

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 maximize 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 m s^{-2}
Total ΔV Required	0.0 m s^{-1}

2.2 Stage Parameters

Table 2: Stage Parameters and Assumptions

Stage	ISP (s)	Mass Fraction (ϵ)
1	300	0.150
2	348	0.100
3	400	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

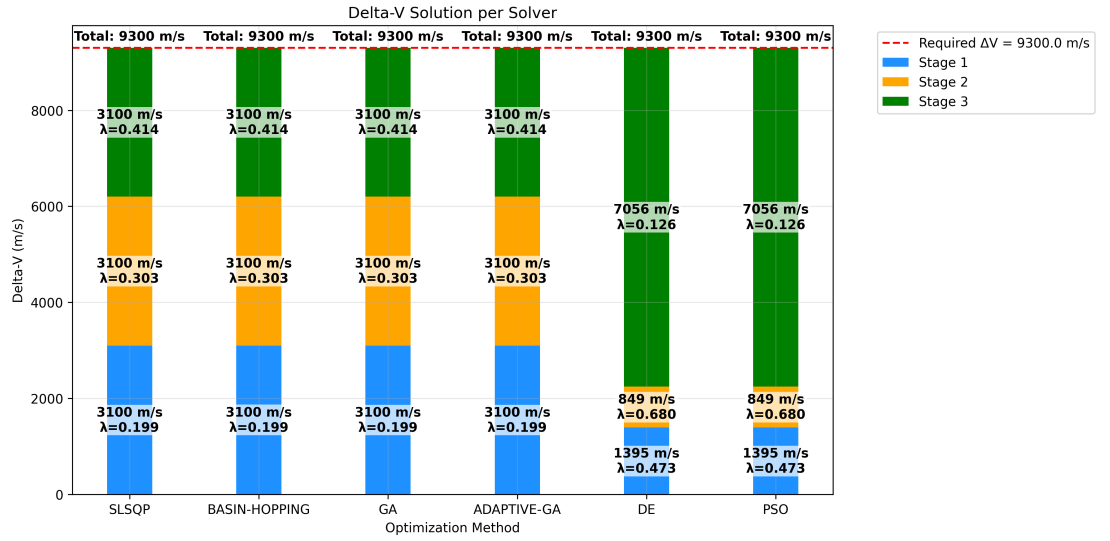


Figure 1: ΔV Distribution Across Stages

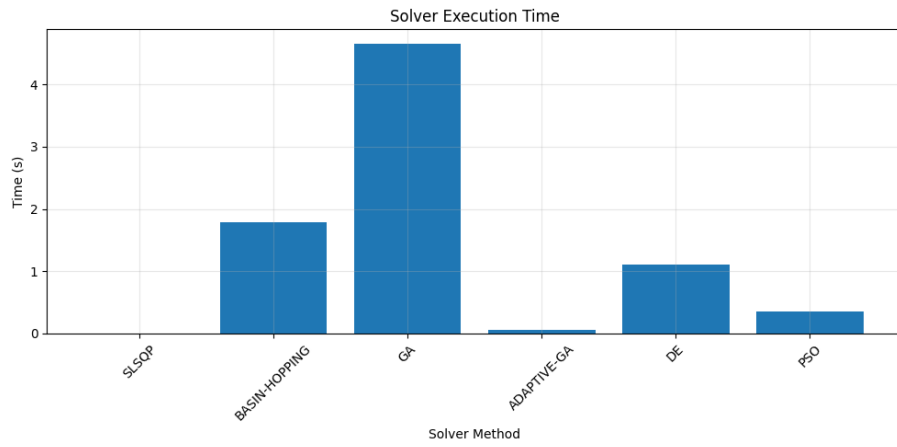


Figure 2: Solver Execution Time Comparison

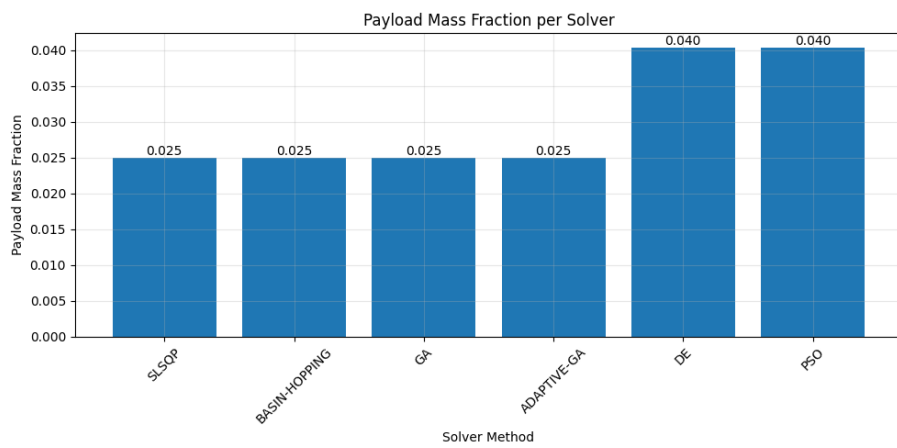


Figure 3: Payload Fraction Comparison

5 Final Results Summary

Table 3: Optimization Results Summary

Method	Payload Fraction	Error	Time (s)
SLSQP	0.0249	0.0000	0.00
BASIN-HOPPING	0.0249	0.0000	1.79
GA	0.0249	0.0000	4.65
ADAPTIVE-GA	0.0249	0.0000	0.05
DE	0.0403	0.0000	1.11
PSO	0.0403	0.0000	0.36

5.1 Stage-by-Stage Analysis

Table 4: Stage 1 Comparison Across Methods

Method	ΔV (m s ⁻¹)	Mass Ratio (λ)	Contribution (%)
SLSQP	3100.0	0.1988	33.3
BASIN-HOPPING	3100.3	0.1987	33.3
GA	3100.0	0.1988	33.3
ADAPTIVE-GA	3100.0	0.1988	33.3
DE	1395.0	0.4725	15.0
PSO	1395.0	0.4725	15.0

Table 5: Stage 2 Comparison Across Methods

Method	ΔV (m s ⁻¹)	Mass Ratio (λ)	Contribution (%)
SLSQP	3100.0	0.3033	33.3
BASIN-HOPPING	3100.1	0.3033	33.3
GA	3100.0	0.3033	33.3
ADAPTIVE-GA	3100.0	0.3033	33.3
DE	848.7	0.6799	9.1
PSO	848.8	0.6799	9.1

Table 6: Stage 3 Comparison Across Methods

Method	ΔV (ms ⁻¹)	Mass Ratio (λ)	Contribution (%)
SLSQP	3100.0	0.4138	33.3
BASIN-HOPPING	3099.5	0.4139	33.3
GA	3100.0	0.4138	33.3
ADAPTIVE-GA	3100.0	0.4138	33.3
DE	7056.3	0.1256	75.9
PSO	7056.2	0.1256	75.9

Table 7: Stage Distribution Summary

Method	Stage 1 (%)	Stage 2 (%)	Stage 3 (%)	Total λ
SLSQP	33.3	33.3	33.3	0.0249
BASIN-HOPPING	33.3	33.3	33.3	0.0249
GA	33.3	33.3	33.3	0.0249
ADAPTIVE-GA	33.3	33.3	33.3	0.0249
DE	15.0	9.1	75.9	0.0403
PSO	15.0	9.1	75.9	0.0403

Key Observations:

- Methods with even ΔV distribution ($\approx 33.3/33.3/33.3$): SLSQP, BASIN-HOPPING, GA, ADAPTIVE-GA
- Methods with uneven distribution: DE, PSO
- Best Stage 1 mass ratio: PSO
- Best Stage 2 mass ratio: DE
- Best Stage 3 mass ratio: BASIN-HOPPING