APP Aircraft Performance Program Demo Notes

Using Cessna 172 as an Example

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1. Program Layout & Organization

- APP Consists of 8 Modules, 5 Input Modules and 2 Calculation Modules. Each is its own separate file contained within the overall APP framework.

  - Configuration Module: This module allows the user to specify basic reference areas, weights, and flight envelope information.
  - Store Module: This module allows the user to specify external fuel and mass items which can be consumed or dropped during flight.
  - Aerodynamics Module: This allows the user to define wing planform, lift, and drag data for the aircraft.
  - Fuel Module: This allows the user to specify fuel consumption across the flight envelope.
  - Thrust Module: This allows the user specify thrust profiles across the flight envelope.
  - Performance Module: This allows the user to calculate a number of performance parameters and trends throughout the flight envelope.
  - Mission Module: This allows the user to examine performance over a defined mission spec and optimize a mission to give specific performance goals.

- The user interface is arranged as an open desktop with a series of windows which contain the various modules.

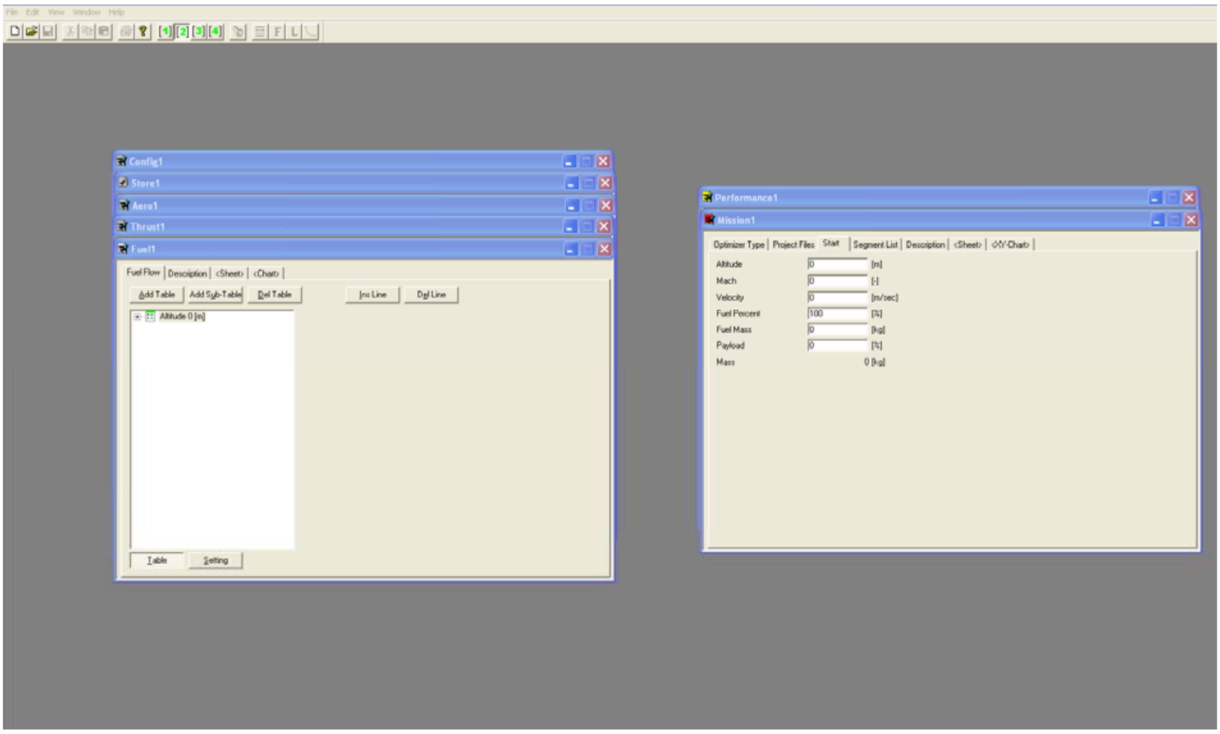

Figure 1.1 APP Graphical User Interface

- The user can switch between units systems quickly and easily by clicking on the green numbers in the tool bar.

Figure 2.1 APP Toolbar

2. Configuration Module

- Mass Tab: In this tab the major weight categories are defined. For this example we are using a Cessna 172. The weight data can come either from manufacturers supplied weights, traditional hand calculations, or AAA.

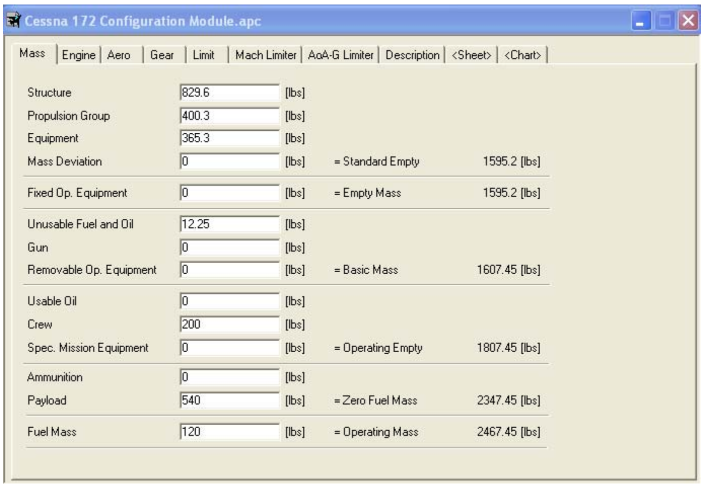

Figure 2.1 Mass Tab

- Engine Tab: In this tab the number of engines and thrust inclination angle are defined. There are also multiplier cells that allow the user to quickly add more (or less) thrust and/or fuel without re-entering thrust data by applying a scaling factor.

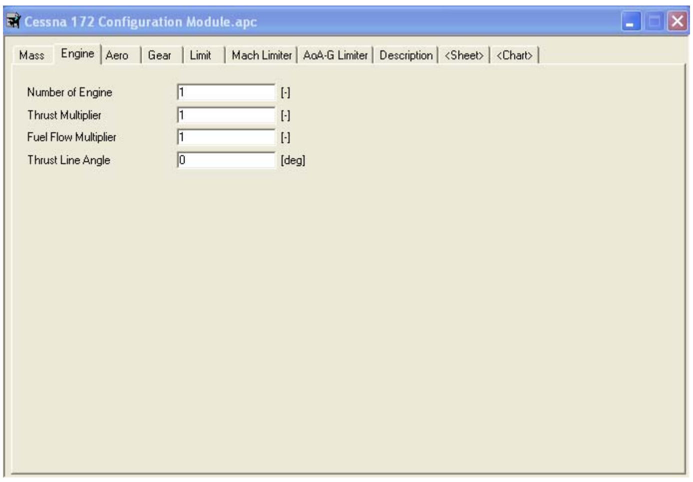

Figure 2.2 Engine Tab

- Aero-Tab: This tab allows the user to define a drag area for items such as speed brakes or spoilers without altering the planform area. There is also a cell for a drag multiplier which allows the user to specify the amount of additional drag induced by the delta drag area.

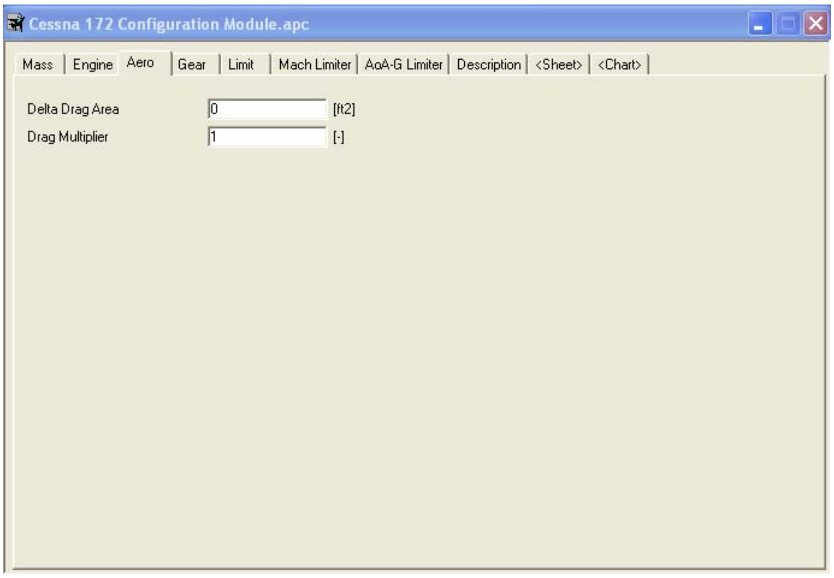

Figure 2.3 Aero Tab

- Gear Tab: In the gear tab, the parasite area of the landing gear and angle of attack on the ground are entered. Here we also specify if it is fixed gear or not.

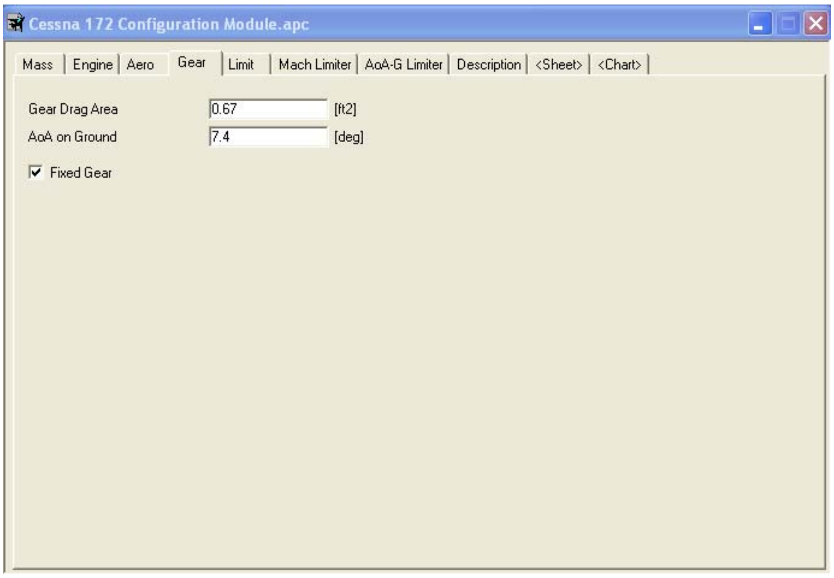

Figure 2.4 Gear Tab

- Limit Tab: The limit tab allows the user to define the g-envelope and angle of attack envelope.

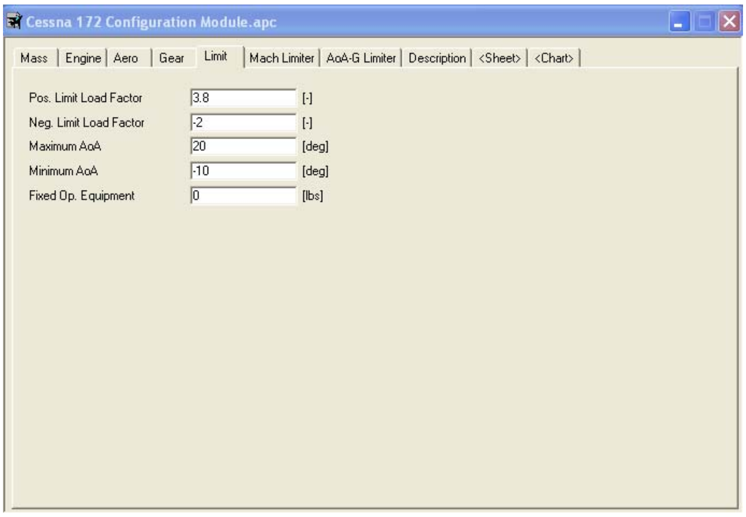

Figure 2.5 Limit Tab

- Mach Limiter Tab: This defines the Placard Mach number over the altitude range. This is usually based on structural limitations of the airframe.

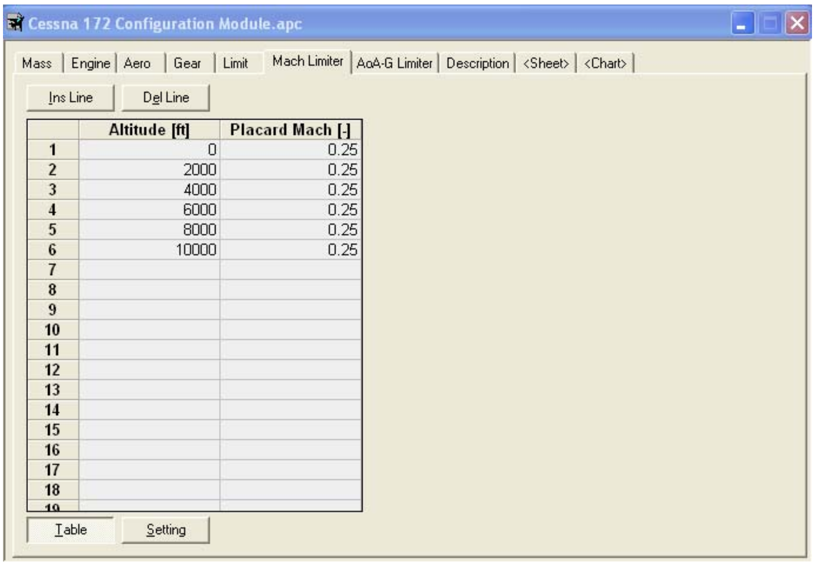

Figure 2.6 Mach Limiter Tab

- AoA-G Limiter Tab: This allows the G-envelope to be defined as a function of angle of attack. For our purposes we will disable this feature.

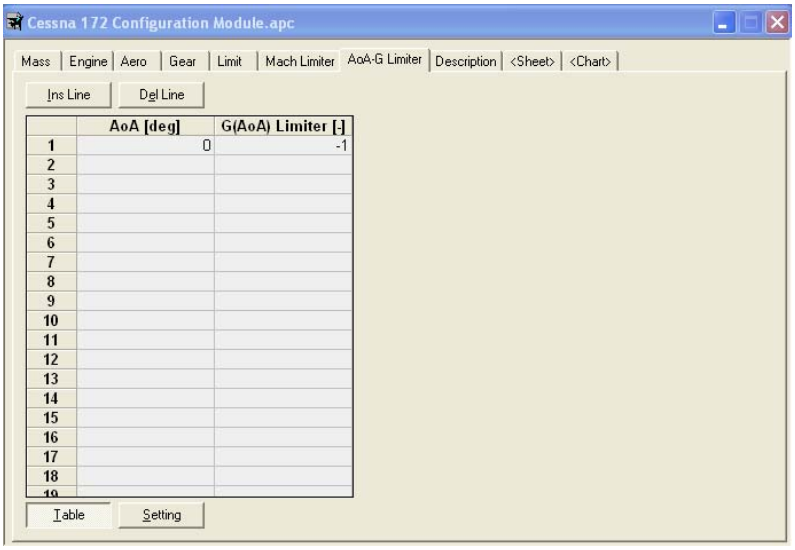

Figure 2.7 AoA-G Limiter Tab

- Description Tab: This is a place for you to document sources, make notes for other users, or for yourself.

- Sheet Tab: This tab summarizes all of the inputs and allows the user to export to an Excel Spreadsheet.

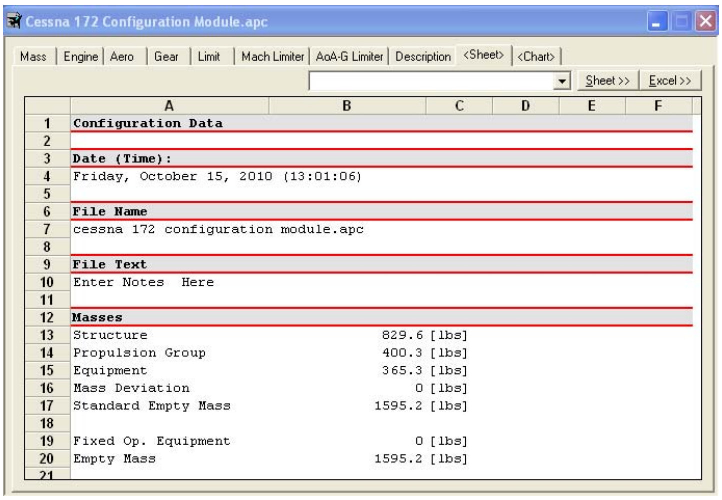

Figure 2.8 Sheet Tab

- Chart Tab: This plots the data points entered into the Mach Limiter and AoA-G Limiter tabs.

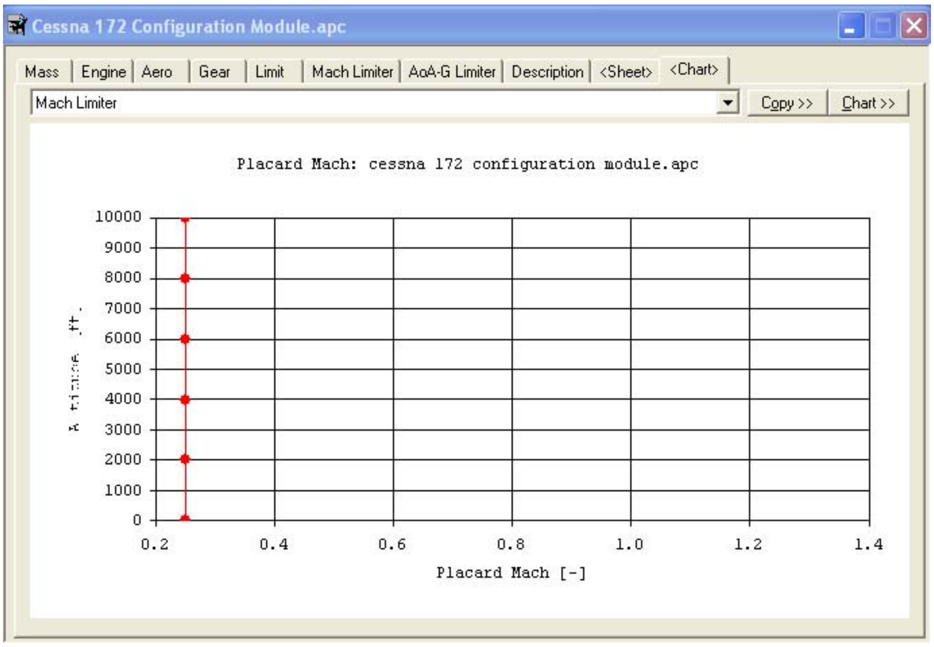

Figure 2.9 Chart Tab

3. Store Module

- The Cessna 172 has no external stores or pods so this Module can be left blank. We will briefly cover the tabs here for the sake of completeness.

  - Mass Tab: This tab defines the mass of the external stores and the mass of the fuel or weapons attached and/or contained.
  - Drag Area Tab: This tab defines the parasite drag area used in the drag calculations for the stores.
  - Releasable Drag Area Tab: This allows for the releasable drag area to be defined as a function of Mach number.
  - Non-Releasable Drag Area Tab: This allows for the non-releasable drag area to be defined as a function of Mach number.
  - Limitations Tab: This allows for load factor and velocity limits to be placed on the external stores.
  - Description Tab: This is a place for you to document sources, make notes for other users, or for yourself.
  - Sheet Tab: This tab summarizes all of the inputs and allows the user to export to an Excel Spreadsheet.
  - Chart Tab: This plots the data points entered into the Mach Limiter and AoA-G Limiter tabs.

4. Aerodynamics Module

- Data Tab: In this tab, the defining parameters for the wing Planform are entered into the program.

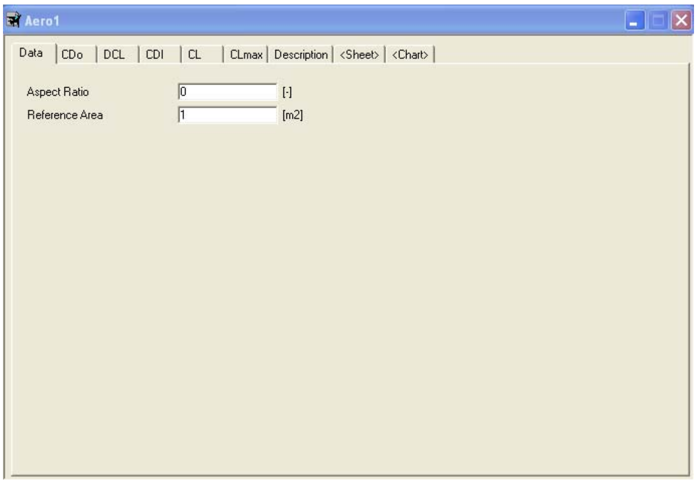

Figure 4.1 Data Tab

- CDo Tab: In this tab the minimum drag coefficient as function of Mach number and Altitude is defined. The user can define as many or as few altitudes and Mach numbers as they feel is necessary to capture the flight Envelope. It is important to be consistent with the range of data that is entered. Here we will assume that the minimum drag coefficient is constant at low Mach numbers. These can come from test data or hand calculations.

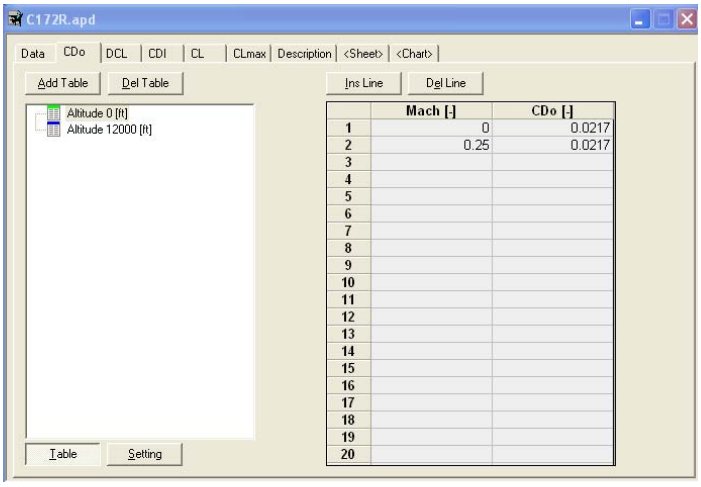

Figure 4.2 CDo Tab

- DCL Tab: In this tab the difference between lift at minimum drag coefficient and zero-lift drag coefficient are entered as a function of Mach number. For the Cessna 172, the zero lift drag is assumed to be the same as minimum drag. This will not always be the case.

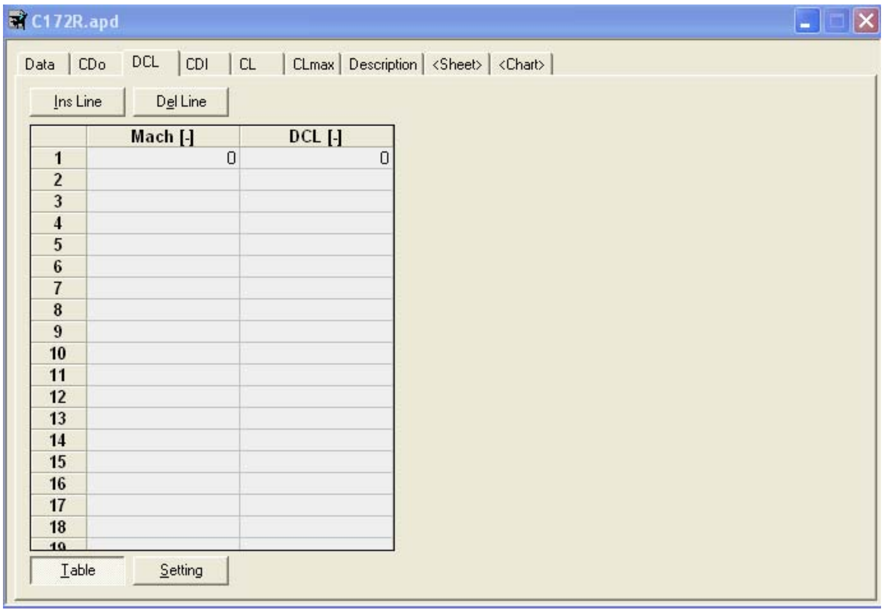

Figure 4.3 DCL Tab

- CDI Tab: This tab defines the induced drag coefficient as a function of Mach number and Lift coefficient. These values again, come from test data or reliable hand calculation methods.

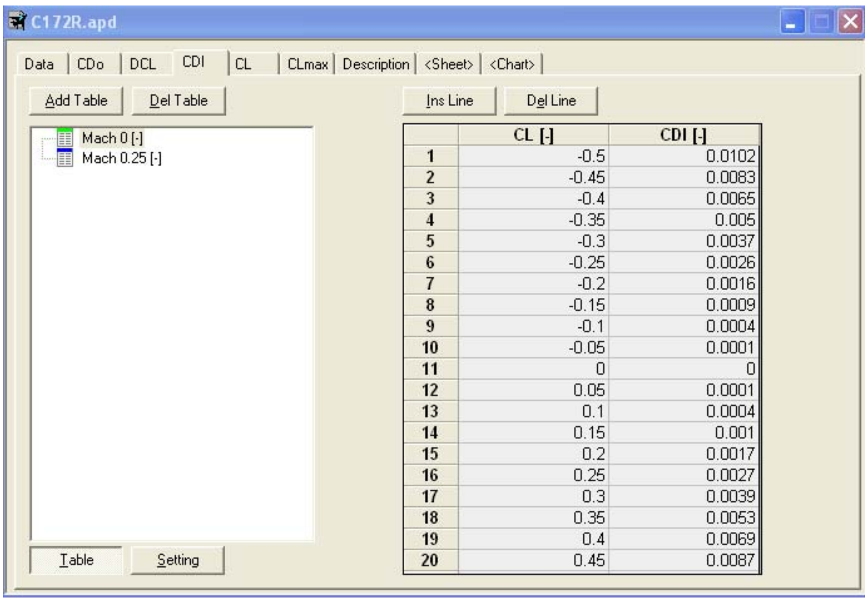

Figure 4.4 CDI Tab

- CL Tab: In this tab the lift curve is defined at various Mach numbers with in the flight envelope. The more points that are defined, the better the performance prediction will be (especially at high AoA).

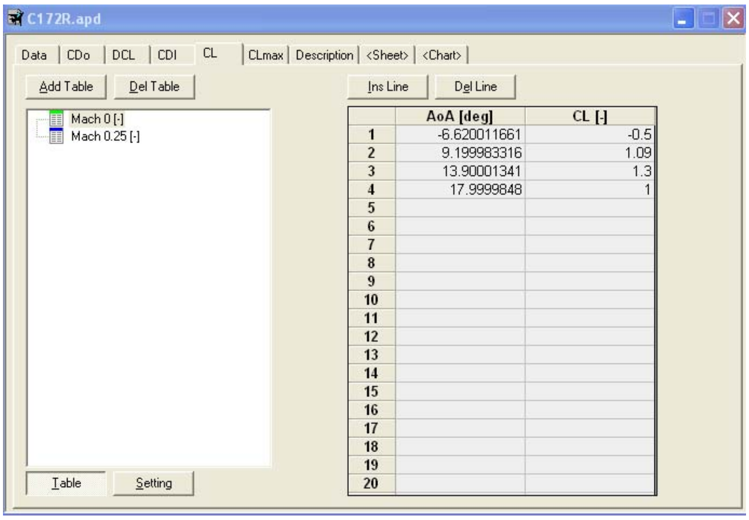

Figure 4.5 CL Tab

- CLmax Tab: In this tab the maximum lift coefficient as a function of Mach number is defined. For the Cessna 172 example we assume it is linear at low Mach numbers and only need to define 2 points.

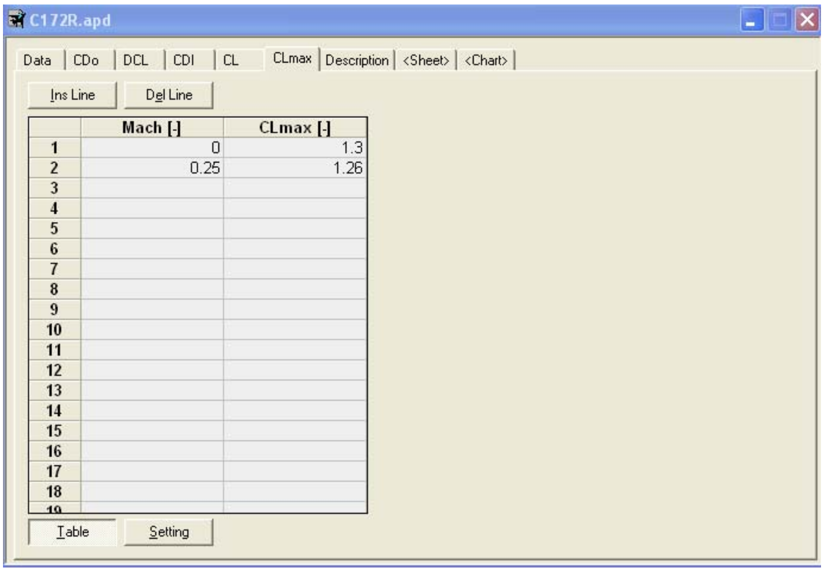

Figure 4.6 CLmax Tab

- The aerodynamics module also has a Description Tab, Sheet Tab, and a Chart Tab that serve the same function as the proceeding modules.

5. Fuel Module

- Fuel Flow Tab: This tab allows fuel consumption as a function of thrust, altitude, and Mach number to be defined. This usually will come from existing engine data and propeller performance data.

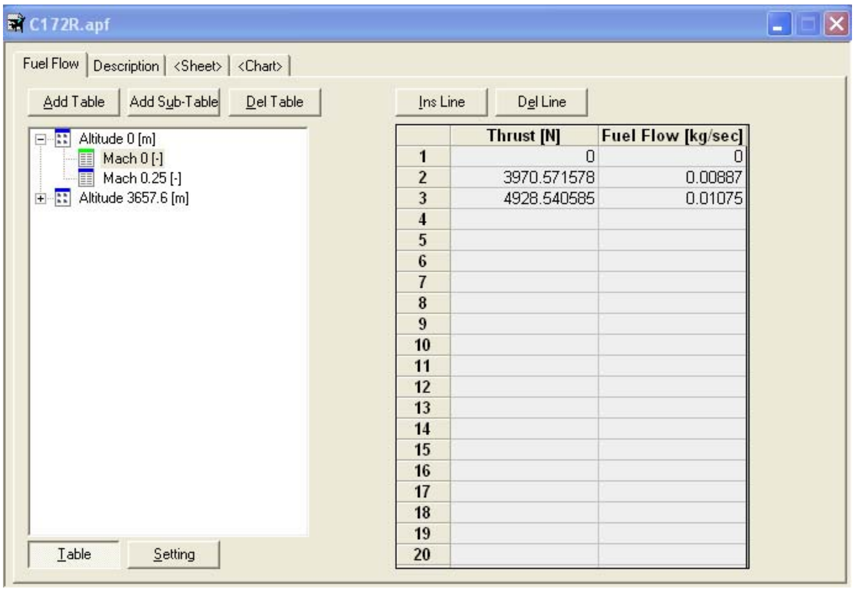

Figure 5.1 Fuel Flow Tab

- The Fuel Module also has Description, Sheet, and Chart tabs like the other modules.

6. Thrust Module

- Max Thrust Tab: This tab defines the maximum thrust the engine/propeller combination can produce as a function of Mach number and Altitude. This usually needs to come from existing engine data or flight test data.

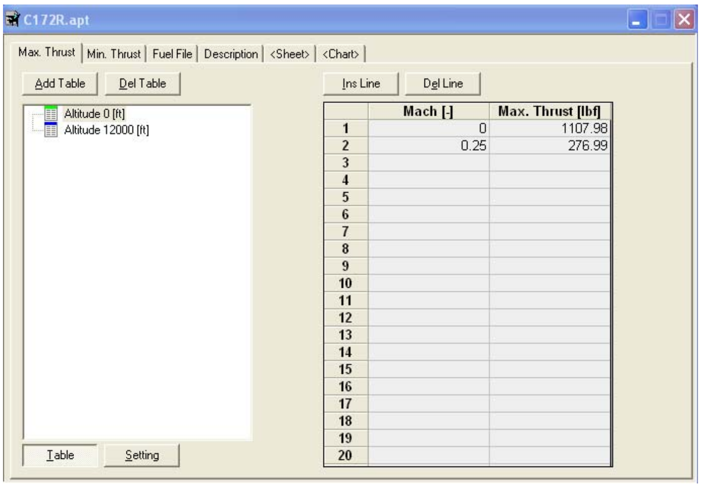

Figure 6.1 Max Thrust Tab

- Min Thrust Tab: This tab defines the minimum thrust the engine/propeller combination can produce as a function of Mach number and Altitude. This usually needs to come from existing engine data or flight test data. For piston/propeller combinations this is almost always going to be zero (meaning the engine can remain in the started condition and throttle down to zero power). Jet engines usually have some lower limit at which they will un-start and die due to low mass flow.

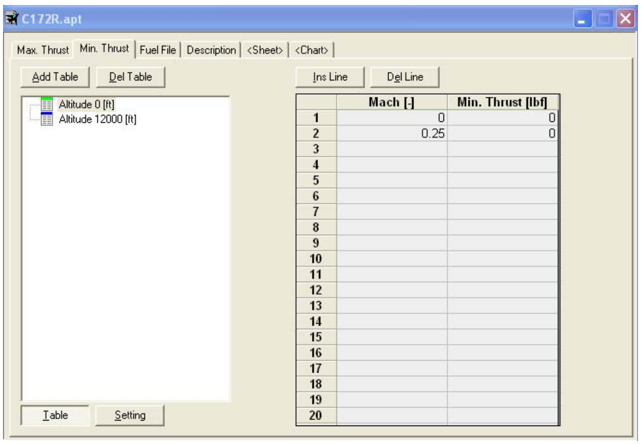

Figure 6.2 Min Thrust

- Fuel File Tab: This tab asks the user to locate the previously completed Fuel Module so the two can be linked together.

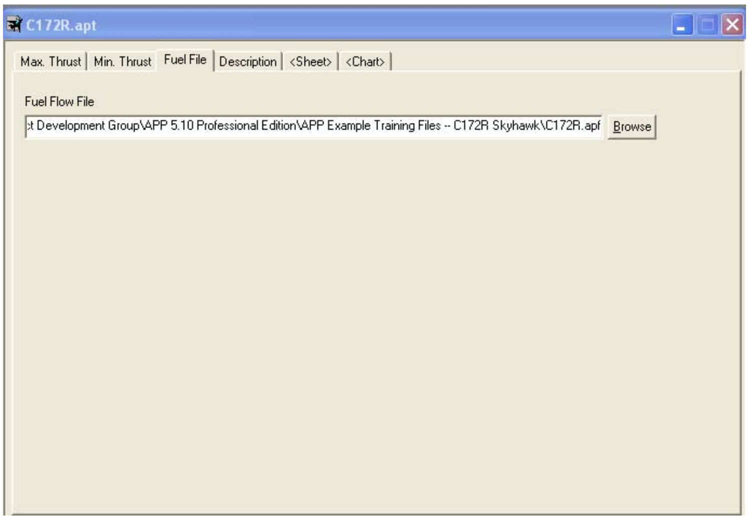

Figure 6.3 Fuel File Tab

- The Thrust Module also includes a Description, Sheet, and Chart tab.

7. Performance Module

- The Project Module is where the meat of the calculations are performed. There are several analysis options available to the user:

  - Point Performance
  - G-Envelope
  - SEP Envelope
  - Turn-Rate Chart based on SEP
  - Turn-Rate Chart based on Altitude
  - Specific Excess Power Chart
  - Thrust vs Drag Chart

- For this example a point performance calculation will be demonstrated.

- Step 1: Attach the completed modules by pressing the buttons to the left and selecting the correct file.

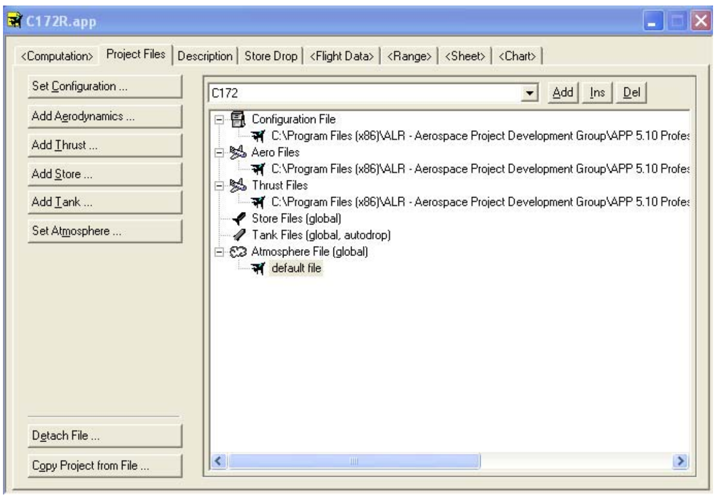

Figure 7.1 Project Files Tab

- Step 2: In the “Param Type” tab, select the type of computation. For this example we will look at specific fuel consumption during cruise. Select “CRUISE_AT_ALTITUDE” in the From File drop down menu and select “Cruise” from the Computation drop down menu.

- Step 3: In the Flight Data tab enter the flight condition dependent data that APP requires. We will assume 8 kft cruise at Mach 0.2 with 80% fuel remaining. The remaining parameters are either defined properly already, will not have an impact in the calculation we have selected, or APP will change the value based on one of your other inputs.

- Step 4: Define the ranges for the X-axis parameters selected in Step 2. We will use [0:0.01:0.25] for Mach number and [0:2000:12000] for altitude.

- Step 5: Press the calculate button and view the Chart Tab. Here we see the SFC vs Mach number for various altitudes. The charts can be extracted using the Chart button in the upper right corner.

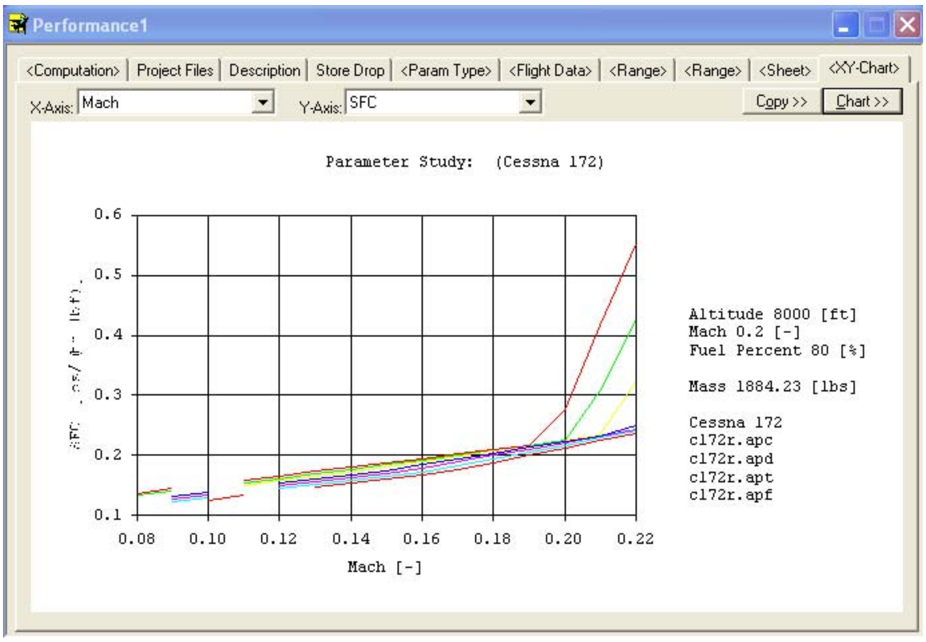

Figure 7.2 SFC vs Mach number for Altitude

- The plotting parameters can easily be changed. There are a large number of combinations of plotting parameters.

8. Mission Module

- The Mission Module allows the user to specify a mission by segments and then examine performance parameters over that range.

- There are also 3 types of optimization available.

  - Range Optimization

  - Endurance Optimization

  - Radius of Action Optimization

- For this example we will not look at the optimization options and just look at the performance over a simple take-off, cruise, and landing type mission.

- Step 1: Again the first step is to attach the completed input modules.

- Step 2: Specify the flight condition parameters corresponding to the beginning of the mission. We will assume we are departing from an airfield at sea level with full fuel and 100 lbs of payload.

- Step 3: Enter the mission segment parameters into the Segment List Tab.

- Step 4: Hit calculate and go the Chart tab to view the results.

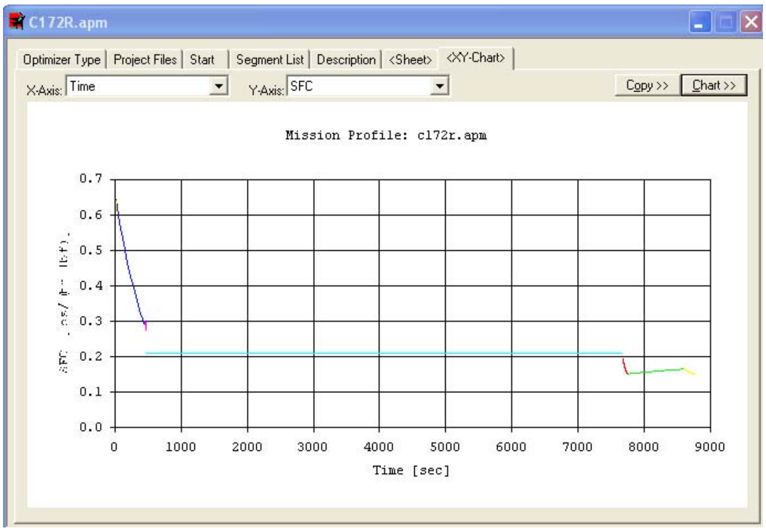

Figure 8.1 Mission Profile- SFC vs Time