#### **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.

n George ⊘ Store t n Marget N Store t	Performance1	-
Ford Flow Description   <5heet)   <dano  <br="">dot Table Add Sigh Table Del Table   yez Line Del Line</dano>	Districe Type   Preisch Film   Staff   Segment Lift   Description   Gifferd   Off-Orab   Albode	

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.

File Edit View Window Help

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.

ass Engine Aero Gea	ar   Limit   Ma	ach Limiter   Ar	aA-G Limiter Description	<sheet>   <chart>  </chart></sheet>	
Structure	829.6	[lbs]			
Propulsion Group	400.3	[lbs]			
Equipment	365.3	[lbs]			
Mass Deviation	0	[lbs]	= Standard Empty	1595.2 [lbs]	
Fixed Op. Equipment	0	[lbs]	= Empty Mass	1595.2 [lbs]	
Unusable Fuel and Oil	12.25	[lbs]			
Gun	0	[lbs]			
Removable Op. Equipment	0	[lbs]	= Basic Mass	1607.45 [lbs]	
Usable Oil	0	[lbs]			
Crew	200	[lbs]			
Spec. Mission Equipment	0	[lbs]	= Operating Empty	1807.45 [lbs]	
Ammunition	0	[lbs]			
Payload	540	[lbs]	= Zero Fuel Mass	2347.45 [lbs]	
Fuel Mass	120	[lbs]	= Operating Mass	2467.45 [lbs]	

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.

📽 Cessna 172 Configuratio	on Module.apc		X
Mass Engine Aero Gear	Limit Mach Lin	niter   AqA-G Limiter   Description   <sheet>   <chart>  </chart></sheet>	
Number of Engine	1		
Thrust Multiplier	1	6	
Fuel Flow Multiplier	[1	ម	
Thrust Line Angle	0	[deg]	

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.

🛱 Cessna 172 Config	uration Module.	арс			
Mass Engine Aero	Gear Limit N	1ach Limiter   AoA-G I	_imiter   Description	<sheet>   <chart>  </chart></sheet>	
Delta Drag Area	0	[ft2]			
Drag Multiplier	1	[·]			

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.

Cessna 172 Config	uration Module.apc	
Mass   Engine   Aero	Gear Limit Mach Limiter AoA-G Limiter Description <sheet> Charb</sheet>	
Gear Drag Area	0.67 [02]	
AaA on Ground	7.4 [deg]	
Fixed Gear		

Figure 2.4 Gear Tab

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

🛱 Cessna 172 Configurati	ion Module.ap	c	
Mass   Engine   Aero   Gea	ar Limit Mac	h Limiter   AoA-G Limiter   Description   <sheet>   <chart>  </chart></sheet>	
Pos. Limit Load Factor	3.8		
Neg. Limit Load Factor	-2	[1]	
Maximum AoA	20	[deg]	
Minimum AoA	-10	[deg]	
Fixed Op. Equipment	0	[bs]	

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.

s Engin	e Aero Gear	Limit Mach Limiter 🛛	aaA-G Limiter Description <sheet> <chart></chart></sheet>
Ins Line	D <u>e</u> l Line		
	Altitude [ft]	Placard Mach [-]	
1	0	0.25	
2	2000	0.25	
3	4000	0.25	
4	6000	0.25	
5	8000	0.25	
6	10000	0.25	
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

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.

iss   Er	igine   Aero   Gear	Limit   Mach Limiter 4	Hand Limiter   Description   <sheets <chards="" th=""  =""  <=""></sheets>
Ins Lin	e D <u>e</u> l Line		
	AoA [deg]	G(AoA) Limiter [-]	
1	0	-1	
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

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.

ss	Engine   Aero   Gear   Limit   Mach L	imiter AoA-G Limiter Desc	cription <sp< th=""><th>neet&gt; <ci< th=""><th>hart&gt;</th><th></th><th></th><th></th></ci<></th></sp<>	neet> <ci< th=""><th>hart&gt;</th><th></th><th></th><th></th></ci<>	hart>			
					-	<u>S</u> hee	t>>	Excel >
	Α	В	С	D		E		F
1	Configuration Data			- 192			- 102	
2								
3	Date (Time):							
4	Friday, October 15, 2010	(13:01:06)						
5								
6	File Name							
1	cessna 172 configuration	module.apc						
8							_	
9	File Text							
10	Enter Notes Here							
11	Maggag							
12	Structure	820 /	5 [lbel					
14	Propulsion Group	400.3	S [lbe]					
15	Fouinment	365.3	(lbe)					
16	Mass Deviation	000.0	lipel					
17	Standard Emnty Mass	1595.2	2 []bs]					
18	Soundaria Employ Hubb	1000.2	. []					
19	Fixed On, Equinment	ſ	libsi					
20	Empty Mass	1595.2	[lbs]					
20	Empty Mass	1595.2	2 [1bs]					

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.

C172R.apd				
Data CDo DCL CDI CL CLmax De	scription   <sheet>  </sheet>	<chart></chart>		
Add Table Del Table	Ins Line	D <u>e</u> l Line		
Altitude 0 [ft]		Mach [-]	CDo [-]	
Altitude 12000 [ft]	1	0	0.0217	
	2	0.25	0.0217	
	3			
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	13			
	14			
	15			
	16			
	1/			
	18			
	19			
Lable Setting	20			

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.

C172R.apd	×
Data CDo DCL CDI CL CLmax Description <sheet> <chart></chart></sheet>	
Ins Line Del Line	
Mach [-] DCL [-]	
3	
4	
6	
7	
8	
9 10	
11	
12	
14	
15	
16	
18	
Lable Setting	

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.

🗃 C172R.apd				
Data CDo DCL CDI CL CLmax Descripti	on   <sheet></sheet>	<chart>  </chart>		
Add Table Del Table	Ins Line	D <u>e</u> l Line		
		CL [-]	CDI [-]	
Mach 0.25 [-]	1	-0.5	0.0102	
	2	-0.45	0.0083	
	3	-0.4	0.0065	
	4	-0.35	0.005	
	5	-0.3	0.0037	
	6	-0.25	0.0026	
	7	-0.2	0.0016	
	8	-0.15	0.0009	
	9	-0.1	0.0004	
	10	-0.05	0.0001	
	11	0	0	
	12	0.05	0.0001	
	13	0.1	0.0004	
	14	0.15	0.001	
	15	0.2	0.0017	
	16	0.25	0.0027	
	17	0.3	0.0039	
	18	0.35	0.0053	
	19	0.4	0.0069	
Iable Setting	20	0.45	0.0087	

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).

	( Description ( Coneers	<ul> <li>(chart)</li> </ul>	
Add Table Del Table	Ins Line	D <u>e</u> l Line	
Mach 0 [-]		AoA [deg]	CL [-]
Mach 0.25 [-]	1	-6.620011661	-0.5
	2	9.199983316	1.09
	3	13.90001341	1.3
	4	17.9999848	1
	5		
	6		
	7		
	8		
	9		
	10		
	11		
	12		
	13		
	14		
	15		
	16		
	17		
	18		
	19		
Table Setting	20		

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.

Ins Line Dgl Line Mach [-] 2 3 4 5 6	CLmax 0 0,25	[-] 1.3 1.26		
Mach [-] 1 2 3 4 5 6	CLmax 0 D.25	[-] 1.3 1.26		
1 2 3 4 5 6	0 D.25	1.3		
2 3 4 5 6	0.25	1.26		
3 4 5 6				
4 5 6				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
40				

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.

dd Table Add S <u>u</u> b-Table Del Table	Ins Line	D <u>e</u> l Line		
Altitude 0 [m]		Thrust INI	Fuel Flow [kg/sec]	
Mach 0 [-]	1	0	0	
Mach 0.25 [-]	2	3970.571578	0.00887	
11 Altitude 3657.6 [m]	3	4928.540585	0.01075	
	4			
	5			
	6			
	7			
	8			
	9			
	10			
	11			
	12			
	13			
	14			
	15			
	16			
	17			
	18			

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.

una un li puz un l	<sheet>   <uhart>  </uhart></sheet>	1	
Add Table	Ins Line	Del Line	
Altitude 0 [ft]		Mach [-]	Max. Thrust [lbf]
Altitude 12000 [ft]	1	0	1107.98
	2	0.25	276.99
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		
	11		
	12		
	13		
	14		4
	15		
	16		
	17		
	18		

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.

Thrust Min. Thrust Fuel File Description	h   <sheeb <charb="" th=""  =""  <=""><th></th><th></th><th></th></sheeb>			
dd Table Del Table	Ins Line	D <u>e</u> l Line		
Altitude 0 [ft]		Mach [-]	Min. Thrust [lbf]	
Altitude 12000 [ft]	1	0	0	
	2	0.25	0	
	3			
	4			
	5			
	6			
	7			
	8			
	9			
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	1/			
	18			

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