Rocket Stage Optimization Results

Generated by Stage_Opt

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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	0.150
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

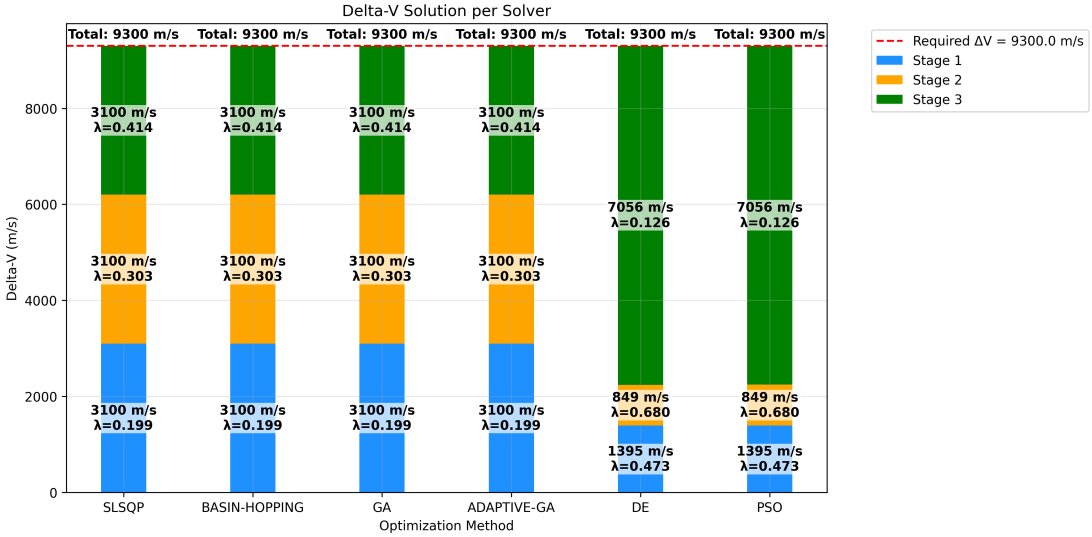

Figure 1: ΔV Distribution Across Stages

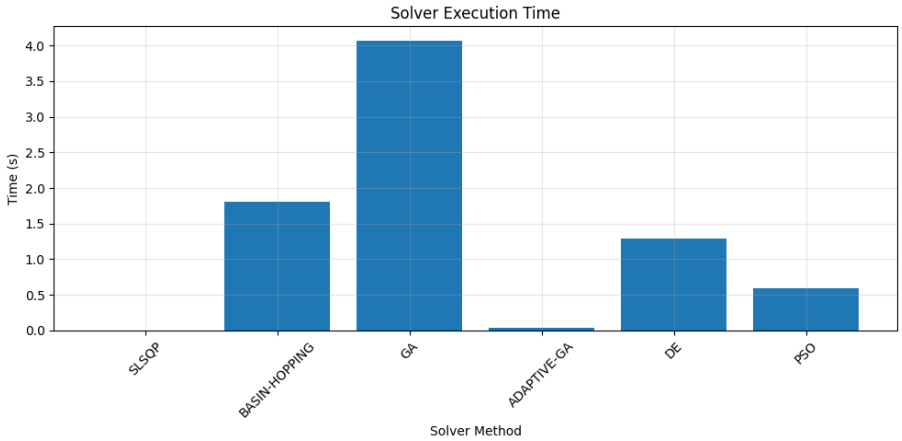

Figure 2: Solver Execution Time Comparison

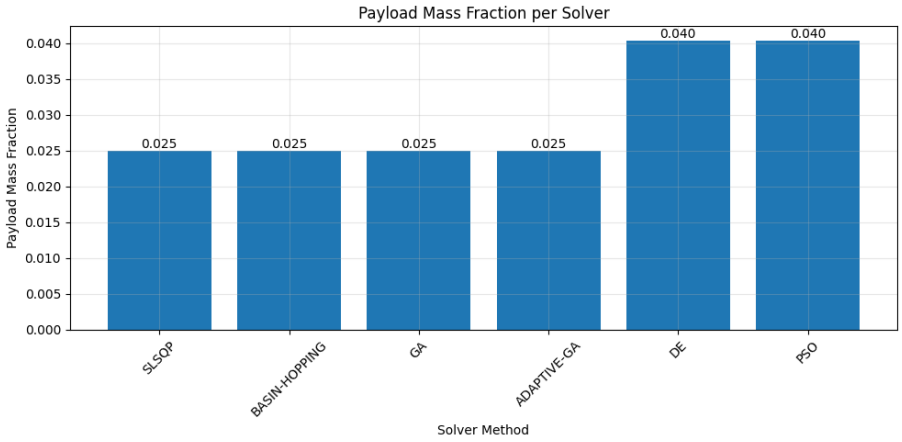

Figure 3: Payload Fraction Comparison

5 Final Results Summary

Table 3: Optimization Results Summary

Method	Payload Fraction	Error	Time (s)
SLSQP	0.0249	0.0000	0.00
BASIN-HOPPING	0.0250	1.8190×10^{-12}	1.81
GA	0.0249	0.0000	4.07
ADAPTIVE-GA	0.0249	0.0000	0.04
DE	0.0403	0.0000	1.29
PSO	0.0403	0.0000	0.60

5.1 Stage-by-Stage Analysis

Table 4: Stage 1 Comparison Across Methods

Method	ΔV ($\mathrm{m\,s^{-1}}$)	Mass Ratio (λ)	Contribution (%)
SLSQP	3100.0	0.1988	33.3
BASIN-HOPPING	3099.8	0.1988	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 ($\mathrm{m\,s^{-1}}$)	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	848.6	0.6799	9.1
PSO	848.8	0.6799	9.1

Table 6: Stage 3 Comparison Across Methods

Method	ΔV ($\mathrm{m\,s^{-1}}$)	Mass Ratio (λ)	Contribution (%)
SLSQP	3100.0	0.4138	33.3
BASIN-HOPPING	3100.1	0.4138	33.3
GA	3100.0	0.4138	33.3
ADAPTIVE-GA	3100.0	0.4138	33.3
DE	7056.4	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	0.0250
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: SLSQP