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**Title**

# Trajectory optimization of semi-reusable launchers

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## Abstract

Reusable launch vehicles allow to push the limits of expendable launch vehicles by reducing launch cost (assuming refurbishment is cheaper than a new production), increasing launch cadence (by reusing parts, less production lines are needed) and decreasing environmental impact (more propellant is used during launch, counterbalanced by the lower impact of reused parts).
Since firsts commercial flights of semi-reusable launch vehicles, a worldwide race for reusable and semi-reusable launch vehicles has started.
The trajectory optimization complexity of a reusable or semi-reusable launch vehicle increases significantly with respect to expendable launcher trajectory optimization. Indeed, the number of optimization parameters increases and the launcher flight is made of several coupled arcs: ascent flight and each return paths.
When maximizing the payload mass, each arc should be optimized to provide the maximal performance to the ascent arc. The coupled paths increase significantly the risk to get stuck on sub-optimal solutions with classic optimization methods. Moreover, they often induce longer optimization duration.
This paper provides a set of methods to improve the convergence of semi-reusable launcher trajectory optimization and limit the risk of sub-optimal solutions. A second objective of these proposed methods is to reduce the optimization duration (in terms of computation time). The methods described in this paper have been designed to be used on advanced projects of semi-reusable launcher and are focused on toss-back returns. However, some of methods can be reused or serve as inspiration for winged return vehicles.