HP-1 Engine Design: Task C Report
Minimum Uninstalled Specific Thrust Calculation

Analysis based on provided script output

March 31, 2025

1 Objective

This report summarizes the calculations performed for Task C of the HP-1 engine design problem, as detailed in `manual.md.txt`. The objective was to determine the minimum required uninstalled specific thrust ($F_{\text{uninstalled}}/\dot{m}_{\text{air}}$) for the engine at the specified cruise condition for various inlet diameters.

2 Methodology

The calculations were performed using a Python script based on the parameters and requirements outlined in Task A and Task C of `manual.md.txt`.

2.1 Cruise Conditions

- Flight Altitude: 11 km
- Flight Mach Number: M = 0.83
- Initial Rate of Climb (P_s): 1.5 m/s (as per Task A.3 for attaining cruise)
- Atmospheric Conditions at 11 km (ISA):
  - Temperature (T): 216.65 K
  - Pressure (P): 22 631.70 Pa
  - Density (ρ): 0.3639 kg/m^3
  - Speed of Sound (a): 295.07 m/s
- Cruise Speed (V = M × a): 244.91 m/s

2.2 Aircraft Parameters (Assumed/Placeholder)

Note: The following values were used in the provided script output but were flagged as placeholders requiring verification against `book.md.txt` Example 1.2 and `manual.md.txt` Table 1.

- Cruise Weight (W): 150 000 kg (1 470 998 N)
- Lift-to-Drag Ratio (L/D): 17.0

2.3 Calculations

1. **Required Installed Thrust ($T_{\text{installed}}$):** Calculated for the twin-engine aircraft to attain the initial cruise condition, including the specified rate of climb (P_s). Based on the assumption that Eq. (1.28) from `book.md.txt` includes the climb component:

$$T_{\text{installed}} = \text{Drag} + \frac{W \times P_s}{V} = \frac{W}{L/D} + \frac{W \times P_s}{V}$$

   Result: $T_{\text{installed}} = 95\,539$ N (Total for aircraft)

2. **Required Uninstalled Thrust ($T_{\text{uninstalled}}$):** Calculated by accounting for installation losses ($\Phi_{\text{inlet}} + \Phi_{\text{noz}} = 0.02$).

$$T_{\text{uninstalled}} = \frac{T_{\text{installed}}}{1 - (\Phi_{\text{inlet}} + \Phi_{\text{noz}})}$$

Result: $T_{\text{uninstalled}} = 97\,489\,\text{N}$ (Total for aircraft)
Result per engine (assuming twin-engine): $T_{\text{uninstalled, engine}} = 48\,744\,\text{N}$

3. **Maximum Inlet Mass Flow Rate ($\dot{m}_{\text{air, engine}}$):** Calculated for one engine based on the inlet diameter (D_{inlet}), assuming the diameter refers to a single engine inlet.

$$A_{\text{inlet, engine}} = \frac{\pi D_{\text{inlet}}^2}{4}$$

$$\dot{m}_{\text{air, engine}} = \rho \times V \times A_{\text{inlet, engine}}$$

4. **Minimum Uninstalled Specific Thrust ($F/\dot{m}$):** Calculated per engine.

$$\left(\frac{F}{\dot{m}}\right)_{\text{min}} = \frac{T_{\text{uninstalled, engine}}}{\dot{m}_{\text{air, engine}}}$$

3 Results

The calculated maximum inlet mass flow rate and minimum uninstalled specific thrust for each specified engine inlet diameter are presented in Table **??**.

Table 1: Minimum Uninstalled Specific Thrust vs. Inlet Diameter at Cruise (M=0.83, 11 km, Ps=1.5 m/s)

Inlet Diameter D_{inlet} (m)	Inlet Area per Engine A_{inlet} (m^2)	Max Air Mass Flow per Engine $\dot{m}_{\text{air}}$ (kg/s)	Min. Uninstalled Specific Thrust $F_{\text{uninstalled}}/\dot{m}_{\text{air}}$ (N s/kg)
2.20	3.801	338.79	143.88
2.50	4.909	437.49	111.42
2.75	5.940	529.37	92.08
3.00	7.069	629.99	77.37
3.25	8.296	739.36	65.93
3.50	9.621	857.49	56.85

4 Conclusion

The analysis shows that, for the given flight condition and required uninstalled thrust per engine (48 744 N), the minimum required uninstalled specific thrust decreases significantly as the engine inlet diameter increases. This is expected, as a larger inlet allows for a higher maximum air mass flow rate, thus requiring less thrust generation per unit of airflow.

The specific thrust ranges from approximately 144 N s/kg for a 2.2 m diameter inlet down to 57 N s/kg for a 3.5 m diameter inlet under the assumed conditions.

Important Reminder: The numerical results presented are based on assumed placeholder values for aircraft cruise weight (W=150 000 kg) and lift-to-drag ratio (L/D=17.0). These values must be verified and updated using the specific data from `manual.md.txt` (Table 1) and `book.md.txt` (Example 1.2) for accurate final results. The interpretation of Eq. (1.28) to include the initial climb rate should also be confirmed.