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Multidisciplinary Design Optimization of Launch Vehicles Using Exergy as an Objective

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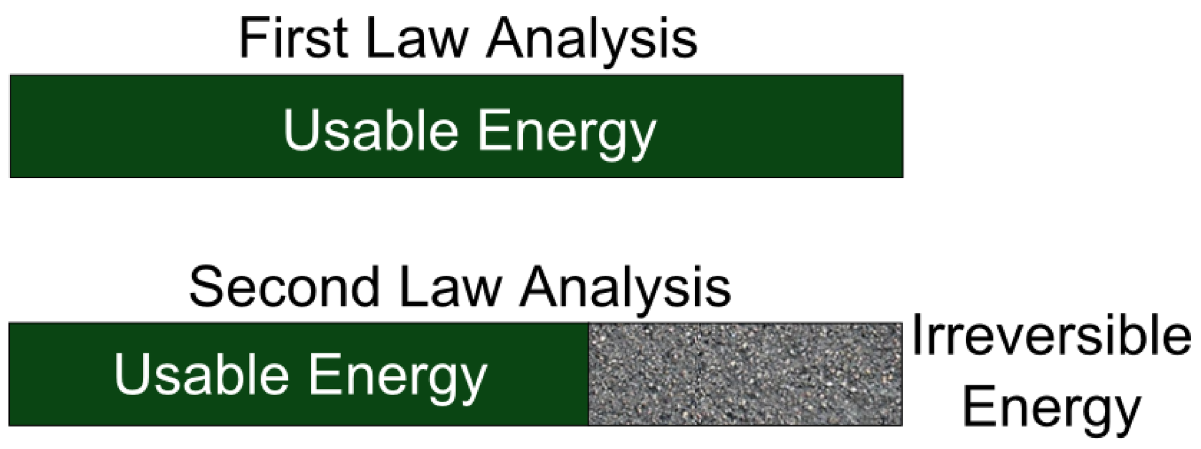
Overview

Typical MDO of space launch vehicles consists of multi-objective functions, which optimize multiple design criteria at once. The use of multi-objective functions results in Pareto solutions which represent tradeoffs between design criteria.



Exergy is defined as the useful work available to a system. A measurement of system efficiency can be calculated using exergy values.

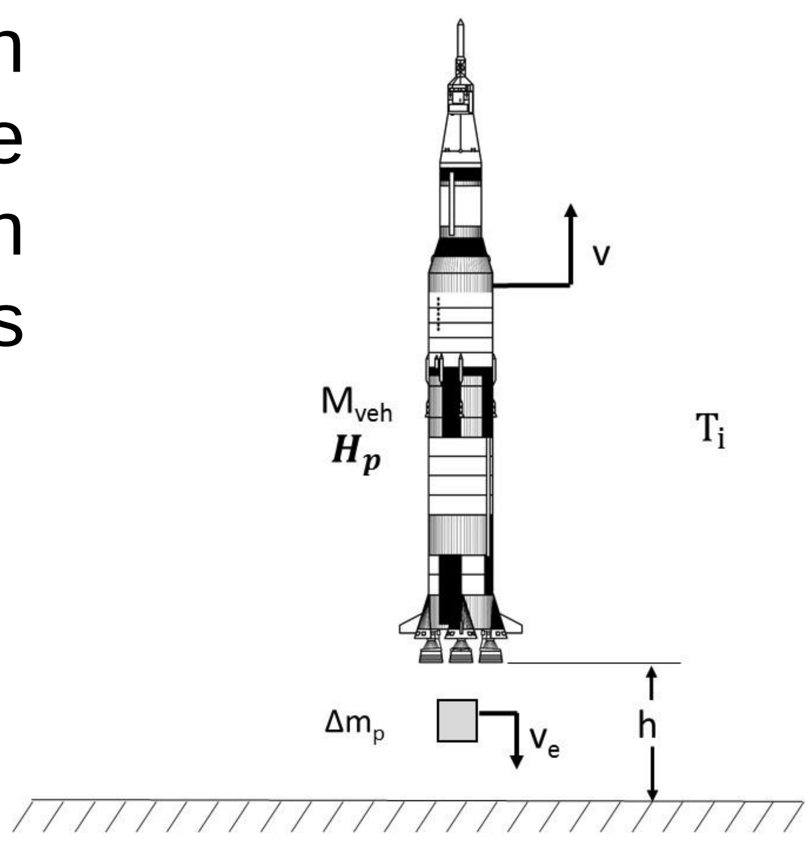
Methodology

After construction of a launch vehicle model an optimization of exergy efficiency will take place. The exergy balance and efficiency equation for a launch vehicle are seen below.

$$\Delta \boldsymbol{m_{propellant}}\left(\boldsymbol{h_{prop}} + \frac{\boldsymbol{V_e^2}}{\boldsymbol{2}}\right) - \boldsymbol{X_{des}} = \Delta \boldsymbol{KE_{vehicle}} + \Delta \boldsymbol{PE_{vehicle}}$$

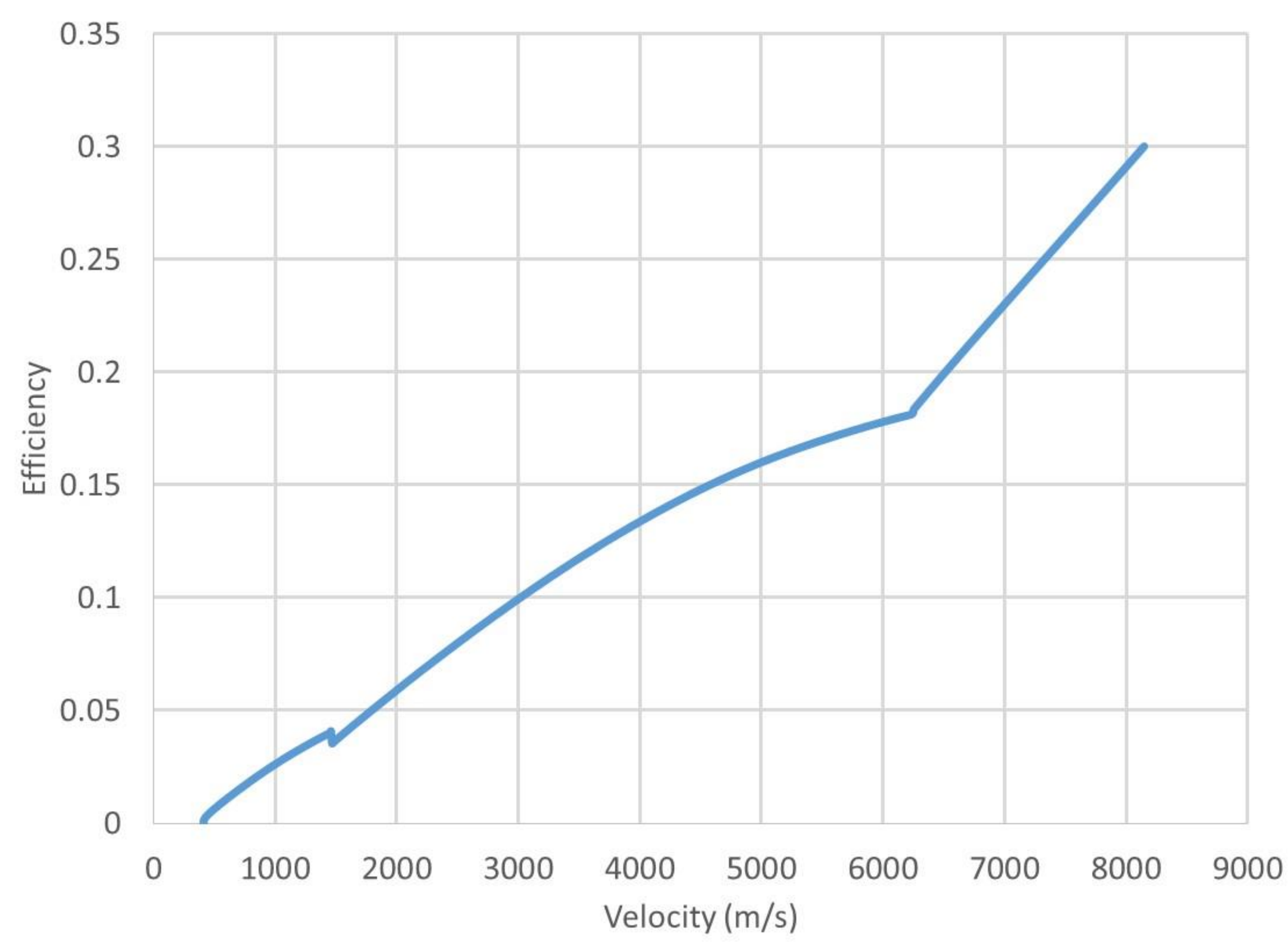
$$\eta_{exergy} = 1 - \frac{X_{des}}{X_{expended}} = 1 - \frac{X_{des}}{\sum_{i=1}^{nstage} \Delta mprop\left(h_{prop} + \frac{V_e^2}{2}\right)}$$

Results



A launch vehicle trajectory model was constructed. This model will be used to determine optimal designs using various objective functions.

The following shows the efficiency curve of a specific design as it relates to velocity.



Stage	First	Second	Third
Dry Mass (kg)	100000	41406	22406
Prop. Mass (kg)	1499171	398773	86402
Isp (s)	179	397	400
Burn Rate (kg/s)	11887	1757	50
Thrust (N)	20810812	6835896	196000

Future Work

The next steps in this project are to determine an optimal design of a launch vehicle which maximizes exergy efficiency. Suitable constraints on the design space will need to be determined to result in a usable design.

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