

# JetCAP: Jet Engine Cycle Analysis and Performance tool



Department of Mechanical Engineering, IIT Gandhinagar  
Abhijit Venkat P (IIT Gandhinagar), Aditya Prasad (IIT Gandhinagar),  
Gauresh Rangaiyan (Texas A&M University)

## 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 ( $\eta, e$ ), necessary pressure ratios ( $\pi$ ), 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),  $\eta_t$  &  $\eta_p$  (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:

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

Overall Specific Thrust:

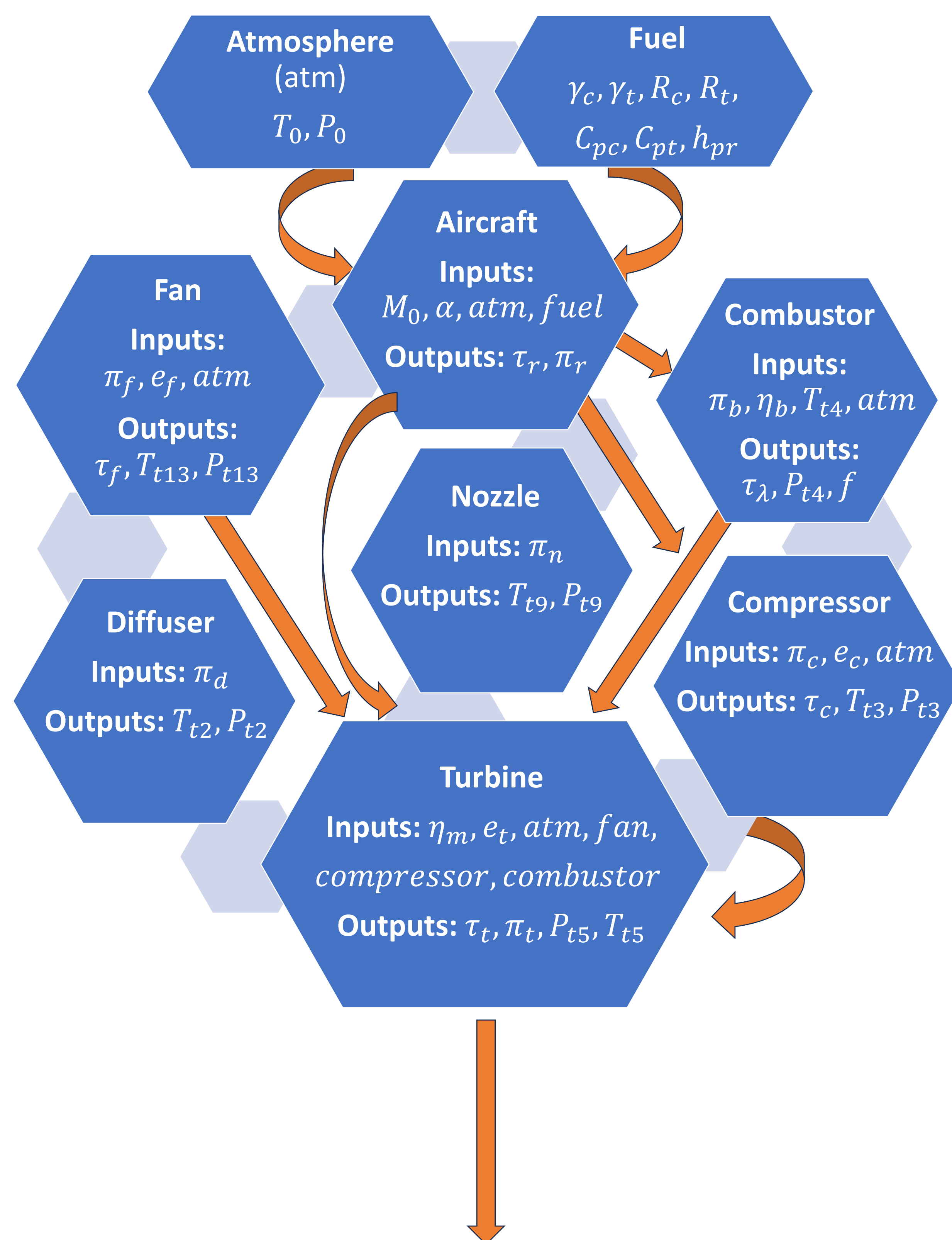
$$ST = \frac{\alpha}{1 + \alpha} \cdot \frac{T_b}{\dot{m}_b} + \frac{1}{1 + \alpha} \cdot \frac{T_c}{\dot{m}_c}$$

Thrust-Specific Fuel Consumption:

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

## Methodology

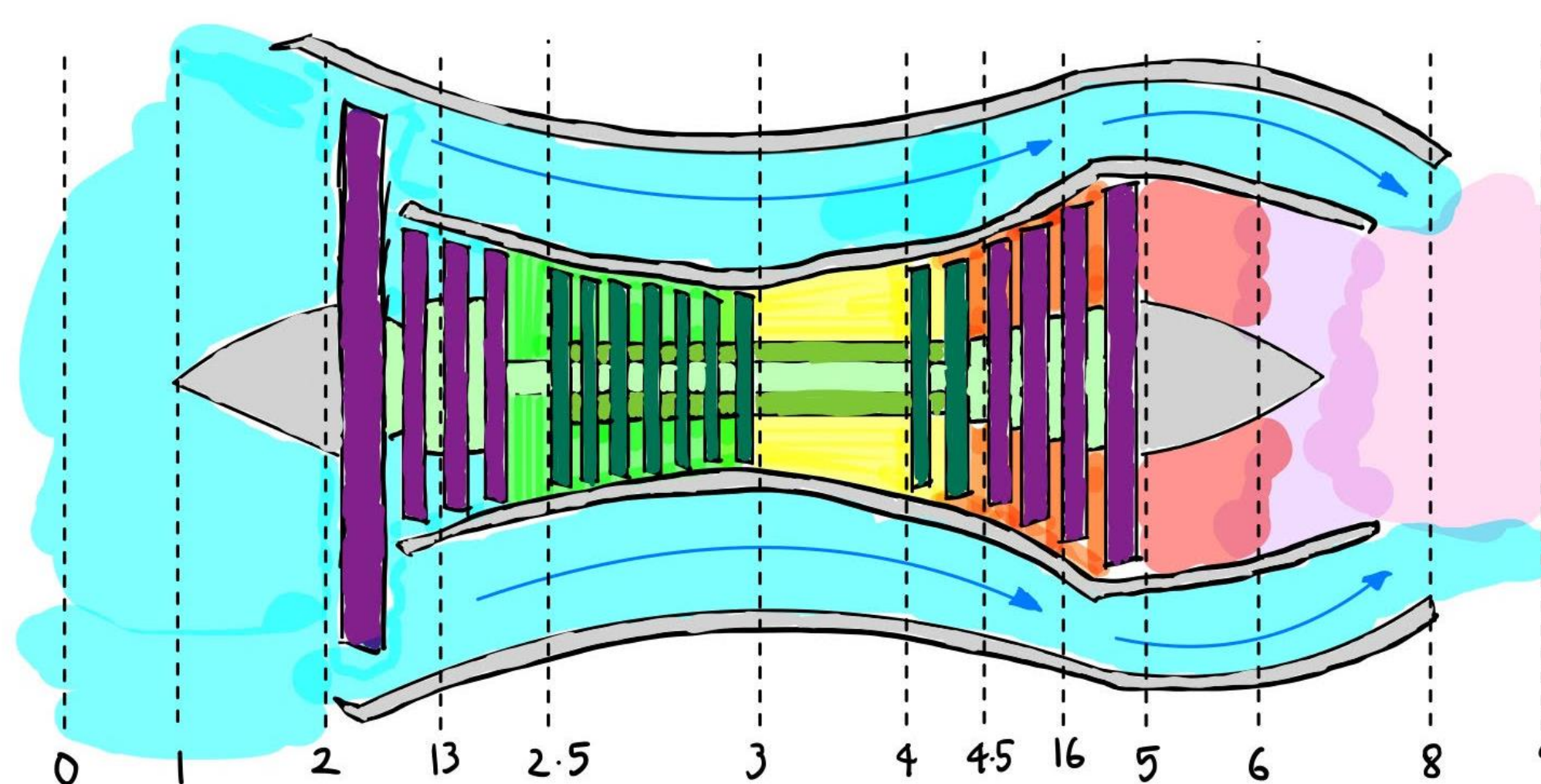
- We used Python to build the software. Each component of the engine was built as a Python Class with necessary parameters and functions.
- Components of Gas turbine Engines:
  - Diffuser
  - Fan
  - Compressor
  - Combustor
  - Turbine
  - Nozzle



### Turbofan

Inputs: All the above Classes

Outputs: Performance Parameters such as ST (Specific Thrust), TSFC (Thrust-Specific Fuel Consumption),  $f$  (Fuel-Air ratio),  $\eta_t$  &  $\eta_p$  (Thermal and Propulsive efficiencies respectively).

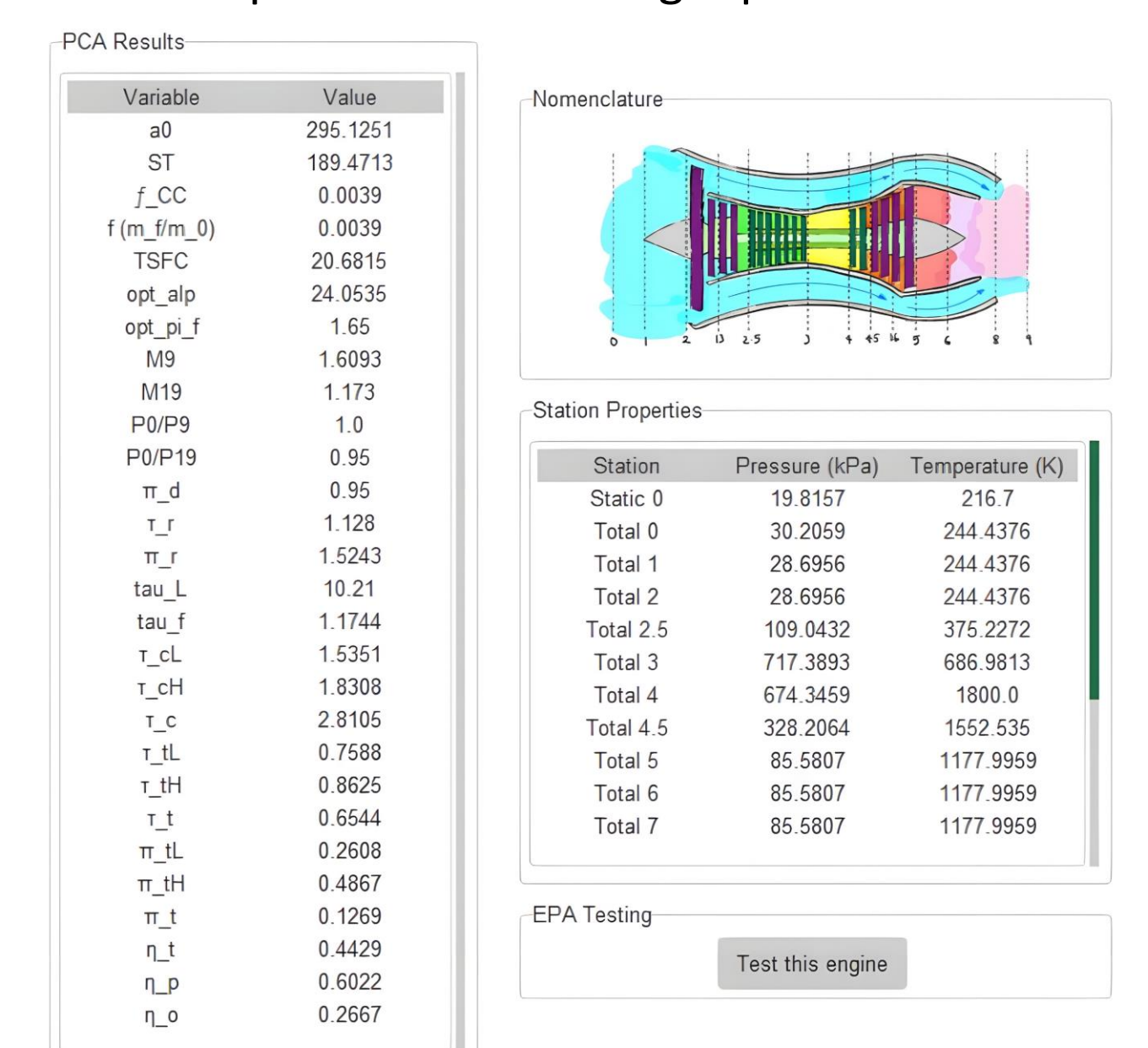


Schematic of Turbofan Engine with Station numbering

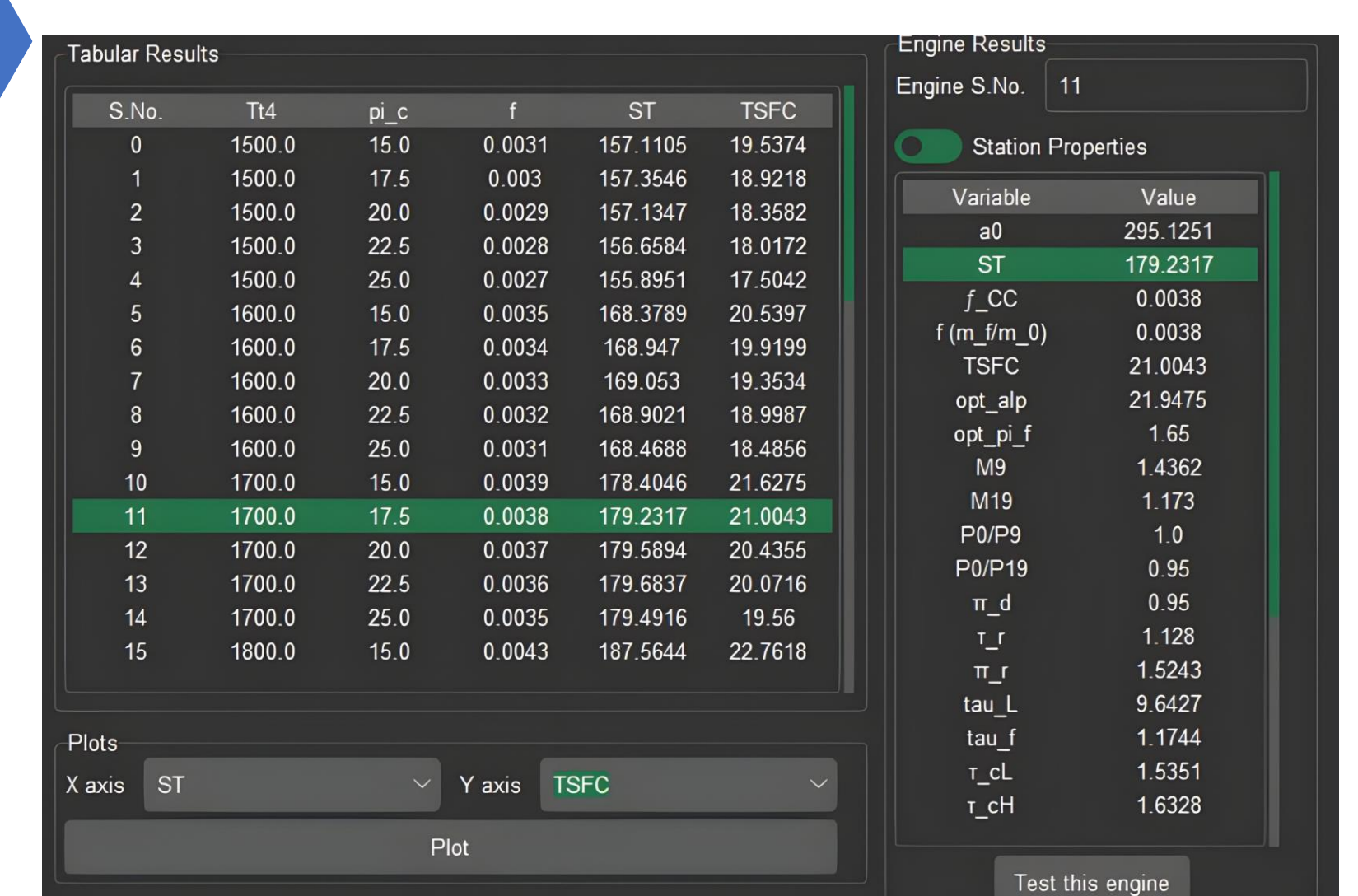
## Results

The screenshot displays the JetCAP software interface. It includes a 'Back' button, 'Inputs' and 'Outputs' sections, and a 'Single Point Calculation' button. The 'Parameters/Properties' section lists various inputs like Altitude (m), Temperature T0 (K), Pressure P0 (kPa), Mach Number M0, Bypass Ratio  $\alpha$ , Fuel/Air Properties (V\_c, V\_t, Cp\_c, Cp\_t, hpr), and Nozzle Properties (Tt4, Tt9, P0/P9, P0/P19). The 'Efficiencies' section lists  $\eta_b, \eta_m, \eta_c, \eta_t, e_c, e_t$ . The 'Set Parameters' section lists engineType, Altitude, T0, P0, M0, M6, alpha, V\_c, V\_t, R\_c, R\_t, R\_AB, Cp\_c, Cp\_t, Cp\_AB, Tt4, Tt7, hpr,  $\eta_b, \eta_m$ . The 'Total Temperature Limits' section lists Tt4 (K) and Tt9 (K). The 'Nozzle Properties' section lists P0/P9 and P0/P19. A 'Set Default Values' button is also present.

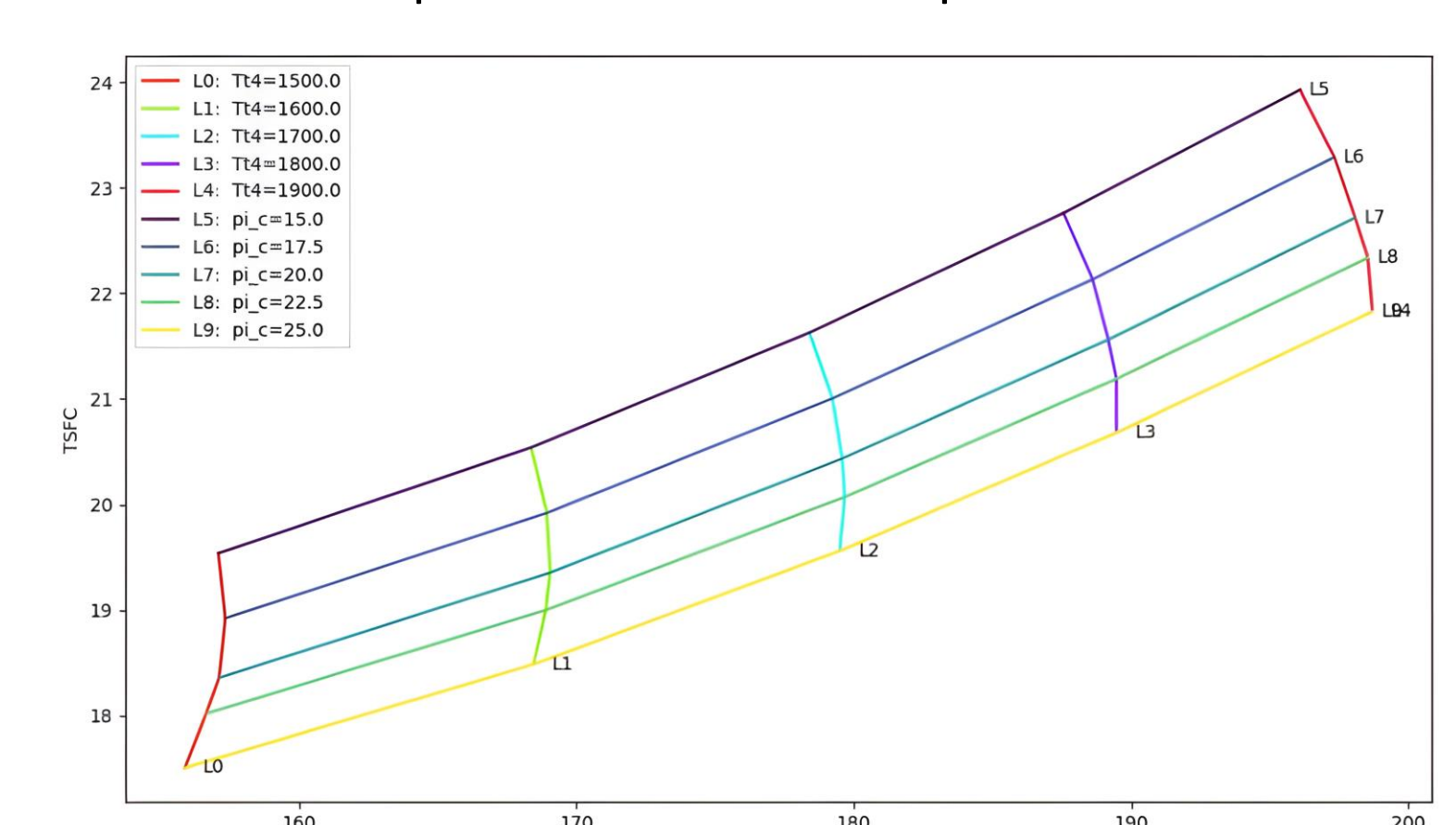
Input window for single-point calculation



Output window for single-point calculation



Output window for multi-point calculation



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

## 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](https://arc.aiaa.org/doi/suppl/10.2514/4.103711/suppl_file)

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