# Rocket Stage Optimization Results

Generated by Stage_Opt

February 24, 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 $\Delta V$ Required | $0.0\,\mathrm{m\,s^{-1}}$ |

### 2.2 Stage Parameters

Table 2: Stage Parameters and Assumptions

| Stage | ISP (s) | Mass Fraction ($\epsilon$) |
|---|---|---|
| 1 | 300 | 0.150 |
| 2 | 348 | 0.100 |

## 3 Optimization Methods

The following optimization methods were evaluated:

- SLSQP
- BASIN-HOPPING

- GA
- ADAPTIVE-GA
- DE
- PSO

# 4 Optimization Results

## 4.1 Performance Visualization

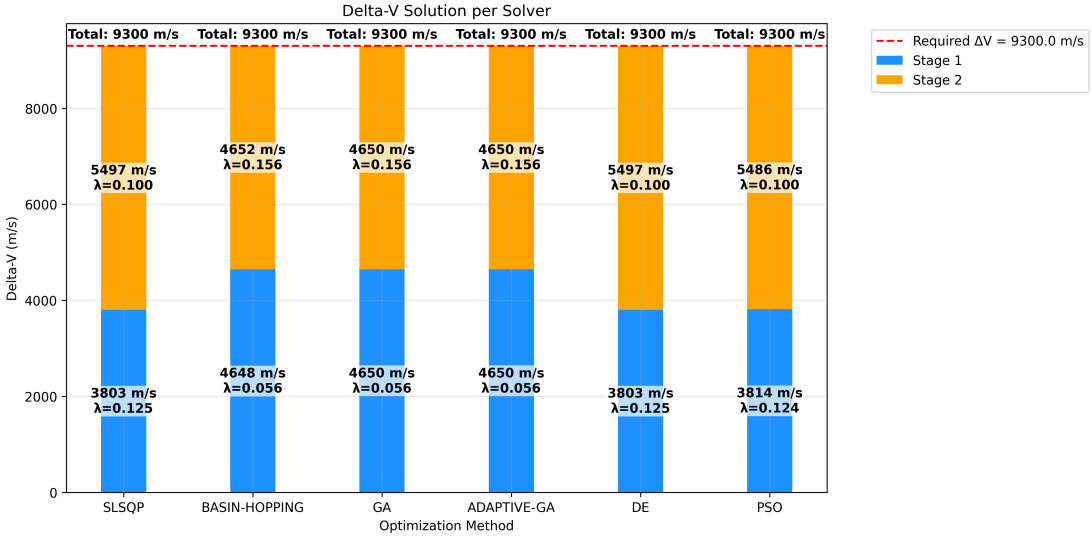


Figure 1: $\Delta V$ Distribution Across Stages

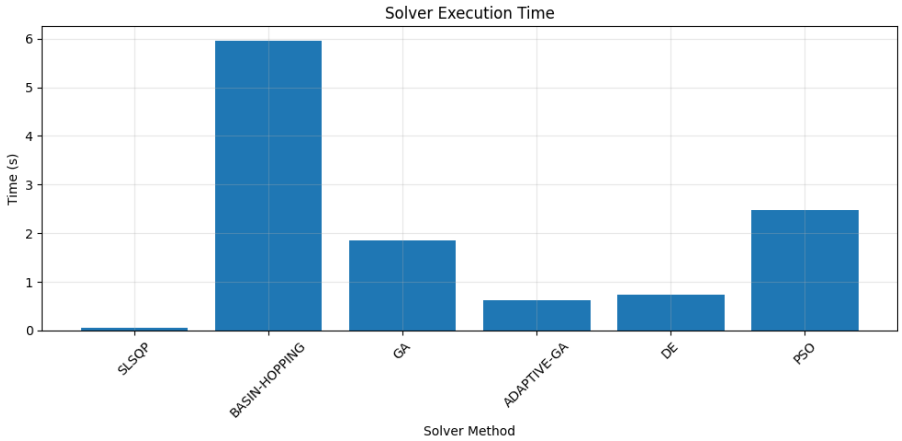


Figure 2: Solver Execution Time Comparison

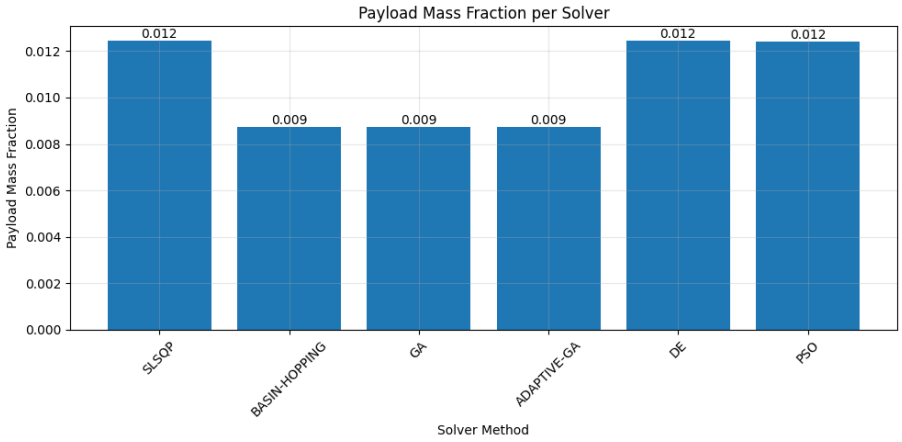


Figure 3: Payload Fraction Comparison

# 5 Final Results Summary

Table 3: Optimization Results Summary

| Method | Payload Fraction | Error | Time (s) |
|---|---|---|---|
| SLSQP | 0.0124 | 0.0000 | 0.05 |
| DE | 0.0124 | 0.0000 | 0.74 |
| PSO | 0.0124 | 0.0000 | 2.48 |
| BASIN-HOPPING | 0.0088 | 0.0000 | 5.95 |
| GA | 0.0087 | 0.0000 | 1.84 |
| ADAPTIVE-GA | 0.0087 | 0.0000 | 0.63 |

## 5.1 Stage-by-Stage Analysis

Table 4: Stage 1 Comparison Across Methods

| Method | $\Delta V$ ($\mathrm{m\,s^{-1}}$) | Mass Ratio ($\lambda$) | Contribution (%) |
|---|---|---|---|
| SLSQP | 3802.6 | 0.1247 | 40.9 |
| DE | 3802.6 | 0.1247 | 40.9 |
| PSO | 3813.7 | 0.1237 | 41.0 |
| BASIN-HOPPING | 4648.0 | 0.0561 | 50.0 |
| GA | 4650.0 | 0.0560 | 50.0 |
| ADAPTIVE-GA | 4650.0 | 0.0560 | 50.0 |

Table 5: Stage 2 Comparison Across Methods

| Method | $\Delta V$ ($\mathrm{m\,s^{-1}}$) | Mass Ratio ($\lambda$) | Contribution (%) |
|---|---|---|---|
| SLSQP | 5497.4 | 0.0998 | 59.1 |
| DE | 5497.4 | 0.0998 | 59.1 |
| PSO | 5486.3 | 0.1005 | 59.0 |
| BASIN-HOPPING | 4652.0 | 0.1560 | 50.0 |
| GA | 4650.0 | 0.1561 | 50.0 |
| ADAPTIVE-GA | 4650.0 | 0.1561 | 50.0 |

Table 6: Stage Distribution Summary

| Method | Stage 1 (%) | Stage 2 (%) | Total $\lambda$ |
|---|---|---|---|
| SLSQP | 40.9 | 59.1 | 0.0124 |
| DE | 40.9 | 59.1 | 0.0124 |
| PSO | 41.0 | 59.0 | 0.0124 |
| BASIN-HOPPING | 50.0 | 50.0 | 0.0088 |
| GA | 50.0 | 50.0 | 0.0087 |
| ADAPTIVE-GA | 50.0 | 50.0 | 0.0087 |

**Key Observations:**

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