nozzle

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Modern-day rocket engines employ nozzles to transform onboard fuel-derived, high-temperature and pressure gasses into a high-velocity exhaust that propels the rocket forward. The efficiency of a rocket engine largely hinges on the velocity and directional precision with which the engine's nozzle ejects propellant gasses. However, due to the static nature of traditional nozzles which are optimized for only one altitude, rocket engines spend most of their flight expelling gas in slightly skewed angles causing inefficiency. In this project, a dynamic rocket engine nozzle that is able to adapt its shape to optimize for every altitude the rocket experiences was developed. The project has two main components: a nozzle-adjusting mechanism capable of physically facilitating these shape changes, and a contour generation software that instructs the nozzle-adjusting mechanism on how exactly to adapt its shape to optimize for every altitude. These two systems work together over the rocket's flight to achieve optimal exhaust directionality at any given altitude, achieving greater efficiencies. The dynamic rocket engine nozzle was tested through a series of simulations conducted on ANSYS CFD, in which the thrust of the rocket engine was measured in environments resembling many altitudes up to 66 kilometers above sea level. It was found that compared to a traditional static rocket engine nozzle, the dynamic rocket engine nozzle achieved a ~10.88% higher efficiency, which would decrease the payload costs (cost per kilogram to space) by ~71%.