Rocket Stage Optimization Results

Generated by Stage_Opt

February 23, 2025

1 Introduction

This report presents the results of optimizing a multi-stage rocket using various optimization methods. The objective was to mazimize the payload mass fraction while satisfying the total delta-V requirement.

2 Input Assumptions

2.1 Global Parameters

Table 1: Global Parameters

Parameter	Value
Gravitational Acceleration (G_0)	$9.81\,\mathrm{m\,s^{-2}}$
Total ΔV Required	$0.0\,\mathrm{m\,s^{-1}}$

2.2 Stage Parameters

Table 2: Stage Parameters and Assumptions

Stage	ISP (s)	Mass Fraction (ϵ)
1	300	0.060
2	348	0.040

3 Optimization Methods

The following optimization methods were evaluated:

- SLSQP
- BASIN-HOPPING

- GA
- ADAPTIVE-GA
- DE
- PSO

4 Optimization Results

4.1 Performance Visualization

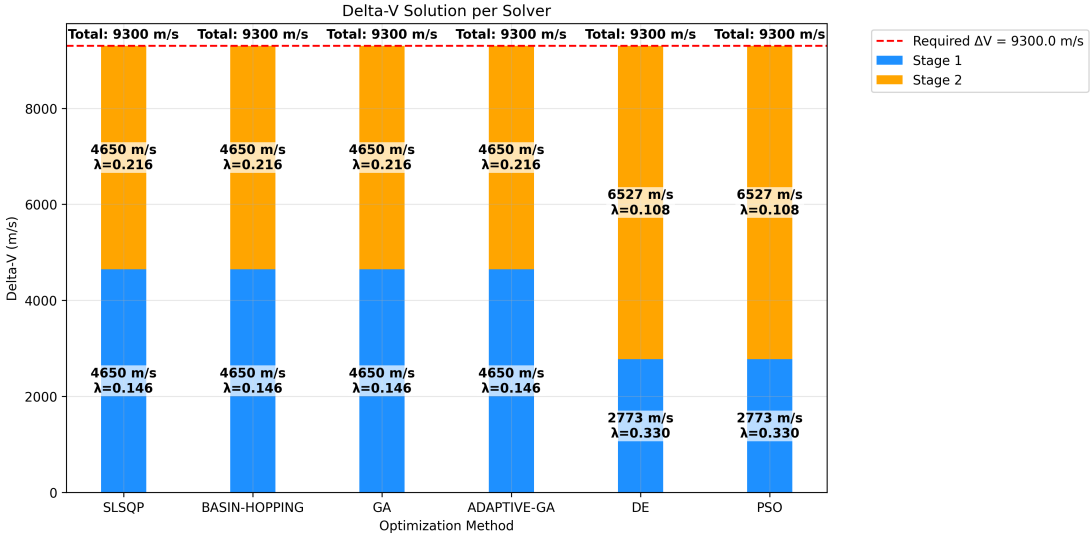

Figure 1: ΔV Distribution Across Stages

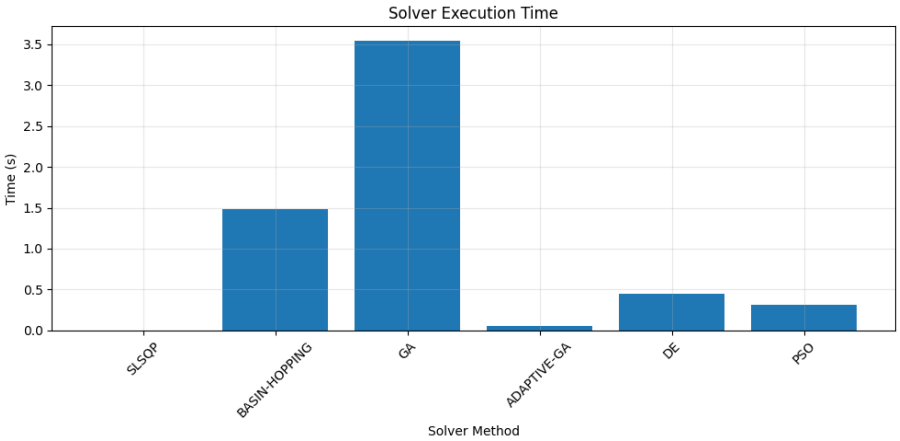

Figure 2: Solver Execution Time Comparison

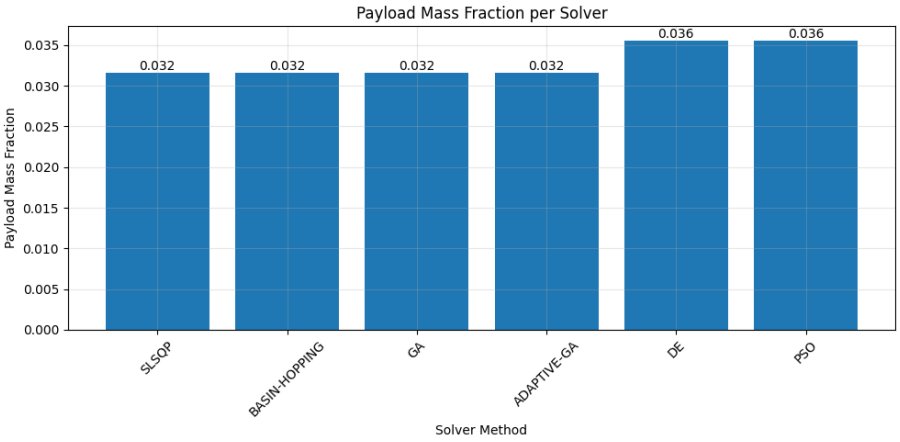

Figure 3: Payload Fraction Comparison

5 Final Results Summary

Table 3: Optimization Results Summary

Method	Payload Fraction	Error	Time (s)
SLSQP	0.0315	0.0000	0.00
BASIN-HOPPING	0.0315	1.8190×10^{-12}	1.49
GA	0.0315	0.0000	3.54
ADAPTIVE-GA	0.0315	0.0000	0.05
DE	0.0355	0.0000	0.44
PSO	0.0355	0.0000	0.31

5.1 Stage-by-Stage Analysis

Table 4: Stage 1 Comparison Across Methods

Method	ΔV ($\mathrm{m\,s^{-1}}$)	Mass Ratio (λ)	Contribution (%)
SLSQP	4650.0	0.1460	50.0
BASIN-HOPPING	4649.7	0.1460	50.0
GA	4650.0	0.1460	50.0
ADAPTIVE-GA	4650.0	0.1460	50.0
DE	2773.0	0.3298	29.8
PSO	2773.0	0.3298	29.8

Table 5: Stage 2 Comparison Across Methods

Method	ΔV ($\mathrm{m\,s^{-1}}$)	Mass Ratio (λ)	Contribution (%)
SLSQP	4650.0	0.2161	50.0
BASIN-HOPPING	4650.3	0.2161	50.0
GA	4650.0	0.2161	50.0
ADAPTIVE-GA	4650.0	0.2161	50.0
DE	6527.0	0.1078	70.2
PSO	6527.0	0.1078	70.2

Table 6: Stage Distribution Summary

Method	Stage 1 (%)	Stage 2 (%)	Total λ
SLSQP	50.0	50.0	0.0315
BASIN-HOPPING	50.0	50.0	0.0315
GA	50.0	50.0	0.0315
ADAPTIVE-GA	50.0	50.0	0.0315
DE	29.8	70.2	0.0355
PSO	29.8	70.2	0.0355

Key Observations:

- Methods with even ΔV distribution ($\approx 50.0/50.0$): SLSQP, BASIN-HOPPING, GA, ADAPTIVE-GA
- Methods with uneven distribution: DE, PSO
- Best Stage 1 mass ratio: PSO
- Best Stage 2 mass ratio: SLSQP