JetCAP: Jet Engine Cycle Analysis and Performance tool

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Introduction

There is a need for user-friendly software in the domain of Aircraft Engine Design and Analysis for the Aerospace Engineering community.
JetCAP has been developed to provide a user-friendly, freely accessible software solution for designing and analyzing aircraft engines across various cycles, filling the gap left by paid alternatives.

Objectives

The objective was to develop a software that does the following:
1. Perform Single-point and Multi-point **Parametric Cycle Analysis (PCA)**, along with the option to plot the results.
2. Perform **Engine performance analysis (EPA)** according to different flight conditions and Throttle settings.

Overview of the software

- **PCA inputs:** Altitude, ambient Temperature, Pressure (h, T_0, P_0), Component efficiencies (η, e), necessary pressure ratios (π), temperature limits (T_{t4}, T_{t7}), and fuel and air properties need to be entered.

- Single and Multiple variable iteration can also be performed.

- **PCA outputs:** ST (Specific Thrust), TSFC (Thrust-Specific Fuel Consumption), f (Fuel-air ratio), η_t & η_p (Thermal and Propulsive efficiencies respectively), and station-wise properties.

- **EPA inputs:** Off-design point flight conditions (T_0, P_0, M_0, alt), Throttle setting (T_{t4}), and inlet mass flow rate ($\dot{m}_0$) in order to size the engine.

- **EPA outputs:** PCA results, off-design Compressor pressure ratio, off-design bypass ratio, off-design mass flow rate, and Thrust in the test conditions.

Performance equations

Total Properties:

$$P = P_t\left(1+\frac{1}{2}(\gamma-1)M^2\right)^{-\frac{\gamma}{\gamma-1}}$$

$$T = T_t\left(1+\frac{1}{2}(\gamma-1)M^2\right)^{-1}$$

Fuel-Air ratio:

$$f_0 = \frac{h_{t4}-h_{t3}}{\eta_b \cdot H_{pr} - h_{t3}}\frac{1}{1+\alpha}$$

Core flow Specific Thrust:

$$\frac{T_c}{\dot{m}_c} = a_0\left(M_9\sqrt{\frac{T_{tR}}{T_9}\frac{C_R}{C_{T_0}}} - M_0 + \sqrt{\frac{T_{tR}}{T_9}\frac{C_R}{C_{T_0}}}\left(1-\frac{P_0}{P_{9t}}M_9\right)\right)$$

Bypass flow Specific Thrust:

$$\frac{T_b}{\dot{m}_b} = a_0\left(M_{19}\frac{T_{19}}{T_0} - M_0\right) + a_{19}\left(1-\frac{P_0}{P_{19}}\right)cM_{19}$$

Overall Specific Thrust:

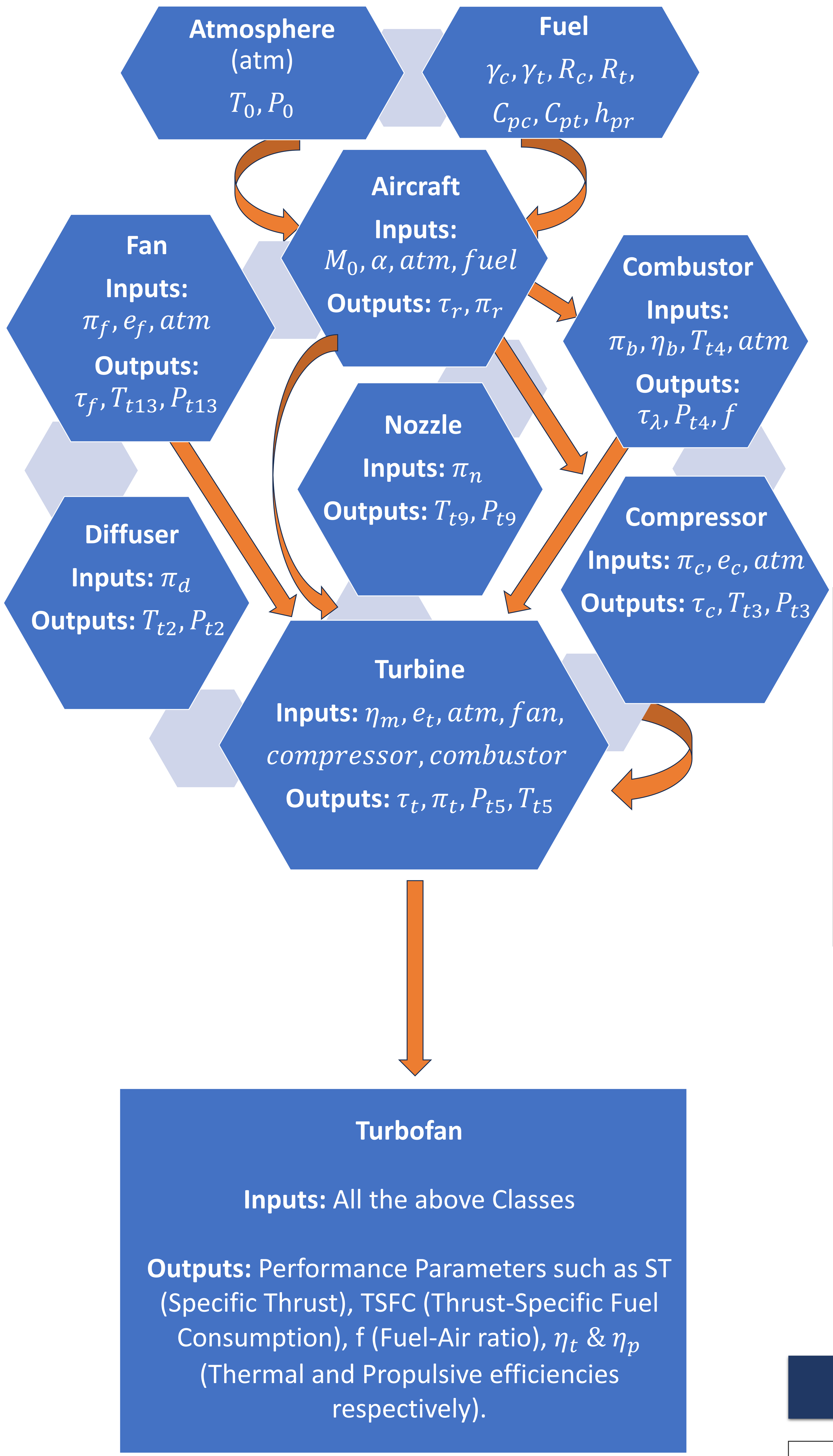
$$ST = \frac{\alpha}{1+\alpha}\cdot\frac{T_b}{\dot{m}_b} + \frac{1}{1+\alpha}\cdot\frac{T_c}{\dot{m}_c}$$

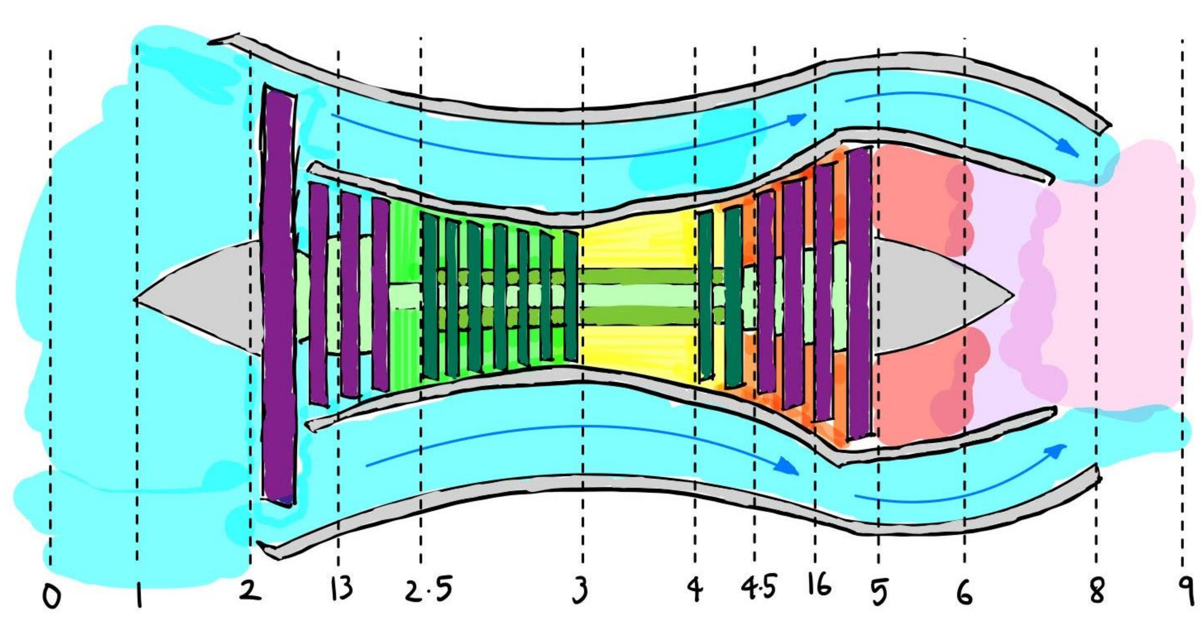
Thrust-Specific Fuel Consumption:

$$TSFC = \frac{f}{ST}$$

Methodology

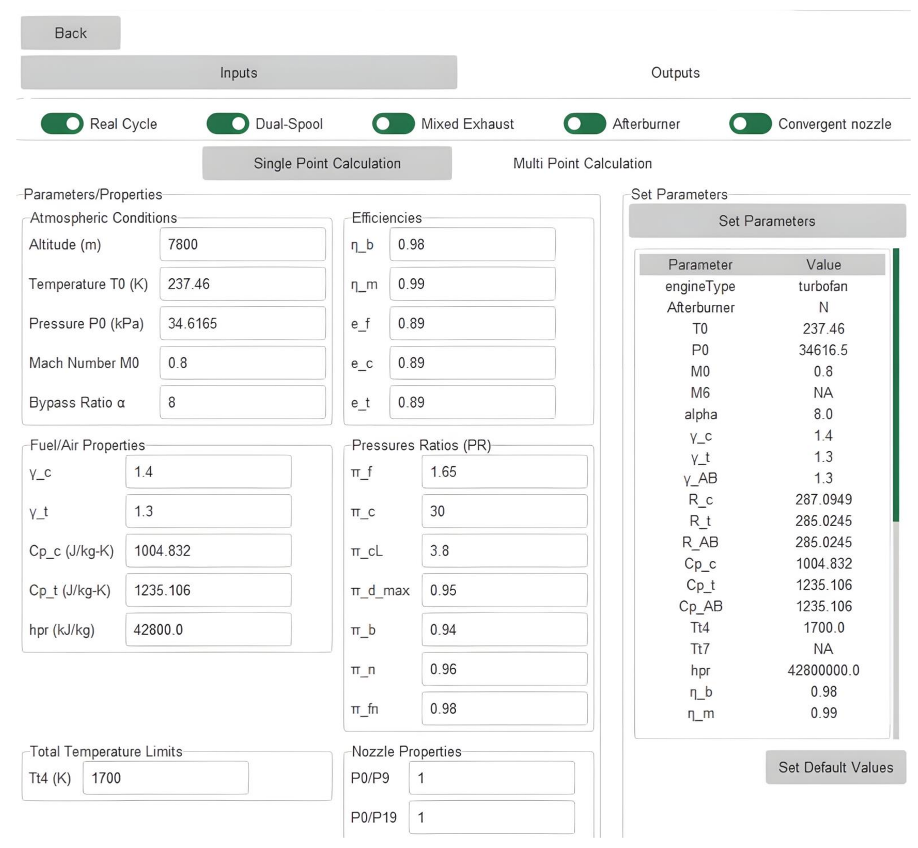
- We used Python to build the software. Each component of the engine was built as a Python Class with necessary parameters and functions.
- Components of Gas turbine Engines:
  - Diffuser
  - Fan
  - Compressor
  - Combustor
  - Turbine
  - Nozzle



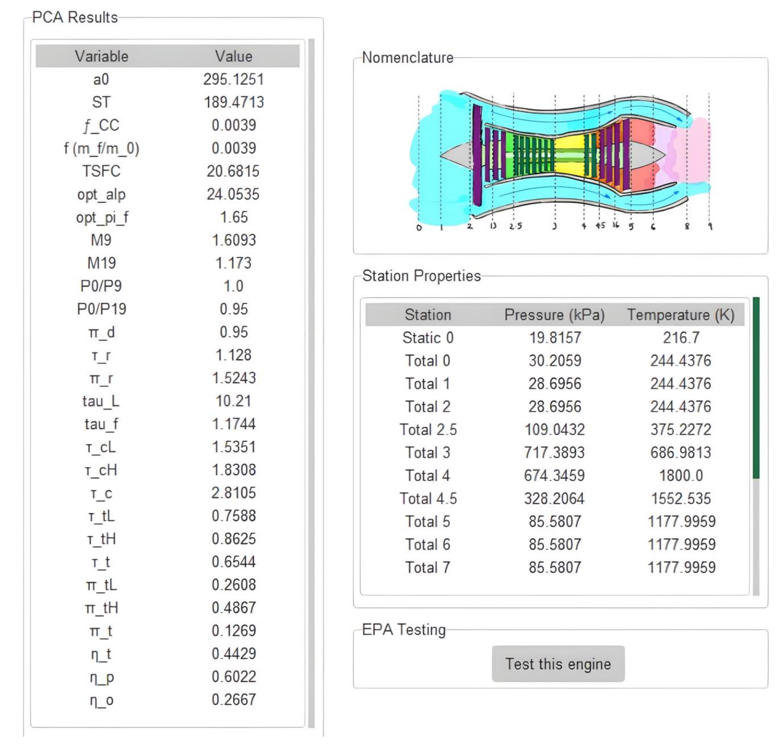


Schematic of Turbofan Engine with Station numbering

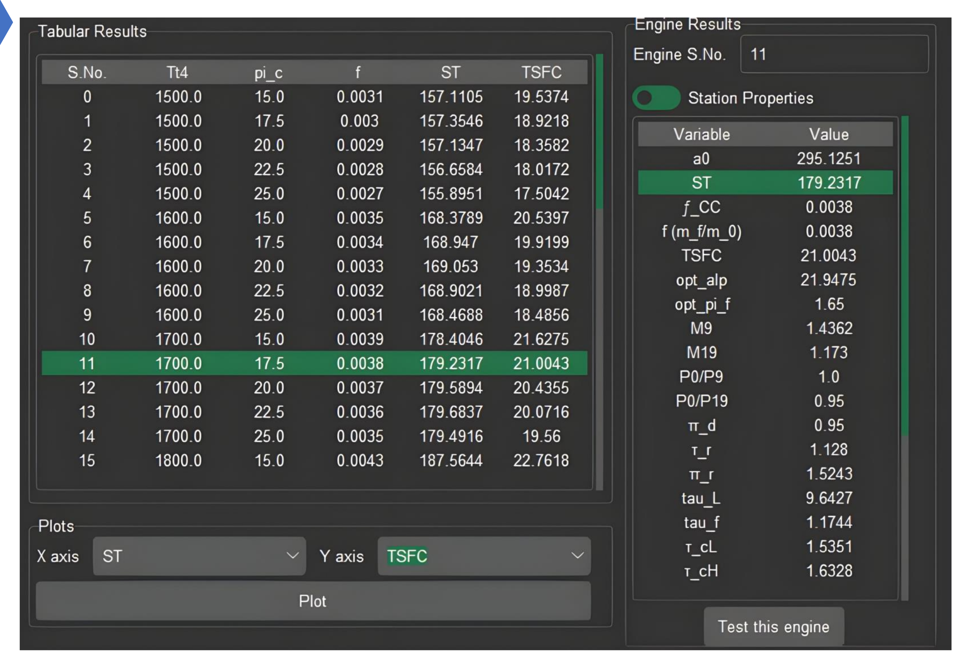
Results



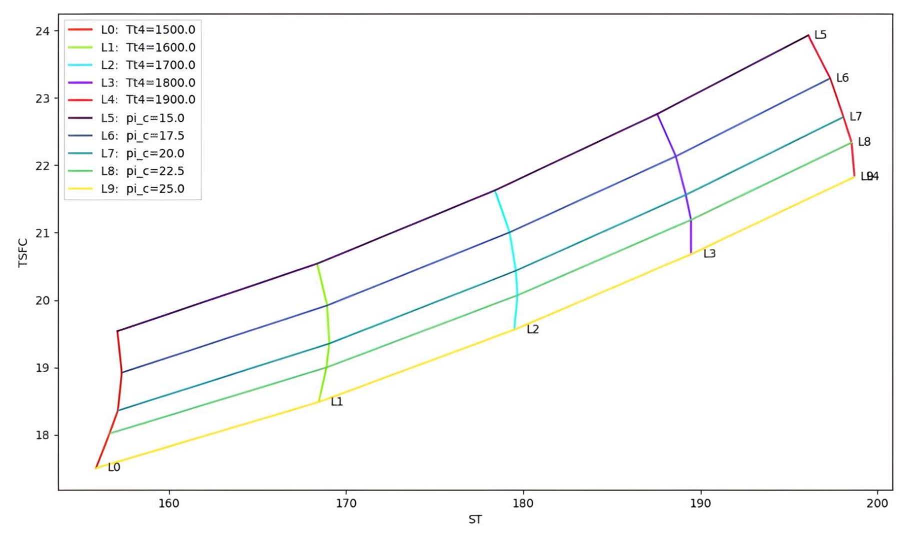
Input window for single-point calculation



Output window for single-point calculation



Output window for multi-point calculation



Carpet plot (TSFC v/s ST) with varying T_{t4} & π_c

Future Scope

The future versions of this software can be developed to automate the process of designing the most optimum engine for a specific mission profile.

References

[1] J. D. Mattingly, *Elements of Propulsion: Gas Turbines and Rockets*. AIAA Education Series, 2006.
[2] PARA, Available: URL https://arc.aiaa.org/doi/suppl/10.2514/4.103711/suppl_file

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