

Plane Maker

A white and purple Lyncar Columbia 400 aircraft is shown from a three-quarter front view. The aircraft features a high-wing configuration, a tricycle landing gear, and a propeller. The fuselage is white with purple accents on the nose, landing gear fairings, and wingtips. The registration 'N842A' is visible on the side. A wireframe overlay, outlined in green, is applied to the upper portion of the aircraft, including the wings, fuselage, and tail, highlighting the structural framework. The background is a solid light gray.

Manual

Plane Maker Manual

About This Manual

This is version 10.0 of the Plane Maker manual, last updated November 4, 2011.

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Using the Manual

For the most part, this manual assumes basic knowledge of the X-Plane user interface—in particular, it assumes knowledge of how to open and fly an aircraft.

The best way to use this manual depends on what you need from it. If you're already a master of Plane Maker, it probably makes sense to just keep this document around for reference. If instead you're coming to this manual as a guide for a complete walkthrough to creating your first aircraft, it probably makes sense to read through in this order:

- About the Plane Maker Manual (this page)
- Chapter 1: Introduction to Plane Maker

- Chapter 2: The Plane Maker Interface
- Chapter 3: Shaping the Body of an Aircraft
- Chapter 4, Section I: Creating the Engines
- Chapter 5: Creating an Instrument Panel
- Chapter 6, Section V: Setting the Weight and Balance
- Chapter 9: Performing a Test Flight

Following Chapter 9, your aircraft would be at least tested, and you could go back through the sections you skipped as necessary.

Throughout the manual are cross-reference links, formatted in bold, dark-gray type, **like this**. Clicking one of these links will take you to the indicated location of the manual. For instance, clicking this reference to “**The Plane Maker Interface**” will take you to Chapter 2.

Note also that most images in the manual can be clicked to bring up a full-sized version found on the X-Plane Wiki.

A **Glossary of Terms** used in this manual is provided beginning on page 83. We recommend that users consult this for reference as needed.

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1. Introduction to Plane Maker

Plane Maker is a program bundled with X-Plane that lets users design their own aircraft. Using this software, nearly any aircraft imaginable can be built. Once all the physical specifications of the airplane have been entered (e.g., weight, wing span, control deflections, engine power, airfoil sections, etc.), the X-Plane simulator will predict how that plane will fly in the real world; it will model the aircraft's performance just like it does for X-Plane's built-in aircraft.

Airplanes are saved in Plane Maker just as one would save a word processing document. These files are then opened and flown in the X-Plane simulator. Users can create a .zip file of all the components of the airplane and distribute that ZIP on the Internet for others to fly. Planes created by others can also be downloaded and used in the simulator. X-Plane.org's ["Download Manager" page](#) is a good place both to upload and download these planes.

Note that information on how to add aircraft to X-Plane can be found in [Chapter 7](#) of the X-Plane 9 (Desktop) manual, or in Chapter 4 of the X-Plane 10 (Desktop) manual.

I. Licensing of Aircraft Created in Plane Maker

You are free to do *whatever you like* with the aircraft you create.

You can, for instance, sell your aircraft files over the Internet, or modify other users' aircraft with their permission. If you choose to, you can share the files freely, even with users of the demo version of X-Plane. You can do whatever you like with the files.

One excellent use for Plane Maker is to create the airplane of

your dreams, fly it in X-Plane, and then upload it to the Internet for others to fly. Even better, if a company has an exciting new airplane, they can build in Plane Maker, test fly it in X-Plane, and then put it on the company's web site for customers or potential customers to download! Anyone that has X-Plane (or even the free demo) will be able to download the virtual version of the aircraft and fly it. This will serve two purposes. First, it will teach more people to fly the airplane, creating potential customers. Then, it will improve the currency of those that already fly it, creating safer customers.

Of course, Plane Maker can also be used to model an aircraft that you already have and fly every day, helping you to keep up your stick-and-rudder and instrument skills.

II. An Overview of the Plane Maker Workflow

There are as many different ways to go about working in Plane Maker as there are aircraft designers. The following steps, though, serve as a good workflow sequence to start from when modeling in Plane Maker:

1. Decide on a design.
2. Create the fuselage, wings, and tail of the aircraft
3. Create secondary objects, such as landing gears and engine nacelles.
4. Set up the systems and internal properties, including the engines, electrical systems, weight and balance, and viewpoints.
5. Set up any additional features of the aircraft, such as added weapons or special controls.
6. Create a 2-D instrument panel.
7. Test-fly the aircraft in X-Plane and fine-tune the features of the aircraft from steps 1-6 as needed.
8. Add textures, 3-D objects, extra liveries, etc.

Steps 2-8 above will be covered in this manual; for Step 1, you're on your own!

2. The Plane Maker Interface

Remember that definitions for any unfamiliar terms may be found in the **Glossary of Terms**, beginning on page 83.

I. Launching Plane Maker

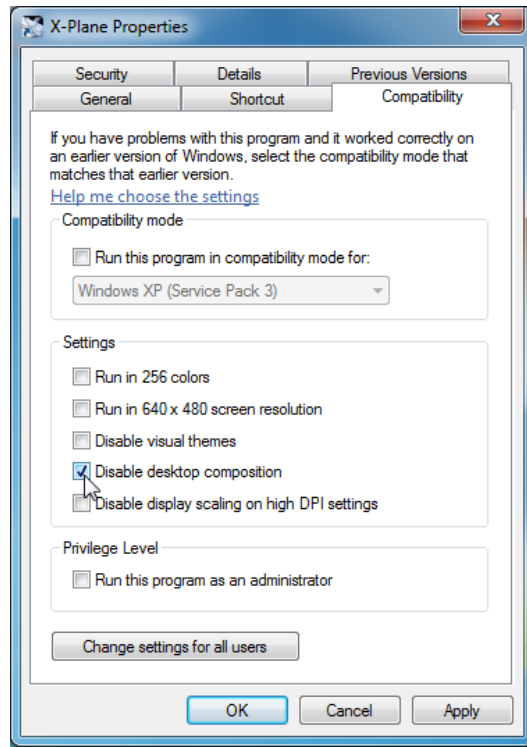


Figure 2.1: Checking the “Disable desktop composition” box in the Compatibility tab

Plane Maker is found in the main X-Plane directory, which is located by default on the Desktop. Simply double click Plane-Maker.exe (Plane-Maker.app in Mac OS X) to start the program.

Note that in Windows 7 and Vista, there is a known issue with both X-Plane and Plane Maker relating to the “Aero” desktop effects. With Aero enabled, boxes and text may appear slightly shifted from where it should be. This problem does not occur on all Windows 7 installations. To correct it if it occurs, right click on the X-Plane.exe icon and click Properties. In the window that appears, go to the Compatibility tab and check the box labeled “Disable desktop composition,” as seen in **Figure 2.1**. Repeat this for the Plane Maker icon.

II. Opening and Saving an Aircraft

To open an aircraft in Plane Maker, click on the File menu and click Open, per **Figure 2.2**. There, navigate to the folder containing the .acf file you want to modify, just like you would if you wanted to open the aircraft to fly in X-Plane. There, double click on the ACF, or click once and click the **Open** button.

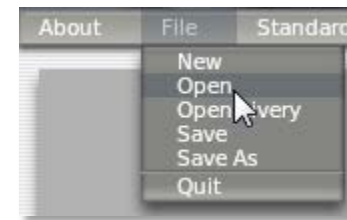


Figure 2.2: Clicking File → Open

To save any changes you have made to the aircraft file, open the File menu and click Save. Any changes you made to the aircraft will be reflected the next time you load the aircraft in X-Plane.

A. Opening a Livery

To load a specific paint job for an aircraft (known as a livery),

first open the aircraft in Plane Maker. Then, open the File menu and click Open Livery. Click the radio button next to the livery you would like to load, then close out of the Livery dialog box (either by clicking one of the Xs in the corner or by hitting the Enter key). Plane Maker will then load the selected livery.

If you save the aircraft file after loading a certain livery, that livery will automatically be applied when you open the aircraft in X-Plane in the future.

III. Creating an Aircraft File

To create a new aircraft project, open the File menu and click New. Plane Maker will create a new aircraft with nothing but a cylindrical fuselage. If you click File → Save As from here, you can choose which folder to save the new aircraft in. Be sure to create the folder first in your file browser (Windows Explorer, Finder, etc.).

The standard place to save aircraft is in the Aircraft directory, located within the main X-Plane directory. For instance, a VTOL craft created for X-Plane 10 might be found in the following location:

```
X-Plane 10\Aircraft\My Custom  
Planes\VTOL\my_new_VTOL.acf
```

However, X-Plane doesn't care where the aircraft is located—you could just as easily save the project in the Scenery folder.

IV. Working with the Views

In the main Plane Maker window sits a 3-D model of the aircraft you're working on.

You can move the whole aircraft model left, right, up, or down by using the arrow keys on the keyboard. Note that the axes are inverted; press the left arrow to move the model right,

press the down arrow to move it up, and so on.

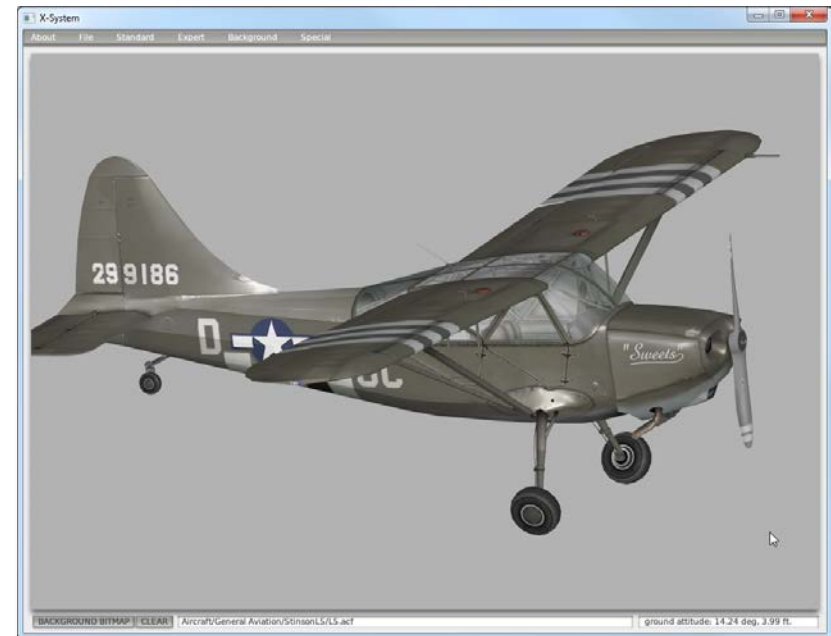


Figure 2.3: The 3-D aircraft model in the main Plane Maker window

You can use the W, A, S, and D keys to spin and roll the 3-D model around its center.

You can use the - and = keys to zoom out and in, respectively.

Note that you can zoom in and out or move the model faster by holding down the Shift key while pressing the up, down, left, right, -, or = keys.

Additionally, in most of the settings dialog boxes, a 3-D model of the aircraft is visible on the right side of the screen when the Plane Maker window itself is wide enough. For example, compare **Figure 2.4** and **Figure 2.5**; in one, the Plane Maker window is as narrow as possible, so no 3-D model is visible. In the other, the window is quite wide, so the model is seen to the right.

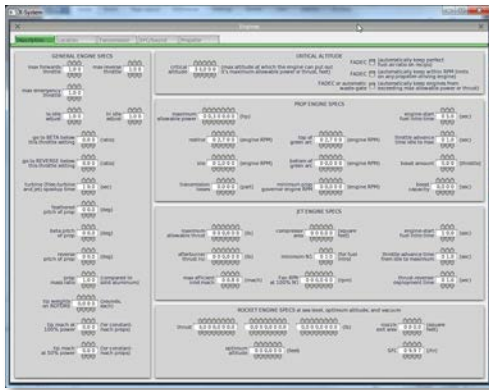


Figure 2.4: This window is not wide enough to see the 3-D model

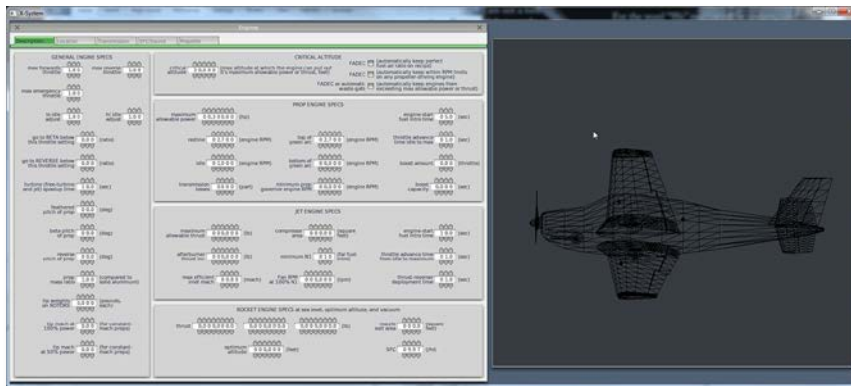


Figure 2.5: This window is wide enough to see the 3-D model

Plane Maker can display either the regular, “skinned” view of the aircraft model (where the model looks as it would in X-Plane), or it can display a wireframe view showing the actual structure of the aircraft. To swap between these two views, press the spacebar. **Figure 2.6** shows these two views side-by-side.

The wireframe view can be especially useful for telling where exactly a piece of the aircraft is in relation to the rest of the body, and it is the only view in which the points representing

the aircraft’s center of gravity, the pilot’s viewpoint, the jet engine locations, and other such features are visible. These are represented as large black dots in the wireframe.

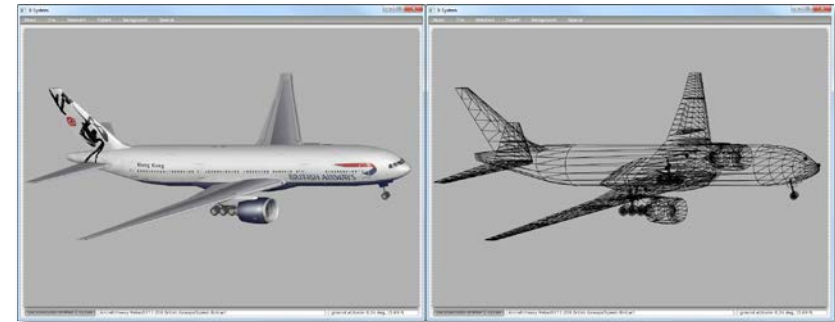


Figure 2.6: The skinned view of the 777, side-by-side with the wireframe view

A. Special Views

The Background menu has a number of special viewing angles that are useful for many designers. These are the Top, Bottom, Side, Front, and Back views, as seen in **Figure 2.7**.



Figure 2.7: The five special viewing angles

Clicking one of these options in the menu will shift the 3-D model to the indicated perspective. For instance, the Top view gives a top-down view of the aircraft, the Side view gives a straight-on view of the craft’s port (left) side, and so on. One potential use for these views is to compare the aircraft model

to an image of the real thing. Click the **Background Bitmap** button in the bottom left corner of the window to load an image to compare your model against.

For instance, if you had a top-down photo of the aircraft you were modeling and you wanted to see how closely your design matched it, you could click the **Background Bitmap** button, load that photo, and then select the Top view from the Background menu. This will display your Plane Maker model on top of the real aircraft's photo, centered on the screen.

V. Altering a Simple Aircraft

To familiarize yourself with the workings of Plane Maker, it may be helpful to begin by tweaking a simple aircraft. The Boeing 777 in X-Plane 9 is a good option. The “triple seven” is found in the following folder:

```
X-Plane 9\Aircraft\Heavy Metal\B777-200
British Airways
```

This is the aircraft we'll show in the following examples. Another good option is the “example” aircraft, found in the folder

```
X-Plane 9\Instructions\Example Plane-Basic.
```

Open the basic aircraft of your choice, then open the Standard menu and click Wings, as in **Figure 2.8**.

When the dialog box opens, click through the tabs labeled Wings 1-4 at the top of the dialog box. Different sections of the aircraft model's wings will go black and flash subtly (this will be easier to see if your window is wide enough to display a secondary aircraft model off to the right). The section of wing that appears black is the section that the current tab controls. In the case of the 777, wing sections 1, 2, and 3 comprise the full wing.

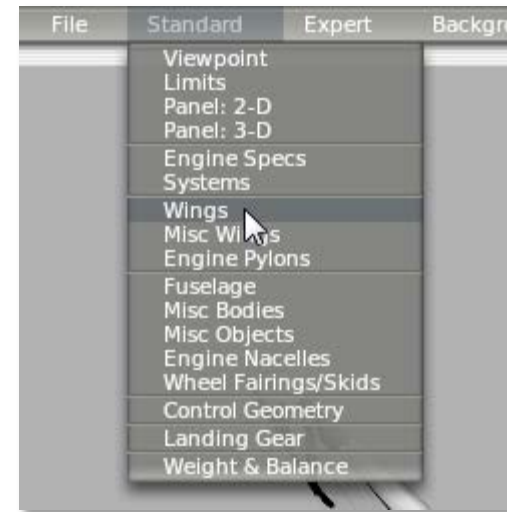


Figure 2.8: Clicking Standard → Wings

Try selecting the Wing 3 tab. This selects the wing section farthest from the fuselage of the 777. Now, there are a large number of ways to modify the wing here. We'll discuss each of them in Chapter 3, **Shaping the Body of an Aircraft**, but for now, find the “semi-length” value, found in the box labeled Foil Specs. Try clicking above and below the digits here to lengthen and shorten the wing segment. For instance, in **Figure 2.9**, we've lengthened the wing segment by about 20 feet.

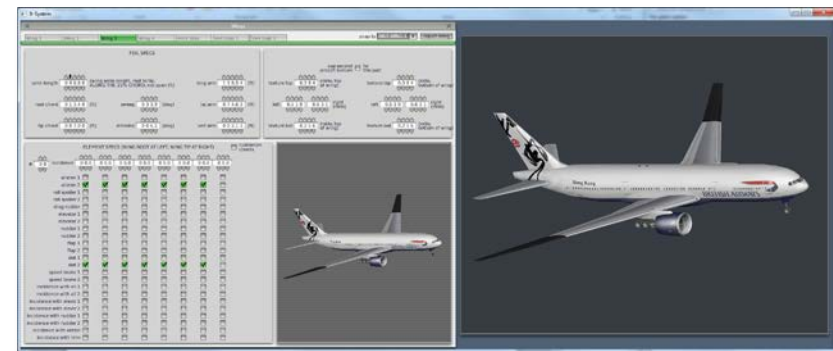


Figure 2.9: Lengthening the wings of the 777

If we were to save this file (as a copy, of course, so that we did not modify the original 777 file) and fly it in X-Plane, we would find that the wings generate significantly more lift, but they also make the aircraft much less maneuverable (functions of having a high aspect ratio).

Taking a step back, this example is useful because it demonstrates a very common interface in Plane Maker. In the Foil Specs portion of the Wings dialog box, we have a number of properties of any given wing, each of which can be set individually and which combine to give a complete wing.

Note also that you can move the mouse over almost every input field in Plane Maker and get a description of what that field controls. Don't know what the sweep field does? Mousing over the numbers in the input field reveals the following description:

The sweep is the angle that the wings are swept back from sticking straight out the side of the airplane. Wing sweep is used to allow high-speed travel (above Mach 0.7 or so), because the wing does not have to attack the air head-on.

Pretty informative, right? If you are ever unsure of what a parameter controls, mousing over it is a good way to get help.

3. Shaping the Body of an Aircraft

In this chapter, we'll look at the things that constitute the body of an aircraft, including the fuselage, tail, landing gear, wings, and airfoils. These represent the core of almost every aircraft design.

I. Fundamental Concepts

A few ideas will come up over and over again throughout the creation of an aircraft body. The first is the concept of the reference point, and the second is the way in which positions in Plane Maker are set relative to the reference point. Understanding these two things ahead of time will make learning the specifics of creating the fuselage, wings, and other objects much faster.

A. The Reference Point

All objects (the fuselage, wings, etc.) in Plane Maker are placed relative to some arbitrary fixed point, called the reference point. This point is created simply through practice. For instance, you might tell Plane Maker that your plane's fuselage (and, in particular, the front tip of your plane's fuselage) is located *at* the reference point—it is zero feet away from it, angled zero degrees away. Likewise, your wings might be located ten feet behind the reference point, angled a few degrees back.

On its own, this point doesn't *mean* anything—it's just some place on the aircraft that everything else gets its location in relation to. While the point could be anything, you should choose a point that makes sense to you. Some aircraft designers prefer to make their reference point the center of the fuselage; many others prefer to make it the tip of the nose.

B. How Positions Are Set in Plane Maker

As we have said, all locations in Plane Maker are defined relative to a fixed, arbitrary point, often the tip of the fuselage. However, there is more to defining the position of, for instance, a wing, than to say that it is five feet behind the tip of the fuselage. How high above this reference point is it? How far left or right?

That's where Plane Maker's position settings come in. **Figure 3.1** shows the three standard controls for an object's position.



Figure 3.1: A standard position-setting group of parameters

The standard position parameters throughout Plane Maker are the longitudinal arm, the lateral arm, and the vertical arm, as illustrated in **Figure 3.2**. Each measurement is in relation to the reference point.

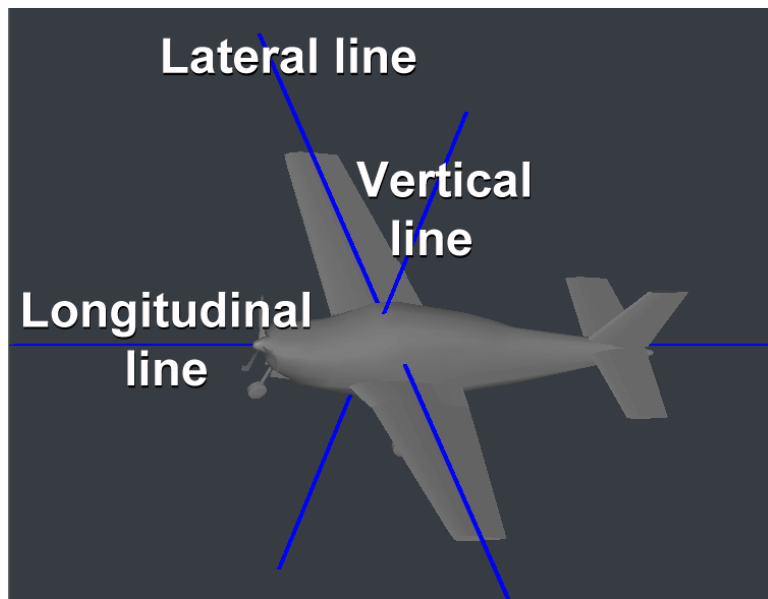


Figure 3.2: The three axes used to position an object on the aircraft

Table 3.1 gives a reference for interpreting what the values in these positional controls mean. For instance, a positive value in the “vert arm” parameter indicates the object will move above the reference point by that many feet.

Parameter	Positive value means...	Negative value means...
Long. arm	Behind ref. pt.	Forward of ref. pt.
Lat. arm	Right of ref. pt.	Left of ref. pt.
Vert. arm	Above ref. pt.	Below ref. pt.

Table 3.1: Interpreting the position-setting values

Note that in cases where an object has lateral symmetry (that is, it is duplicated on both sides of the aircraft, as a wing section is), the guidelines in Table 3.1 apply to the object on the *right* (starboard) side of the aircraft. Likewise, the lateral arm value is reversed for the object on the left (port) side. Thus, a positive lateral arm value for a certain wing section

means the right wing section will move right of the reference point, while the left wing section will move left of the reference point.

II. Shaping the Fuselage

To begin work on a fuselage, open the Standard menu and click Fuselage, as seen in **Figure 3.3**.

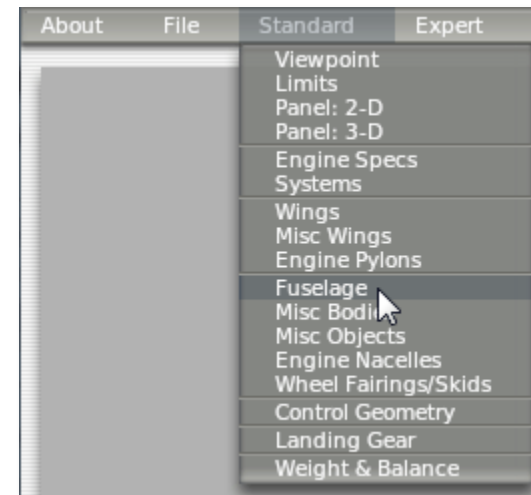


Figure 3.3: Clicking Standard → Fuselage

There are three tabs across the top of the Fuselage dialog box, seen in **Figure 3.4**. In order, these are Section, Top/Bottom, and Front/Back.

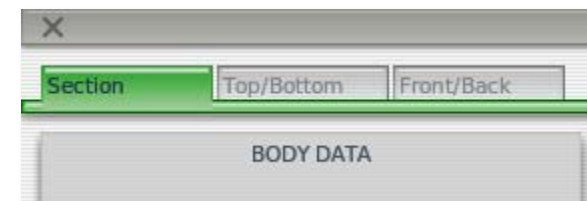


Figure 3.4: The three tabs across the top of the Fuselage dialog box

Each tab serves a different purpose. The Section tab displays a cross-section view of the fuselage, sliced into a number of pieces. The Top/Bottom tab shows three different perspectives of the points defined in the cross-section view, allowing you to see their relation in three-dimensional space. Finally, the Front/Back tab shows the same points of the fuselage from a head-on or perspective; this is like looking down the nose and tail, respectively, of a wireframe model of the aircraft.

In creating a fuselage, it makes sense to take the following approach (note that the parameters mentioned below are discussed in the following sections, which dive into each tab in depth):

1. Begin in the Section tab and set the number of stations (usually 20), the number of radii per side (usually 9), and the body radius.
2. Referencing whatever specifications you have for your fuselage (this may just be an image of it), set a rough outline of its shape in the cross-sections of the Section tab.
3. Still in the Section tab, move those rough cross-section shapes to the appropriate distances above or behind the reference point.
4. Go to the Top/Bottom tab and drag the points around in three dimensions, possibly with reference to a background image.
5. Alternate between the three tabs to fine-tune the shape.

A. The Section Tab

In the top-center of the Section tab's window is a checkbox labeled "aircraft has fuselage." By default, this box is checked; if the aircraft is a flying wing or another such oddity, it may need to be unchecked.

If you need to use the shape data from another file, you can use the two buttons in the upper right of the window, labeled

Import Weapon Body and **Import Aircraft Body**. These will set the fuselage shape based on data from either a weapon or another aircraft, respectively.

You can save a description of the fuselage (or some other note about it) in the text box in the bottom right corner of the window, labeled "part description."

Aside from these miscellaneous controls, the Section tab has four main divisions. These are the Body Data box, the Body Location box, the Body Texture box, and the Cross-Sections box, described in the following sections.

i. The Body Data Box

The Body Data portion of the window, seen in **Figure 3.5**, controls the basic features of the fuselage. It is, effectively, your first stop when designing a new fuselage. The "number stations" field sets how many individual cross-sections Plane Maker will link together to form your aircraft's body. In most cases, setting this at the maximum of 20 is not a bad idea, as each additional station will allow you greater control over the body's shape. In any case, you will probably want to add 2 to the number of sections you had in mind to account for the fuselage's two closed ends. For instance, if, when looking at the body, you saw 13 "real" divisions, you would input 15 stations here: 13 "real" sections, which meet at a point at the nose and tail, for a total of 15.

The "number of radii/side" value sets the number of points used in each half of the cross-section. Unless your aircraft has a very simple shape to its body, you'll probably want to use the maximum of 9; this will allow the smoothest curves possible on the body.

The "body radius" setting controls the width of the cross-section views in the bottom half of the window. For the greatest accuracy when placing the points that make up the

body, this should be set to the actual maximum radius of the fuselage. You should, however, err on the side of setting this too high so that all your points are visible.

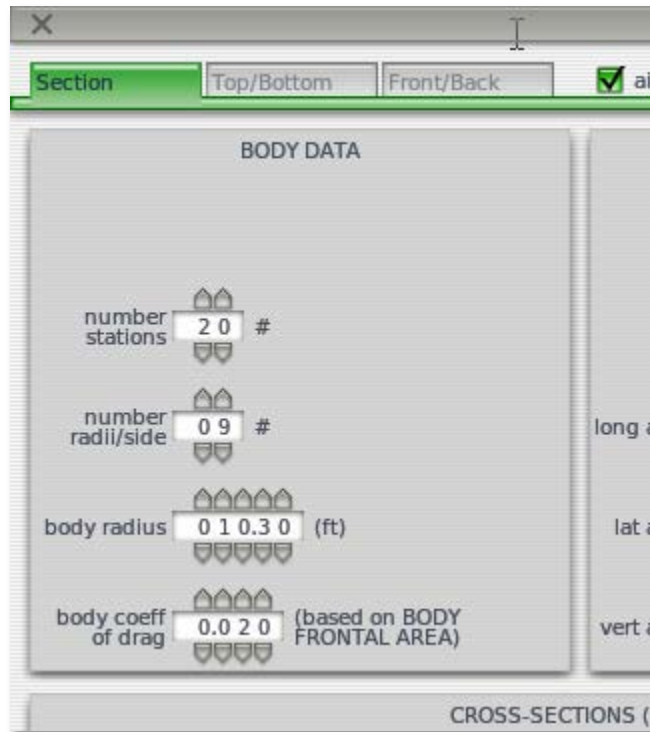


Figure 3.5: The Body Data portion of the Section tab

The final setting in the Body Data section of the window, labeled “body coeff of drag,” is the body’s coefficient of drag based on its frontal area. This determines the amount of drag generated by the fuselage. An average fuselage will have a coefficient of drag of 0.1, while a very sleek one will have a coefficient of 0.025.

ii. The Body Location Box

The Body Location portion of the Fuselage dialog box controls

the fuselage’s location. The three standard location controls (“long arm,” “lat arm,” and “vert arm”) specify the point in space of the front tip of the fuselage. See the section “**Fundamental Concepts**” above for an explanation of these three controls.

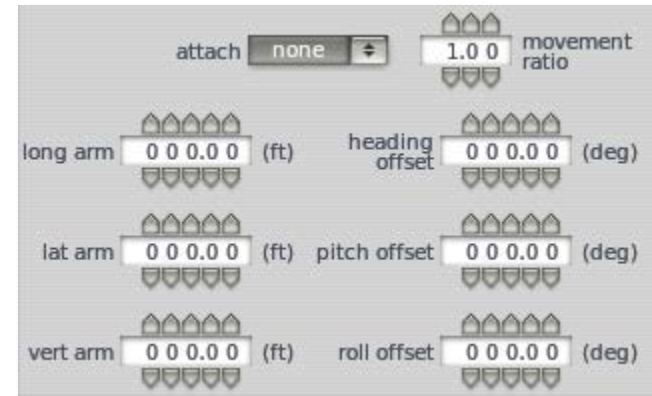


Figure 3.6: The Body Location controls

Since all measurements of location in Plane Maker are relative to the reference point, the fuselage position could be anything—the rest of the aircraft just has to be positioned accordingly. Many aircraft designers, though, prefer the reference point to be the front tip of the aircraft. In this case, the fuselage’s location will be zero feet offset from the reference point.

Parameter	Positive number means...	Negative number means...
Heading offset	Pivots to point right (starboard)	Pivots to point left (port)
Pitch offset	Pivots to point up	Pivots to point down
Roll offset	Rolls right (to starboard side)	Rolls left (to port side)

Table 3.2: Interpreting the direction-setting values

In addition to the standard location controls, the Body Location box also contains directional controls. These are in the form of

the heading, pitch, and roll offset parameters. **Table 3.2** lists the interpretations of these values. For instance, setting a negative value in the heading offset will cause the fuselage to pivot to point left; when seen from above, the fuselage will pivot counterclockwise however many degrees are input here.

In the vast majority of aircraft designs, it makes sense to think of the fuselage as the center of the aircraft, so these parameters will not be used.

iii. The Body Texture Box

The Body Texture box is used for fine-tuning the painted texture on the aircraft (alternately known as a skin or a livery). For information on working with paint textures on the aircraft, see Chapter 8, **Modifying the Appearance of an Aircraft**. For information on the parameters found in this box in particular, see the section of that chapter titled “**Fine-Tuning a Paint Job.**”

iv. The Cross-Sections Box

The Cross-Sections box shows slices of the aircraft’s fuselage. There is one slice of the fuselage for each gridded, white box, as seen in **Figure 3.7**. Each of these slices is composed of the number of points you specified in the “number radii/side” parameter in the Body Data box (see the section “**The Body Data Box**” above for more information on this). Since most designs warrant the maximum of nine radii per side, each of your slices will probably be composed of nine points.

When building your model, Plane Maker will stitch these slices together, so all the cross-sections together will form a complete aircraft body.

We’ve been referring to each of the gridded white boxes as containing a “slice” of the fuselage. In reality, they each

contain a half-slice. The nine points (or however many radii/side you have set) seen here compose the *right side* of a slice; they will be mirrored by another nine points on the left side, for a total of eighteen (or so) points to compose a “full” slice.

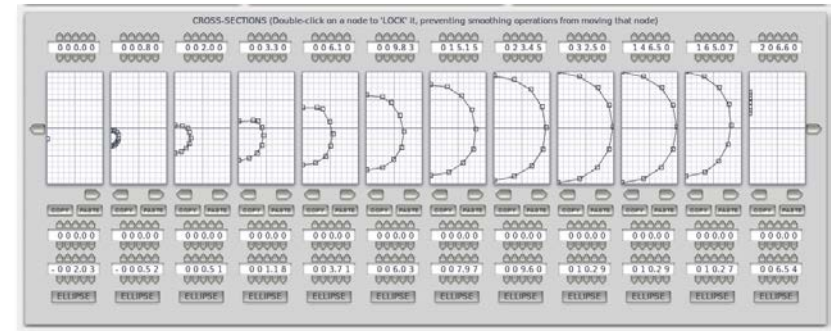


Figure 3.7: The Cross-Sections box

Up to twelve of these half-slices are shown at any one time; if you have set more than twelve “stations” (as described in the section “**The Body Data Box**” above), you can use the left and right arrows to cycle through the slices not seen. These arrows are highlighted in red boxes in **Figure 3.8**.

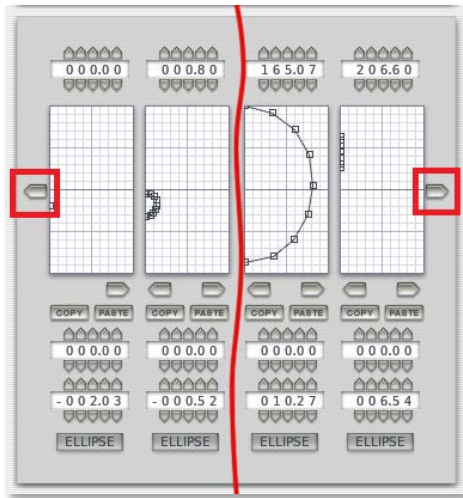


Figure 3.8: The left and right arrows highlighted

Let's dissect each cross-section view—each “station”—in detail.

At the top of each station is an input field controlling how far behind the reference point this particular slice will be. For instance, in the example cross-section of **Figure 3.9**, the slice is located 15.15 feet behind the reference point (indicated by the box labeled 1 in the image). Thus, in an aircraft whose reference point is the tip of the nose, this section would be about 15 feet from the nose. Of course, a cross-section could have a negative value here and be moved in front of the reference point.

Note that Plane Maker will stitch your cross-sections together in the (left-to-right) order that they appear in this box—even if the distances from the reference point that you set in this box do not always increase from left to right. In this way, you could have a fuselage that overhangs itself, or curves inward in some way.

The gridded white box, labeled 2 in **Figure 3.9**, is the cross-section box itself. Click any point and drag it to reposition it

and thus to reshape this slice of the fuselage. Double click on a point to lock its position, protecting it from being smoothed. (Note that smoothing operations are described in the section “**Smoothing the Fuselage**” below.)

Sometimes in the course of editing these cross-section points, it may be useful to zoom in and out or move the cross-sections around. You can zoom using the – and = keys, and you can move the sections using the left, right, up, and down arrow keys. This does not affect the model itself; it only changes the view of the model in editing. To return to the default level of zoom and the default positioning, simply click the **Reset editing offsets** button, located beneath the “Cross-Sections” box itself.



Figure 3.9: A single cross-section view, or “station”

The left and right arrows beneath the cross-section box

(labeled 3 in **Figure 3.9**) are used to copy a cross-section as a whole into the station to the left or right, respectively. This might be useful if you added a new station after working on the stations you already had. In this case, you would start with the farthest right of the stations you had *previously* worked on and press the right arrow. Then, you would move *left* and keep pressing the “copy to the right” button, stopping when you got to the place in the station order that you needed a new one.

Beneath those copy-left and copy-right buttons are general copy and paste buttons, labeled 4 in **Figure 3.9**. Press the **Copy** button beneath the cross-section you want to copy *from*, and press the **Paste** button beneath the cross-section you want to copy *to*.

Beneath the general copy and paste buttons are two fields for setting the left/right and up/down location of a given point in relation to the reference point. This allows for much greater accuracy in placing the individual radius points of a cross-section than can be achieved using a mouse. Click any point in the cross-section (labeled 2 in **Figure 3.9**) to see its distance both to the side and above or below the reference point. With the point selected, use the box labeled 5 in **Figure 3.9** to change its distance to the side of the reference point. Positive values here indicate a point is on the right of the reference point. The box labeled 6 in **Figure 3.9** sets the point's distance above or below the reference point, with positive values indicating it is above the reference point.

Finally, at the bottom of each station is the **Ellipse** button, labeled 7 in **Figure 3.9**. Clicking this button will round the cross-section above into the closest-fitting, smoothly-curving ellipse. It will do so, however, without modifying any points that you have locked. To lock a point's position, double click on it; rather than being represented in the cross-section view as a white-filled box, it will turn black.

B. The Top/Bottom Tab

The Top/Bottom tab of the Fuselage dialog box displays the fuselage's cross-sectional “slices” stitched together in three different views; that is, it shows the top, side, and bottom views of the complete fuselage formed from the cross-sections. (Recall that these cross-sections may initially be laid out in the Section tab, described in the preceding section of the manual.)

To shape a station, simply click the radius points that make it up and drag them around. Just like in the Section tab, you can double click a point to lock it, preventing future smoothing operations from moving it on it.

The standard movement controls (the up, down, left, and right arrows, as well as the – and = keys for zooming) all operate as you would expect in this window, allowing you to zoom in or out and shift your view around.

Now, how do these three views (top, side, and bottom) fit together? It all starts with the side view—the *left* side view, in particular. The points that make up the left side are mirrored on the right, similar to the way the half-slices of the Section tab's cross-section view are mirrored to form a complete slice. The middle, roughly horizontal line in the side view corresponds to the top- and bottommost lines in the top and bottom views.

The top and bottom views are mirrored in their upper and lower halves; dragging a point in the upper half of the top view will drag its corresponding point in the lower half of that view (in addition to dragging the same point in the side view). They are mirrored like this because the left side view itself is mirrored on the right; thus, the top view, for instance, shows the top half of both the left and right sides.

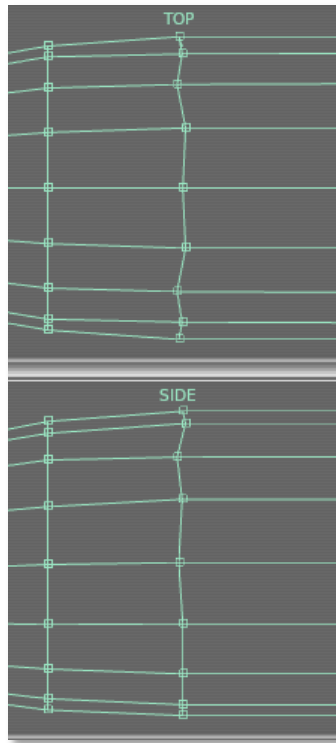


Figure 3.10: A situation where the “reset to vertical” buttons are useful

At the top of the window are two buttons, **Reset this section to vertical** and **Reset all sections to vertical**. Often in the course of editing the points of a fuselage, the points of a given section will get out of alignment purely by accident, due simply to the inaccuracy of using a mouse. That’s where these buttons come in. For instance, in the example fuselage in **Figure 3.10**, you might want to click the **Reset all sections to vertical** button, thus lining up the points in each cross-section.

However, in some cases, it is desirable to *not* have all your sections vertically aligned. In this case, if you still wanted to align the out-of-whack section seen in **Figure 3.10**, you would need to first click one of the points in the section you wanted to align. Then, after you have effectively told Plane Maker which

section you want to modify, you would click the **Reset this section to vertical** button.

At the bottom of this window are buttons to load an image or clear it. This can be quite useful for laying out your points properly. For instance, you could take two scale drawings of your aircraft (one to be used in both the top and bottom views and one to be used in the side view) and drag the radius points to match up with this image.

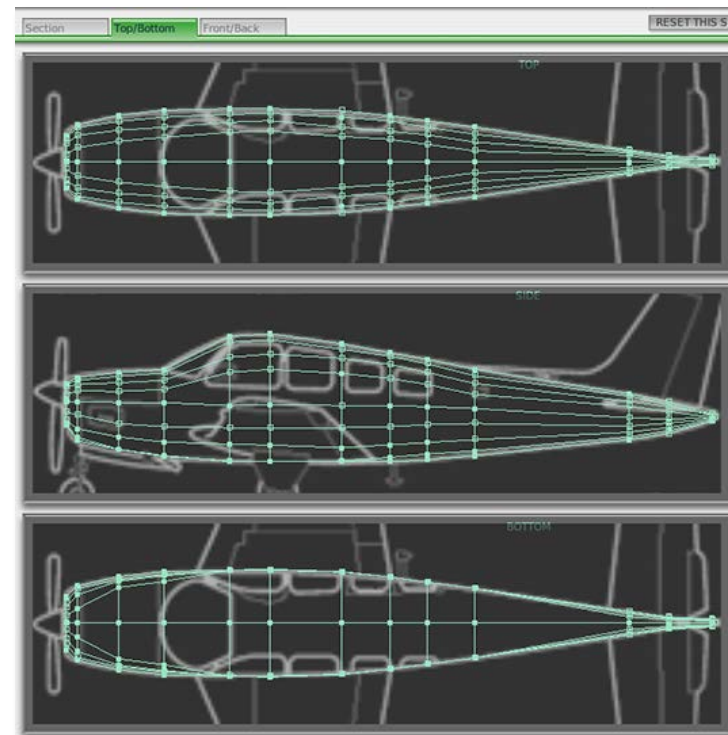


Figure 3.11: Using scale drawings to lay out the points of a fuselage

For instance, in **Figure 3.11**, we cut up two scale images to be the same size, with the center of the image corresponding to the center of the fuselage, and loaded the images into Plane Maker. From there, we simply dragged the outermost points (or uppermost points, as the case may be) to match the edges

of the fuselage in the image. Following that, we dragged the inner points to match the known shape of the fuselage.

C. The Front/Back Tab

The Front/Back tab of the Fuselage dialog box contains two views of the cross-section, front and back. The front view shows the first twelve stations (if there are twelve stations to show) as though you were looking down the nose of a wireframe fuselage model. The back view, on the other hand, shows the last ten stations (again, if there are ten stations to show) as though you were standing at the tail looking down the wireframe model.

The standard movement controls (the up, down, left, and right arrows, as well as the – and = keys for zooming) all operate as you would expect in this window. Using the arrow keys, you can move the wire model over to view the whole fuselage, too, instead of just a half.

The radius points displayed in both these views operate just like the ones in the other two tabs. Simply click a point and drag it to change the fuselage shape there. You can also double click a point to prevent it from being changed in a future smoothing operation (described in the section “**Smoothing the Fuselage**” below).

The buttons **Reset this section to vertical** and **Reset all sections to vertical** are available in this tab as they are in the Top/Bottom tab. However, it may be wise to confine your use of them to the Top/Bottom tab, as you will not be able to see its effect in this view—the view is essentially without perspective, so a point that is far away looks the same as a much closer point with the same up/down and left/right position.

D. Smoothing the Fuselage

The most basic smoothing operation that can be performed on

the fuselage is the smoothing of individual cross-sections to an elliptical shape. This is done using the **Ellipse** button in the Section tab of the Fuselage dialog, as described in the section “The Cross-Sections Box” above.

A much farther-reaching version of this smoothing operation can also be performed. Using the “Ellipse-Smooth Fuselage” option, located in the Special menu, will nudge all cross-sections of the fuselage toward the elliptical shape that would be obtained using the **Ellipse** button. Repeatedly using the “Ellipse-Smooth Fuselage” will have an effect identical to clicking the **Ellipse** button on all stations in the fuselage.

E. Adding Other Bodies to the Fuselage

Some aircraft have odd protrusions (such as a large fuel tank poking out from under the fuselage) or even special physical objects attached to them. In this case, it may be best to model the fuselage itself as *not* having these things. Instead, you might model these things as separate “bodies” (physical objects) which *intersect* the fuselage. X-Plane doesn’t care whether the large protrusion on the underside of the aircraft is actually part of the fuselage or just another object touching the fuselage; it will model the aerodynamics the same way.

In this case, you would model the other things using the Miscellaneous Bodies dialog box, found in the Standard menu.



Figure 3.12: Clicking Misc. Bodies from the Standard menu

Each body created in this window is modeled almost identically to the fuselage; there is a Section, Top/Bottom, and Front/Back tab for each body, just as there is for the fuselage. To add a new body, simply click a new tab from the top of the window and check the box labeled “aircraft has this external fuel tank, float, or other external body,” as seen in **Figure 3.13**. You can add up to twenty miscellaneous bodies in this dialog box.

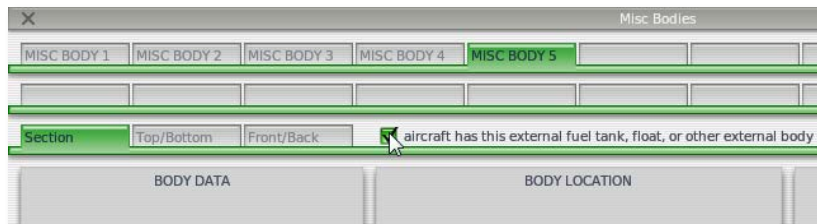


Figure 3.13: Checking the "aircraft has this . . . body" box

Finally, be aware of the **Insert** button, located between stations in the Cross-Sections box. Clicking this button will insert a new station between the stations on the left and right

sides of the button. From there, you can of course use the **Copy** and **Paste** buttons to move your stations around. Note that you can only use the **Insert** button when you have fewer than 20 stations.

III. Shaping the Wings

Wings in Plane Maker are composed of individual wing *sections*. A very simple wing might be made up of a single wing section, while a very complex wing might be made up of four or more wing sections. Each wing section can have control surfaces added, such as ailerons, elevators, or flaps. Furthermore, each wing section can have its cross-sectional shape (its airfoil) set independently of other sections.

A. Setting the Basic Features

To create and modify wing sections, open the Wings dialog box from the Standard menu.

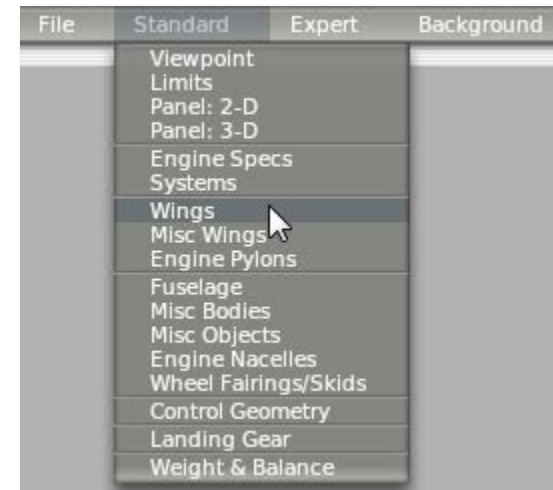


Figure 3.14: Clicking Wings from the Standard menu

The Wings dialog box houses a number of tabs whose contents all look identical. The only difference between them is that, whereas the tabs labeled “wing” and “horizontal stabilizer” control two identical wing sections mirrored on either side of the fuselage, the tabs labeled “vertical stabilizer” control only a single wing section.

When you click on any of the tabs, you will see three boxes in the window: the Foil Specs box, the texture fine-tuning box, and the Element Specs box.

The Foil Specs box controls all the basic properties of a wing section. All wing sections have the following properties:

- a semi-length, the length of the wing section from its root to its tip when measured 25% of the way back from the wing’s leading edge,
- a root chord length, the width of the wing section where it is closest to the fuselage,
- a tip chord length, the width of the wing section where it is farthest from the fuselage,
- a sweep angle, the angle backward or forward that the wing is pointing (when viewed from above),
- a dihedral angle, the upward or downward angle of the wing section relative to horizontal, and
- a location.

Figure 3.15 shows the foil specifications not including the location controls; for information on using the standard location controls, see the section “**How Positions Are Set in Plane Maker**” at the beginning of this chapter.

In most cases, a wing is composed of more than one wing section. In this case, you *could* specify the location of the outer wing sections manually so that they meet up with the next sections closest to the fuselage. However, in the upper right corner of the Fuselage dialog box is a drop-down menu labeled “snap to,” as seen in **Figure 3.16**. To snap a wing section to another one—that is, to have Plane Maker automatically align the root of the section you’re applying the

snap to with the tip of the section you choose—simply click the drop down button and click on the wing section to snap to.

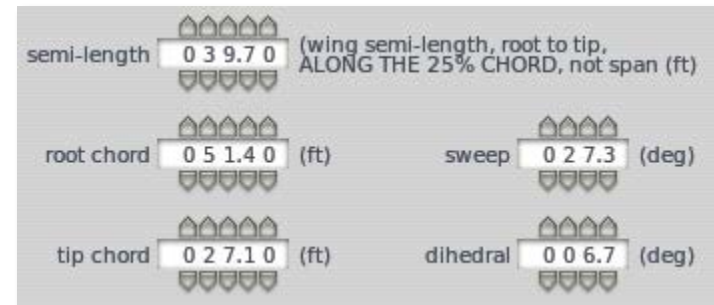


Figure 3.15: The foil specification parameters

To the right of the Foil Specs box is the texture box, used for fine-tuning the painted texture on the aircraft (alternately known as a skin or a livery). For information on working with paint textures on the aircraft, see Chapter 8, **Modifying the Appearance of an Aircraft**. For information on the parameters found in this box in particular, see the section of that chapter titled “**Fine-Tuning a Paint Job.**”



Figure 3.16: The “snap to” drop-down menu

The Element Specs box in the bottom half of the window determines where ailerons, elevators, flaps, or other control surfaces go on the wing surface.

The **Import Wing** button has a very specific function. Clicking this button from the tab corresponding to a certain wing section (Wing 1, Wing 2, Horiz Stab, Vert Stab 1, etc.) will

open a dialog box. In this dialog box, you can navigate to an aircraft (.acf) file and select it. That aircraft's wing section corresponding to the tab you have open will then replace whatever is currently set on your aircraft. An example will clarify.

Suppose I am making a new model of the Boeing 777. I'm creating many things from scratch, but perhaps I am already satisfied with the wings found on the stock 777 model; I might as well just import them from the Speed-Bird.acf file into my New_and_Better_777.acf file.

Then, I will load up New_and_Better_777.acf in Plane Maker, open the Wings dialog box, and select the Wing 1 tab. I will click the **Import Wing** button, find the Speed-Bird.acf file, and click **Open**. Wing 1 will be replaced with the Wing 1 section from Speed-Bird.acf. I could continue on down the line, moving to the Wing 2 tab, the Wing 3 tab, and so on, importing each one.

B. Adding Ailerons, Flaps, and Other Control Surfaces

To add control surfaces like elevators, rudders, ailerons, or flaps to a given wing section, you must tell Plane Maker where you want each control surface on the wing and you must define the control surfaces themselves. The first part is done using the Element Specs box found in the Wings dialog box, while the second part is done in the Control Geometry dialog box, launched from the Standard menu. The order in which you do these does not matter; do them in whatever order makes the most sense to you.

For our purposes, we will start off in the Control Geometry dialog box. The only thing to be concerned with in this dialog box, at least until after the first test flight, is the Controls tab.

In the Controls tab, a number of possible control surfaces can

be created, from ailerons to elevators to rudders to speedbrakes to flaps. Each of these works in a similar way. The left half of the window, in the box labeled Control Sizes, sets up ailerons, elevators, rudders, roll spoilers, drag rudders, and speedbrakes. The right half of the window, labeled Flap Specs, sets up flaps and slats only.

i. Specifying Ailerons, Elevators, and Other Surfaces

The right half of the Control Geometry's "Controls" tab is labeled Control Sizes, and it is used for all control surfaces except the flaps and slats.

Figure 3.17 shows the parameters to specify a single control surface (namely, an aileron). There are four input fields here. On the far left is the control surface's root-side width, as a decimal part of the chord length of the wing section it is placed on. Thus, if this root width were set at 0.50 and it were used in a wing whose root was 5 feet wide, the control surface would have a width of 2.5 feet on the side closest to the fuselage.

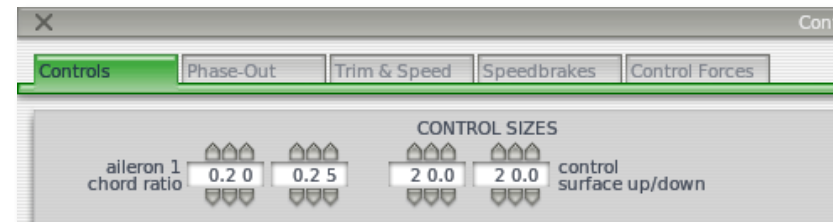


Figure 3.17: A single, representative control surface specification

To the right of the root width is the tip width, also specified as a decimal part of the wing it is placed on. So, if the tip width were set at 0.1 and it were used on a wing whose tip was 10 feet wide, the control surface would have a width of 1 foot on the side farthest from the fuselage.

These two parameters, root and tip width, function identically on all the control surfaces available.

To the right of the two size parameters are the fields controlling how far the surface can move, measured in degrees. For instance, in the aileron of **Figure 3.17** these are, from left to right, how far *up* the aileron can deflect and how far *down* it can deflect.

Specifications for ailerons, elevators, and rudders all follow this same pattern: parameters for the root and tip width, followed by parameters for the maximum deflections. The roll spoilers and drag rudder are exceptions to this pattern. They move one at a time, and they only move upward. For this reason, they have only one parameter for maximum deflection.

Additionally, the speedbrake may have two maximum deflections: one for normal, in-flight operation, and one for ground use. Unlike the other control surface types, speedbrakes don't have to be mounted to a wing—they can also be mounted directly on the fuselage (or anywhere else, for that matter). For information on doing this, see the section “**Adding Body-Mounted Speedbrakes**” below.

At the bottom of the Control Sizes box is the “control surface type” setting, which modifies how effective the surfaces are in X-Plane. Surfaces which are “corrugated with gaps” are least effective.

ii. Specifying Flaps and Slats

The right half of the Control Geometry's Controls tab is labeled Flap Specs, and it is used to set up the aircraft's flaps and slats.

Let's walk through the settings here.

Slats change the lift characteristics of a wing. They allow a higher angle of attack for the wing, resulting in a lower stall speed. Two slats can be set up for each aircraft. Using the parameters seen in **Figure 3.18**, you can set the type of slat—

either true slats or Krueger flaps. (Note that Krueger flaps are not technically slats. They deploy by hinging forward from the wing instead of sliding from the top of the wing's leading edge like slats do.)

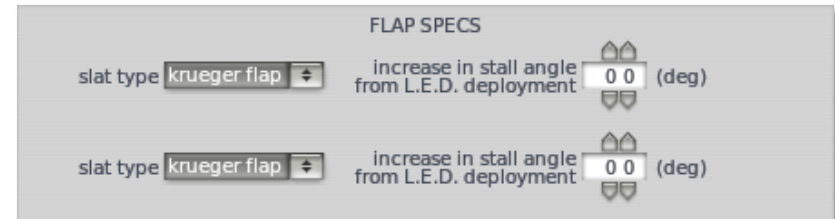


Figure 3.18: The “slat type” and “increase in stall angle” settings

Next to the “slat type” control is the “increase in stall angle from leading edge device deployment” parameter, seen in **Figure 3.18**. Slats work by allowing the wing to go to a higher angle of attack without stalling—that is, without losing lift. Slats in the real world allow the wing to gain up to eight degrees of angle of attack without stalling.

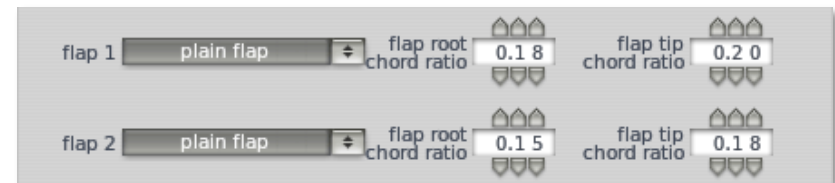


Figure 3.19: The flap type and size settings

Like slats, flaps alter a wing's lift characteristics. They allow the wing to generate a given amount of lift at a lower speed, resulting in the aircraft stalling at a lower speed. Two flaps can be set up for each aircraft. Using the parameters shown in **Figure 3.19**, you can set the type of flap, chosen from a large number of options. Each type of flap has unique lift, drag, and moment characteristics, as described in the dark gray box below the flap type setting. Four types of flaps available in X-Plane are illustrated in **Figure 3.20**.

To the right of the flap type setting are the two parameters controlling the size of the flaps. Just like when setting up ailerons, rudders, and elevators, you must specify the flap size on both the root side and the tip side. These are set as a decimal part of whatever wing section the flap is placed on.

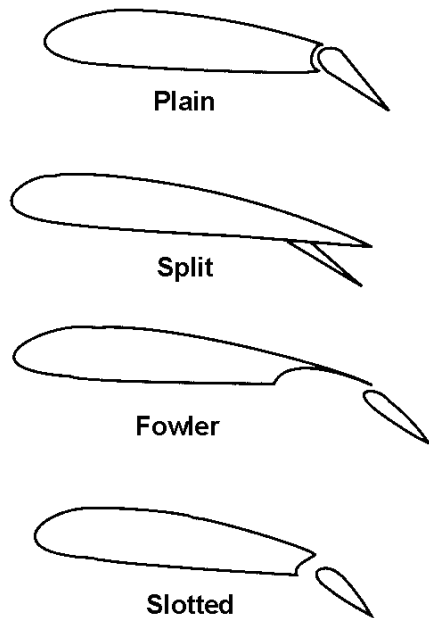


Figure 3.20: Four types of flaps illustrated

Beneath the flap type and size settings are the parameters that control the aerodynamic coefficients for each flap, as seen in **Figure 3.21**. Plane Maker will automatically calculate the coefficients of lift (C_l), drag (C_d), and moment (C_m) based on the size of the flap, but these may be modified manually as well.

If you find that the real aircraft slows down more than X-Plane predicts when flaps are lowered, you may want to increase the flaps' drag coefficient, perhaps by about 0.01. If, on the other hand, you find that the real aircraft gives a lower stall speed than X-Plane predicts when the flaps are lowered, you may want to increase the flaps' lift coefficient, perhaps by about

0.1. If you find that the real aircraft does not pitch up or down like it does in X-Plane when the flaps are lowered, you may need to increase or decrease the coefficient of moment. Decrease the flaps' C_m by, say, 0.1 to pitch down more (or to pitch up less, as the case may be).

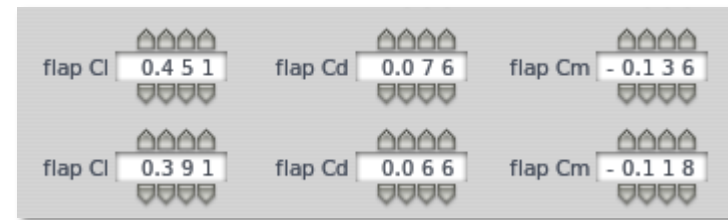


Figure 3.21: The flaps' aerodynamic coefficients

Beneath the flaps' coefficients, you can set the deflection time as well as the detent (or stop-point) characteristics for both the flaps and slats, as seen in **Figure 3.22**. The flap deflection time is critical for getting proper pitch characteristics when the flaps are lowered.

Checking the box labeled "flaps are infinitely adjustable between detents" allows a pilot in X-Plane to hold the "flaps up" or "flaps down" button to select *any* flap setting, not just the ones at the detents. Even for aircraft with infinitely adjustable flaps, though, it is still useful to set the detents below, as they will be used in the maximum allowable flap deployment speeds. (Note that the max allowable speeds are set in the Viewpoint menu, as described in Chapter 4, in the section "Configuring Instrument Performance Ranges, Display Limits, and Colors.")

Beneath the "flaps are infinitely adjustable" checkbox is the flap deflection time parameter, as seen in **Figure 3.22**. This sets the amount of time in seconds that it takes the flaps to go from fully retracted to fully extended.

Beneath the flap deflection time is the number of flap detents (as seen in **Figure 3.22**). A detent is a stopping place for the

flaps, a middle-of-the-road between being totally retracted and totally extended. General aviation aircraft might have only one or two stopping points, while airliners might have many more.

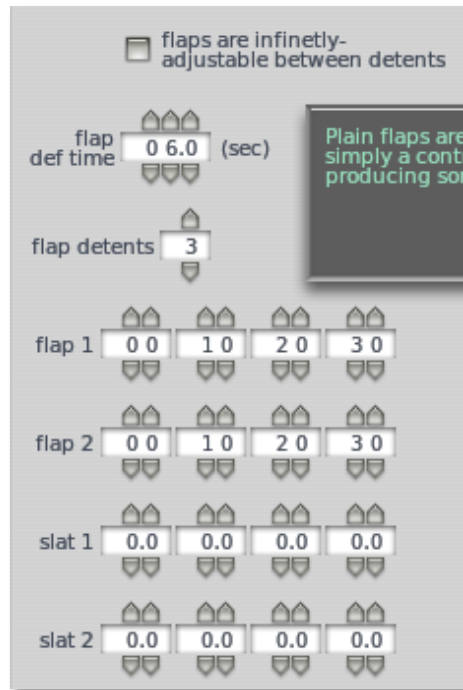


Figure 3.22: The flap and slat detent characteristics and deflection time

Finally, beneath the number of detents are the detent parameters themselves—one set of detent boxes for each flap and slat. Each box sets the flap/slat deflection in degrees at that detent. Note that there is one more box here than the number of detents you set above. This is to account for the “zeroth” detent, which in most aircraft will be a flap deflection of zero degrees.

For instance, in in **Figure 3.22**, three flap detents were set. Thus, there are *four* boxes for “flap 1,” four boxes for “slat 1,” and so on.

iii. Adding Control Surfaces to the Wings

With the control surfaces (elevators, ailerons, rudders, flaps, etc.) all set up in the Control Geometry dialog box, as described in the sections above, it’s time to actually add those control surfaces to the wings. You will need to set the control surfaces individually for each wing section.

To do this, open the Wings dialog box from the Standard menu. In the bottom half of each wing’s tab is a box labeled Element Specs, as shown in **Figure 3.23**.

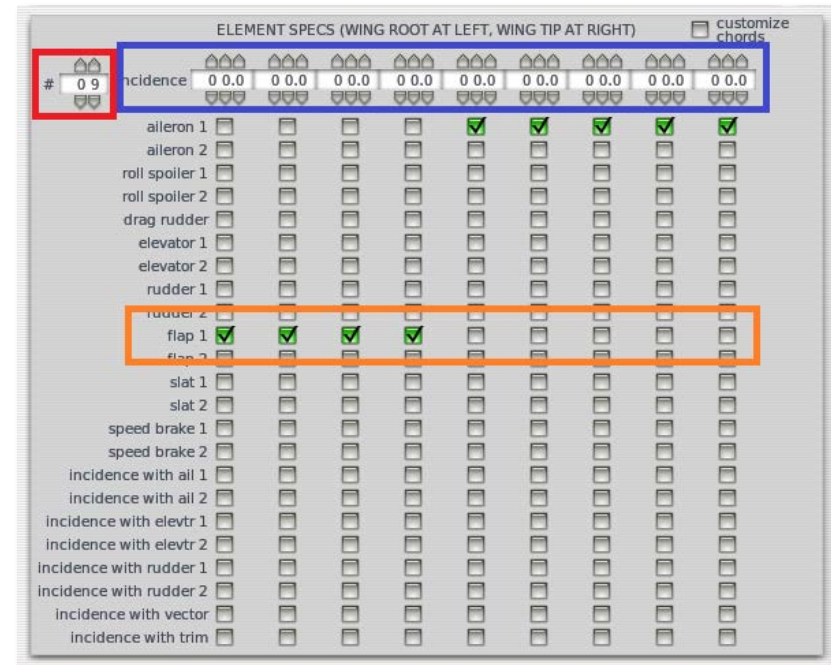


Figure 3.23: The Elements Specs box, specifying the control surfaces of a wing section

Highlighted in red in **Figure 3.23** is the box controlling the number of pieces that the wing section will be broken into. The

wing section will be divided into this many pieces of equal size.

These pieces serve a couple of purposes. First, they represent the divisions of the wing on which X-Plane will calculate forces for its flight simulation. The simulation works by breaking the wing into pieces, calculating the forces on those pieces, and summing the forces on all the pieces in order to move the aircraft as a whole.

These pieces also serve as divisions across which control surfaces are stretched. For instance, in **Figure 3.23**, the first four pieces (and thus the first four-ninths of the wing section as a whole) will have the “flap 1” on them. Likewise, the last five pieces (and thus the final five-ninths of the wing section, moving from root to tip) will have the “aileron 1” on them.

This brings us to the next feature of the Element Specs box. Highlighted in orange is a single control surface (the “flap 1”), with the boxes checked corresponding to the pieces of the wing section that it is present on.

We have said that the wing section is broken into a number of equal-sized pieces. These pieces are represented here, from left to right, from the root to the tip of the wing section. Thus, when the checkbox on the far left is checked, it means the piece of this wing section that is *closest to the fuselage* has that control surface. This means that in **Figure 3.23**, the four pieces closest to the fuselage have flap 1.

Check each of the boxes for the control surfaces that a wing section has. (Note once again that these boxes will only actually do something to the wing if the control surfaces have been set up as described in the sections “**Specifying Ailerons, Elevators, and Other Surfaces**” and “**Specifying Flaps and Slats**” above.)

It may be useful when deciding how many pieces of the wing section a given control surface takes up to use the “Show with still/moving controls” option from the Special menu, as shown

in **Figure 3.24**. This will cause Plane Maker to move all the aircraft model’s control surfaces, so you can see immediately where the surface extends to.



Figure 3.24: Show the aircraft with moving control surfaces

iv. Adding Body-Mounted Speedbrakes

Speedbrakes may be added to an aircraft in one of two ways. The first, and most common, is to specify them in the Controls tab of the Control Geometry dialog box, as described in the section “**Specifying Ailerons, Elevators, and Other Surfaces**” above. However, you can also add them directly to an aircraft’s body (its fuselage, wings, etc.), placing them using the standard Plane Maker position controls.

Body-mounted speedbrakes like these are created in the Speedbrakes tab of the Control Geometry dialog box. Once again, the Control Geometry dialog box is opened from the Standard menu.

Up to four body-mounted speedbrakes can be added to an aircraft using this tab; there is one box per speedbrake, as seen in **Figure 3.25**.

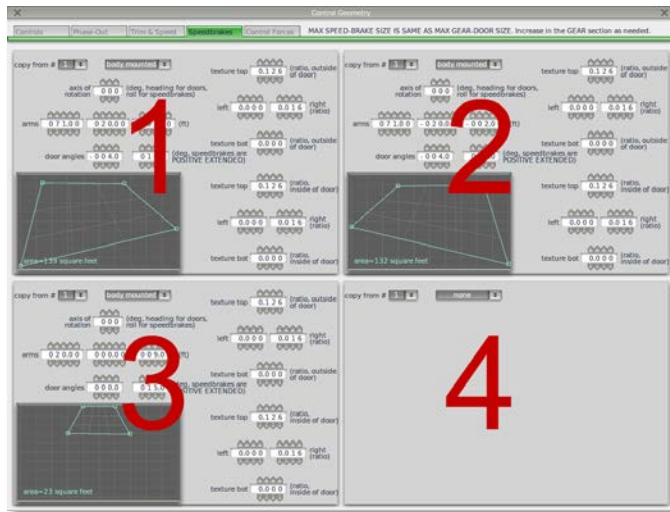


Figure 3.25: The four boxes for creating body-mounted speedbrakes

Since each speedbrake is created in the same way, we will look at the parameters for creating a single speedbrake.

In the upper left of the speedbrake's box is the “copy from” drop-down menu, labeled 1 in **Figure 3.26**. To copy the geometry, location, and texture from another body-mounted speedbrake to this one, just click the drop-down button here and click the number of the surface you want to copy from. (Note that for the purpose of copying, the speedbrakes are numbered beginning with 1 in the upper left box. **Figure 3.25** shows the numbering for each of the boxes.)

If you are not copying another object's geometry, you must start by selecting the speedbrake's type. The drop down box labeled 2 in **Figure 3.26** selects a type of either “none” or “body mounted.” Any speedbrake box that you are not using should have a type of “none” set for it. Likewise, if you do

intend to use a body-mounted speedbrake, set its type to “body mounted.”

After turning on any body-mounted speedbrakes you want to use, it makes sense to jump down to the geometry box, labeled 6 in **Figure 3.26**. Speedbrakes in X-Plane are 2-dimensional, composed of up to four points. Click away from any existing points to create a new one, and click a point and drag it to change the speedbrake's geometry.

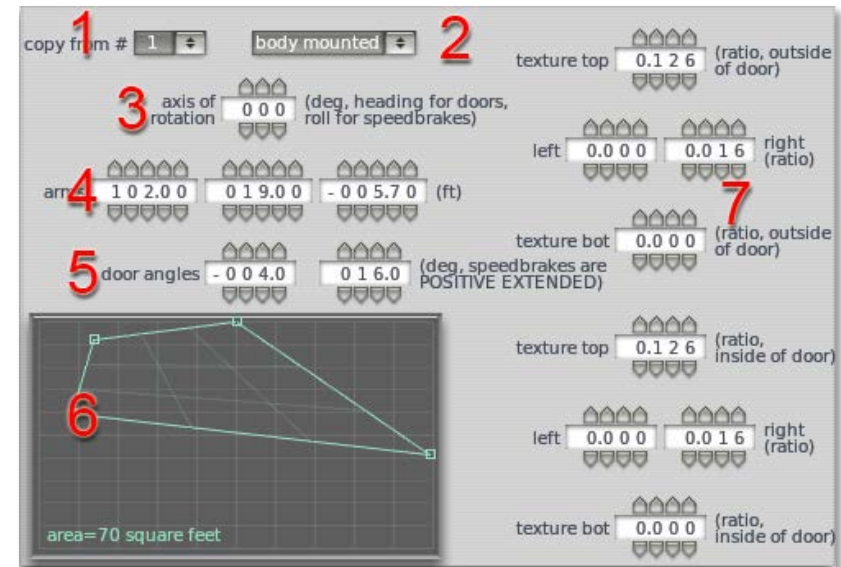


Figure 3.26: The controls to create a single body-mounted speedbrake

Note that the maximum width of the speedbrake geometry box here is the same as the maximum gear door size parameter, located in the Gear Data tab of the Landing Gear menu. For information on setting this, see the section “**Finishing Retractable Gears**” below.

After creating at least a rough model of the speedbrake's shape, you can position it on the aircraft and set its extended and retracted angles.

To begin positioning a speedbrake, you can set its roll attitude. This is done using the axis of rotation parameter, located beneath the speedbrake type control and labeled 3 in **Figure 3.26**. A roll of 90 degrees makes the speedbrake point straight up, while a roll of 0 degrees makes it completely horizontal.

Next are the standard location controls, labeled 4 in **Figure 3.26**. These are presented here in longitudinal-lateral-vertical order, from left to right. For information on using these controls, see the section “**How Positions Are Set in Plane Maker**” at the beginning of this chapter.

Beneath the location controls are the speedbrake's open and closed angles, labeled 5 in **Figure 3.26**. The parameter on the left is the angle of the speedbrake when it is retracted; the one on the right is its angle when extended. Positive values here will cause the speedbrake to hinge upward, while negative values cause it to hinge downward.

The final settings in each speedbrake's box (labeled 7 in **Figure 3.26**) are related to its paint textures. Information on working with the paint is found in Chapter 8, in the section “**Creating a Basic Paint Job.**”

C. Customizing a Wing's Pieces (for Incidence, Size and Position)

In the Element Specs box—the same box used for applying control surfaces to wing pieces—is the piece incidence setting, highlighted in blue in **Figure 3.23**. This sets the upward angling (or incidence) of each piece, in degrees. This allows you to warp a wing section to point up or down.

Using the checkbox labeled “customize chords,” you can change the width of the wing section from its leading edge to its trailing edge (that is, its chord length) for each piece. Pieces are modified just like when adding a control surface to a piece;

the boxes on the far left correspond to the portion of the wing section that is closest to the fuselage, while the boxes on the far right correspond to the portions farthest from the fuselage.

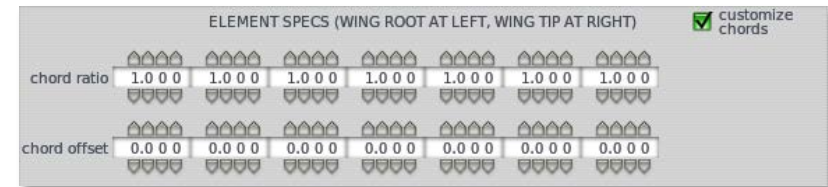


Figure 3.27: Customizing an aircraft's chord size and position

Normally, Plane Maker calculates the chord length of each piece (again, the distance from its leading to its trailing edge) by interpolating between the root chord and the tip chord, which you set in this tab's Foil Specs box. Using the “chord ratio” setting, though, you can modify the width of each piece. The Plane Maker-calculated value for the chord length is *multiplied* by the ratio you set here to get the actual width of this piece.

For instance, if Plane Maker saw that the chord length should be 5 feet at the center of a given piece, and you used a chord ratio of 2, the center would end up with a 10-foot chord length. Likewise, if you had chosen a ratio of 0.5, it would end up with a chord length of 2.5 feet.

Finally, the “chord offset” setting, seen in **Figure 3.27**, determines how far forward or back a given piece gets shifted. Positive values will push the wing section behind the reference point, while negative values will push it forward of the reference point. This is specified as a ratio of the Plane Maker-calculated chord length. Thus, with a calculated chord length of 5 feet, and a chord offset of 0.5, a given piece will be pushed farther behind the reference point by 2.5 feet.

Use the above settings to customize the fine details of a wing section's size and shape.

D. Setting a Wing's Airfoils

Creating a wing in the standard Wings dialog box specifies only the wing's size, location, and the direction it's pointing—it does not specify what shape the wing has. Is it thin along the trailing edge and fat along the leading edge? Maybe it is fat along both edges, or maybe it is fat in the middle and thin at the edges. To tell Plane Maker just what (cross-sectional) shape the wing has, we need the Airfoil dialog box, which is launched from the Expert menu.

Each wing section can have four different airfoils set for it. These four airfoils come in two sets, one for high Reynolds numbers and one for low Reynolds numbers. Each set has one airfoil for the root and one for the tip. These airfoil shapes are then blended together linearly in the portion between the root and tip, and the two sets (the low and high Reynolds number sets) are blended together between the Reynolds numbers.

The airfoil shapes themselves must be created using the separate Airfoil Maker application, which, like Plane Maker, is included in the X-Plane installation folder. X-Plane does *not* look at the *shape* of the wing and then decide how much lift, drag, etc. the foil will put out—X-Plane is *not* a computational fluid dynamics program. Instead, X-Plane uses pre-defined airfoils that list the *performance* of any airfoil (lift, drag, moment) to predict how the plane will fly with that foil. For information on using Airfoil Maker to create these airfoils with predefined performance, see [the Airfoil Maker supplement to the X-Plane Desktop manual](#).

To apply an airfoil shape to a wing after the wing has been created, open the Expert menu and click Airfoils. In the Airfoils dialog box, go to the Wings tab. Here, you can set two versions of both the root and the tip airfoil for each wing section. The foils on the left are for the root side of the section, and the ones on the right are for the tip side, as seen in **Figure 3.28**. Plane Maker will interpolate between the root and tip

airfoil to create the shape of the middle of the wing section.

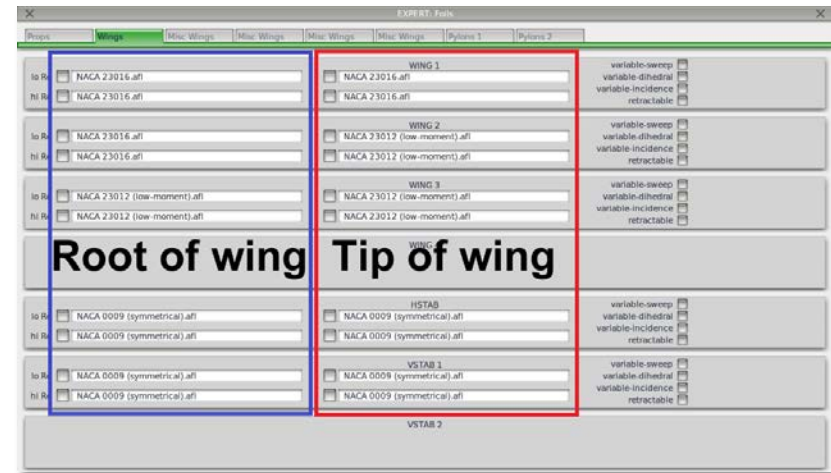


Figure 3.28: The root and tip airfoils

The top root-and-tip pair of foils in each wing's box specifies the low Reynolds number version of the foil; the bottom pair specifies the high Reynolds number version. Once again, X-Plane will interpolate between these two when your Reynolds number is between the high and low values.

The following two pages may be useful in determining what airfoils to use in your wing (assuming you're modeling an aircraft that is already in production):

- [The Incomplete Guide to Airfoil Usage](#)
- [StrategyWiki: Airfoils](#)

To set an airfoil to be used on a particular wing, in a particular place (root or tip), and for a particular Reynolds number (high or low), click the gray box to the left of that position on that wing. A dialog box will appear for you to navigate to the airfoil file's location. X-Plane's default airfoils are found in the X-Plane 9\Airfoils directory.

E. Making a Wing Movable

Just like in the real world, wings in X-Plane do not have to be static. They can be swept forward or back, they can be angled up or down, and they can even be retracted.

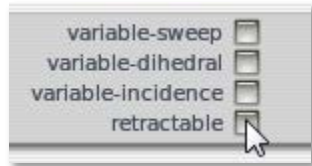


Figure 3.29: The parameters to make a wing movable in the Airfoils dialog box

In the Airfoils dialog box (launched from the Expert menu), each wing has a group of four checkboxes, as seen in **Figure 3.29**.

i. Setting Variable Wing Sweep

Checking the first box in **Figure 3.29**, labeled “variable sweep,” will allow you to set the maximum wing sweep in degrees. Positive values here will allow the wing to angle further behind the reference point, while negative values will allow it to angle forward of the reference point. This variable sweep is illustrated in **Figure 3.30**.

Wing sweep is measured in degrees of sweep along the 25% chord (that is, along the line 25% of the way behind the *leading edge* of the wing). Note that you set the maximum sweep here; the minimum sweep is set as the default wing sweep, found in the Wings dialog box (opened from the Standard menu).

Variable wing sweep is useful in aircraft that approach or exceed the speed of sound, but which must also perform well at low speeds. As your speed increases toward Mach 1, a wing that meets the air head-on generates more and more

drag. Variable sweep wings are most popular in military aircraft (like the B-1 Lancer and the F-14 Tomcat).

To use a variable sweep in X-Plane, you can add a sweep control to the instrument panel. Alternatively, you could assign a button or key to the “vector sweep aft” and “vector sweep forward” controls in the Joystick and Equipment dialog box.

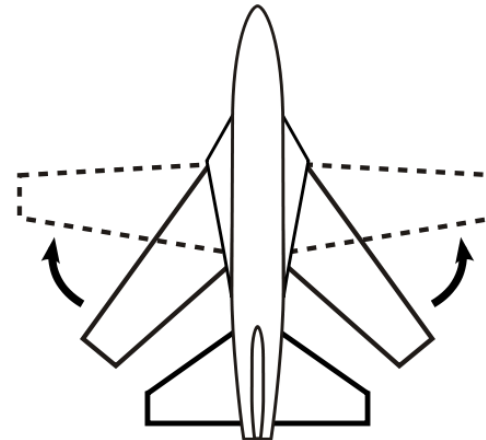


Figure 3.30: Variable wing sweep illustrated (thanks to Wikimedia Commons user [Steelpillow](#) for the image)

ii. Setting Variable Wing Dihedral

Checking the box labeled “variable dihedral” in the Airfoils dialog box (seen in **Figure 3.29**) will allow you to change the angle of the wing above or below the horizontal plane in flight. This is illustrated in **Figure 3.31**.

Entering a positive value here corresponds to an angle upward from horizontal (like the wings in **Figure 3.31**). Likewise, entering a negative value will correspond to a downward angle. A relatively high dihedral angle will increase the “dihedral effect” on the wings—that is, the wings’ tendency to stabilize and level the aircraft in a roll.



Figure 3.31: Wing dihedral, the upward angle of the wings, illustrated (thanks to Wikimedia Commons user [Steelpillow](#) for the image)

iii. Setting Variable Wing Incidence

Checking the box labeled “variable incidence” in the Airfoils dialog box (seen in **Figure 3.29**) will allow you to change the wing’s angle of attack in flight. This angle, known as the angle of incidence, is illustrated in **Figure 3.32**.

Enter the maximum incidence here, in degrees. Positive values correspond to an upward angle of the wing when viewing the aircraft from the side, while negative values correspond to a downward angle.

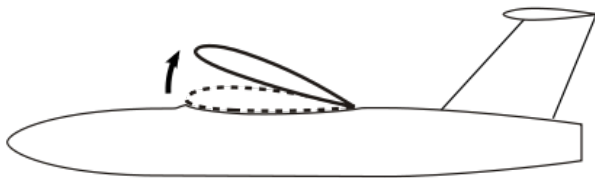


Figure 3.32: Variable wing incidence illustrated on a high-wing plane (thanks to Wikimedia Commons user [Steelpillow](#) for the image)

A small positive angle of incidence is used in most aircraft in order to keep the fuselage horizontal when the aircraft is cruising. Thus, changing the angle of incidence in flight will also change the angle of the fuselage as the aircraft flies.

iv. Making a Wing Retractable

The final dynamic wing checkbox in the Airfoils menu is labeled “retractable” (as seen in **Figure 3.29**). Check this box, then set the maximum retraction as a ratio of the wing section’s semi length. For instance, if the wing section was 10 feet long and you set the max retraction ratio at 0.5, the section would retract up to 5 feet into the fuselage.

F. Adding More Wing Sections

In some cases, the four “regular” wing sections, two vertical stabilizer sections, and single horizontal stabilizer section found in the Wings dialog box are not enough to accurately model an aircraft’s wings. In this case, you can add more wing sections by launching the Misc Wings dialog box from the Standard menu.

Wing sections here are added and modified just like in the regular Wings dialog box, with one exception: wing sections are *not* mirrored across the body. Instead, when you need a section duplicated on each side of the craft, you’ll need to create the wing section as it should be on the right side of the craft, copy that section to a new miscellaneous wing tab, and there check the box labeled “this wing is on the *left* side,” as shown in **Figure 3.33**.



Figure 3.33: The checkbox to add a wing section on the left side of the aircraft

IV. Shaping the Tail

A typical aircraft tail is made up of a horizontal stabilizer and a vertical stabilizer. With this in mind, there are two vertical

stabilizer sections and a single horizontal stabilizer wing section available in the Wings dialog box (launched from the Standard menu). These wing sections are shaped just like a standard wing, as described in the previous section, “**Shaping the Wings.**”

If you need more wing sections than are present in the Wings dialog box, you can add more sections using the Misc Wings dialog box, as described in the section “**Adding More Wing Sections**” above.

V. Shaping the Landing Gear

The landing gear is created using the Landing Gear dialog box, which is opened from the Standard menu.

A. Setting the Gear’s Type, Size, and Position

Landing gears come in a variety of configurations, ranging from simple metal skids, to a single wheel, to groups of many wheels. Any landing gear needs to have its position on the aircraft specified, and if the gear is retractable, it must have a retracted position that is different from its extended position. The gear also must have a size—both its tire size and its strut length.

These properties of the gear are defined using the first tab of the Landing Gear dialog box, labeled Gear Loc (that is, gear location). In this tab, you can create up to ten different gears. Each gear has a column dedicated to setting its properties; **Figure 3.34** highlights a single gear’s column.

Let’s walk through the settings for each gear.

Note: If you are using a retractable gear, you will want to do two things before trying to specify the gear’s properties. First, move to the Gear Data tab of the Landing Gear dialog box and

check the box labeled “gear is retractable.” Then, close the Landing Gear dialog box and click “Show with still/moving controls,” found in the Special menu. This will animate the gear as you work on it, so you can see just how far it extends and retracts.

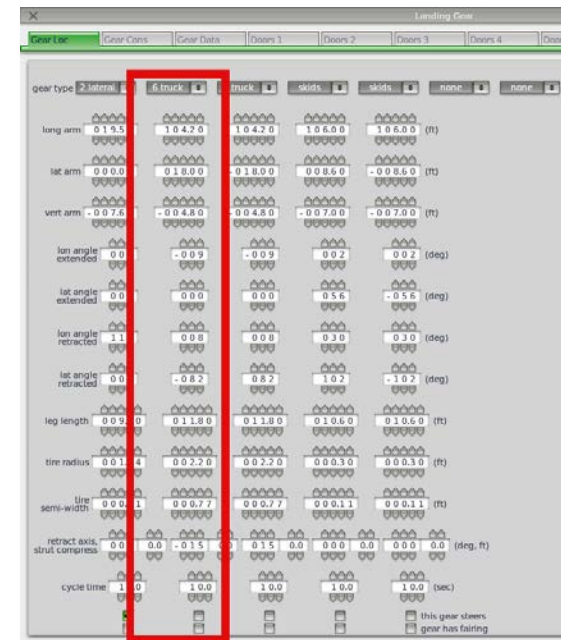


Figure 3.34: A single landing gear’s column

At the top of the Landing Gear dialog box’s Gear Loc tab is the gear type parameter. Click the drop-down button and select from a wide array of wheel (or skid) configurations. A lateral wheel configuration arranges the wheels side-by-side, while a truck configuration arranges them in rows. A “long” wheel configuration arranges them one in front of another. Finally, note that any gears you will not be using should have a type of “none” selected.

Next, beneath the gear type parameter are the three standard positional controls. These are, in order, the longitudinal arm, the lateral arm, and the vertical arm. For information on using

these position controls, see the “**Fundamental Concepts**” section at the beginning of this chapter, which discusses the reference point and its use in determining locations on the aircraft.

Following the standard position controls are the parameters determining the gear’s angle when extended and retracted. There is a “gear extended” pair of parameters, and there is a “gear retracted” pair. Each of the angles measures the gear strut’s deviation in degrees from being perfectly vertical, lined up with the reference point.

In the case of the longitudinal angles, the parameters measure how far the gear is angled to the fore of the reference point. Thus, if the gear needed to angle toward the aft of the reference point, you would use a negative number here. Positive 90 degrees will angle the gear forward and perfectly horizontal, while negative 90 degrees will angle it backward and horizontal.

In the case of the lateral angles, the parameters measure how far the gear’s strut is angled to the right of the reference point. Thus, if the gear needed to angle to the left, you would use a negative number. Positive 90 degrees will angle the gear to the right to be horizontal.

Following the gear’s extended and retracted angles is the leg length parameter. This sets the length of the strut, or the “leg” of the gear, when it is extended. (For many aircraft, the extended and retracted length will be the same; some, though, may compress the gear when retracting it.)

Next are the two parameters controlling the tire size. Each of the tires on a given gear must be the same size. The tire radius is the length from the outer edge to the center of the tire, when viewing the aircraft from the side. Don’t confuse this with the diameter, which is the length from one side to the other when crossing through the tire’s center. The tire semi-width is half the width of the tire, when viewing the aircraft

head-on. In **Figure 3.35**, the tire radius is shown in red, while its semi width is shown in blue.

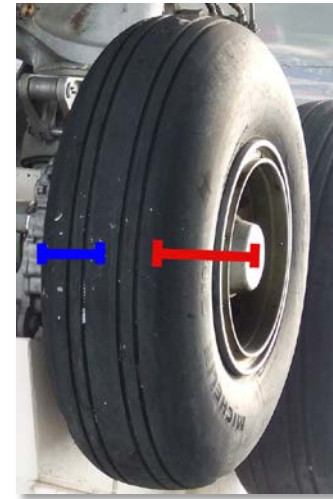


Figure 3.35: The tire radius (red) and semi width (blue); thanks to Wikimedia Commons user [Kozuch](#) for the photo.

Beneath the tire size settings are the “retract axis” and “strut compress” controls (in left to right order, respectively). The first parameter sets the amount, in degrees, that the wheel rotates around its own axis when it is retracted. Note that its axis is effectively the gear’s strut. Positive numbers here correspond to a clockwise rotation when viewed from the aircraft’s underside.

The strut compression parameter sets the amount, in feet, that the strut collapses on itself when the gear is retracted. In some aircraft, like the F-4 Phantom II, the gear compresses on itself like this to save space.

Next, beneath the retract axis and strut compression parameters is the “cycle time.” This is the time, in seconds, that it takes for the gear to go from fully extended to fully retracted, and vice versa.

Finally, at the bottom of the dialog box are two checkboxes. The first, labeled “this gear steers,” should be checked for all gears that are used to steer the aircraft. The final checkbox, labeled “gear has fairing,” should be checked if the wheels have a streamlined fairing (also known as a wheel pant or spat). These structures are used to reduce the drag the gear generates by presenting a streamlined surface for the air to interact with. For information on creating the fairings themselves, see the section later in this chapter titled **“Designing Wheel Fairings and Skids.”**

Using the parameters above, you can create a basic gear with wheels and a simple strut. If the gear is retractable, you will still need to set a few more of its properties, as described in the following section, **“Finishing Retractable Gears.”** To fine-tune a gear’s steering properties, see the section **“Customizing Wheels and Steering”** below.

B. Finishing Retractable Gears

When creating a retractable gear, you will need to specify a few properties in addition to the size, position, and type. Many of these are located in the Landing Gear dialog’s Gear Data tab.

The most important property here is the “gear is retractable” checkbox, located in the upper quarter of the dialog box, as seen in **Figure 3.36**. This must be checked for the gear to be retractable.

Directly beneath the “gear is retractable” checkbox is the “gear can retract on ground” checkbox. With this *unchecked*, the aircraft will sense that the gear is bearing the weight of the craft when it is on the ground and will thus not allow you to retract the gear. This is useful for preventing damage to the aircraft.

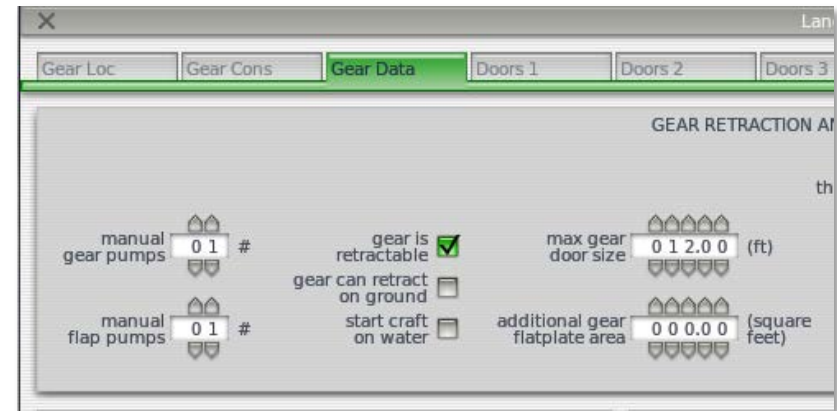


Figure 3.36: The portion of the Gear Data tab relevant to retractable gears

If you’re using an emergency gear pump in the instrument panel (used for extending the gear manually in the event of a power failure), you can use the “manual gear pumps” field to set the number of times you must “pump” the button in X-Plane for the gear to actually extend. This field is located just to the right of the “gear is retractable” checkbox, as seen in **Figure 3.36**.

To the right of the “gear is retractable” checkbox is the “max gear door size” parameter. This sets the maximum width of the gear doors in feet. The gear doors are created in the five Doors tabs up at the top of the dialog box, which we will discuss momentarily.

Beneath the max gear door size is the “additional gear flatplate area.” When the gear is extended, X-Plane will automatically add drag based on the frontal area of the struts, the wheels, and the doors in its flight model. However, any time a gear door opens up to let a wheel out, it also opens the gear wells. These wells disrupt the airflow over the craft, so you should enter the frontal area of the inside of this well here so that X-Plane can calculate the drag generated by it.

What’s left to create on the retractable gears? The gear doors,

of course! Move to one of the Doors tabs at the top of the Landing Gear dialog box to begin creating these. (It doesn't matter *which* Doors tab, though Doors 1 is a logical place to start.)

Each Doors tab contains four boxes, each box able to create one gear door. Each of the doors is created in the same way.

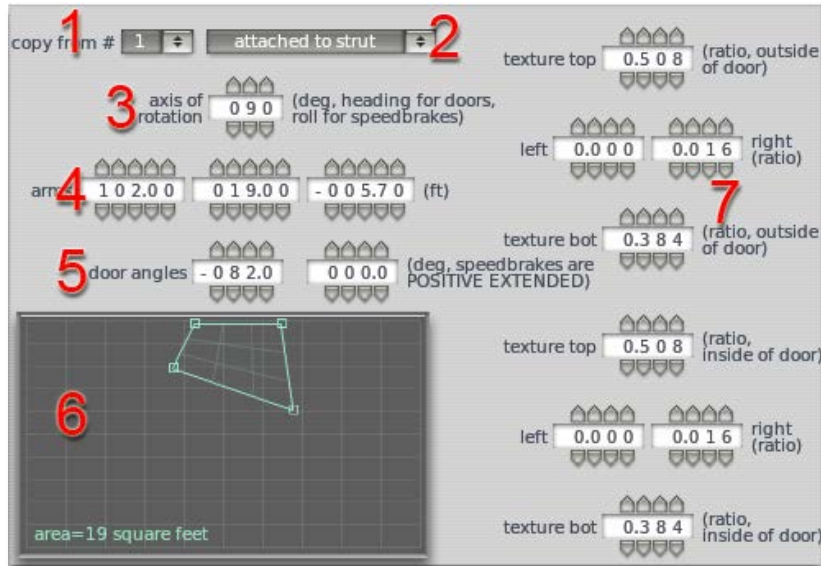


Figure 3.37: The controls to create a single gear door

At the top of the gear's box is the "copy from" drop-down menu, labeled 1 in **Figure 3.37**. To copy the geometry, location, and texture from another gear door to this one, just click the drop-down button here and click the number of the gear door you want to copy from. (Note that, for the purpose of copying, the doors are numbered beginning with 1 in the upper left of the Door 1 tab. **Figure 3.38** shows the numbering pattern; the upper left box in the Doors 2 tab is gear door number 5, and the lower right box in the Doors 3 tab is door number 12.)

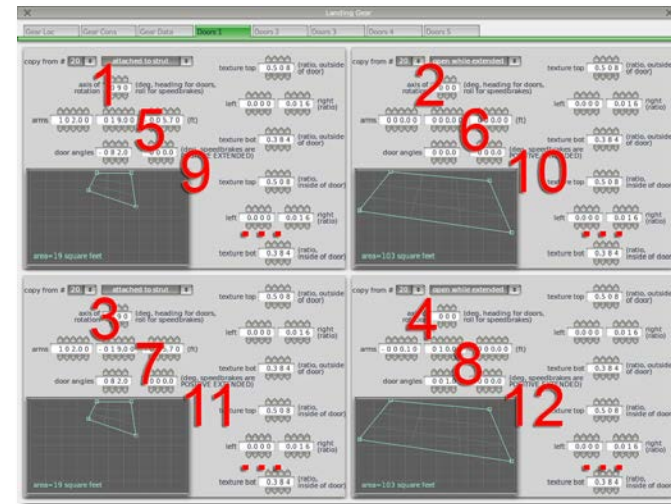


Figure 3.38: Numbering of the landing gear door boxes

If you are not copying the gear door's geometry, you must start by selecting the door's type. The drop down box labeled 2 in **Figure 3.37** selects between four different door types.

Any gear door box that you are not using should have a type of "none" set for it.

The "open while extended" door type creates a door that opens around the extending landing gear, as seen in the left half of **Figure 3.39**.

The "attached to strut" type creates a door that is stuck to the leg of the gear, as seen in the right half of **Figure 3.39**.

Finally, the "closed while extended" door type creates a gear door that closes when the gear is extended. This is useful for minimizing the drag associated with the gear well, which would otherwise be open to the air and disrupting the airflow over the craft.

After setting the door type, it makes sense to jump down to the

door geometry box, labeled 6 in **Figure 3.37**. Gear doors in X-Plane are 2-dimensional, composed of up to four points. Click away from any existing points to create a new one, and click a point and drag it to change the door's geometry.

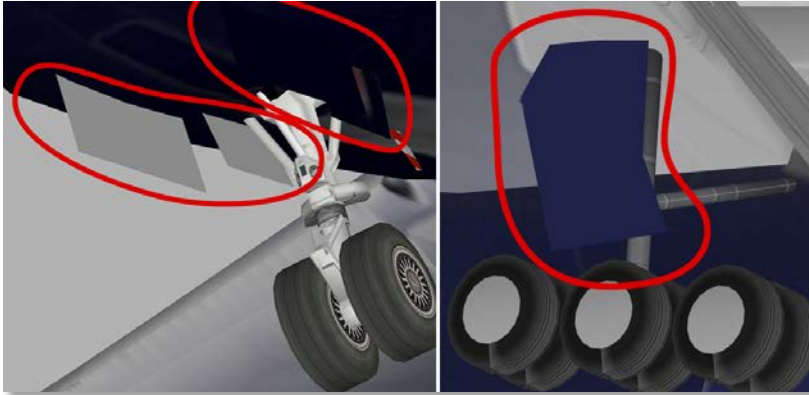


Figure 3.39: “Open while extended” gear doors on the left and an “attached to strut” gear door on the right

After creating at least a rough model of the door's shape, you can position the door on the aircraft and set its opening and closing angles.

To begin positioning the door, you can set its heading (that is, the direction the door is pointing). This is done using the axis of rotation parameter, located beneath the gear door type and labeled 3 in **Figure 3.37**. A heading of 90 degrees makes the door point straight ahead, presenting the least surface area possible in flight.

Next are the standard location controls, labeled 4 in **Figure 3.37**. These are presented here in longitudinal-lateral-vertical order, from left to right. For information on using these controls, see the section “**How Positions Are Set in Plane Maker**” at the beginning of this chapter.

Beneath the location controls are the door's open and closed angles, labeled 5 in **Figure 3.37**. The parameter on the left is

the door's angle when the gear is retracted; the one on the right is its angle when the gear is extended. Positive values here will cause the door to hinge to the right of the reference point, while negative values will cause it to hinge to the left.

The final settings in each gear door's box (labeled 7 in **Figure 3.37**) are related to its paint textures. Information on working with the paint is found in Chapter 8, in the section “**Creating a Basic Paint Job.**”

i. Gear Retraction Warnings

If a landing gear is retractable, there will often be a speed above which it is not safe to have the gear extended (the maximum landing gear extended speed, V_{le}) and a speed above which it is not safe to extend or retract the gear (the maximum landing gear operating speed, V_{lo}).

To have X-Plane play a gear warning noise if you operate the gear beyond these speeds, open the Viewpoint dialog box from the Standard menu. There, in the Default tab, check the box near the bottom-center of the screen labeled “has gear warning horn.”

C. Customizing Wheels and Steering

Using the preceding sections, you can build a landing gear with the right wheel configuration, the right position, the right retraction characteristics, even the right gear doors. What we haven't touched on yet is the steering characteristics of the gear, as well as the properties of the wheels themselves. These settings are all found in the Gear Data tab of the Landing Gear dialog box.

There are two “nosewheel steering” parameters here (the top two input boxes in **Figure 3.40**). These control how far, in degrees, the wheels responsible for steering can deflect. The

one on the left sets the maximum deflection at speeds below the transition speed, and the one on the right sets the maximum deflection above the transition speed.

If the aircraft does not use the typical nosewheel steering configuration and instead uses free caster wheels which are controlled using differential braking, set this parameter to zero. (Note that nosewheel steering is a general term for steering by moving the wheels—it applies to taildraggers that steer with the tail wheel also.)

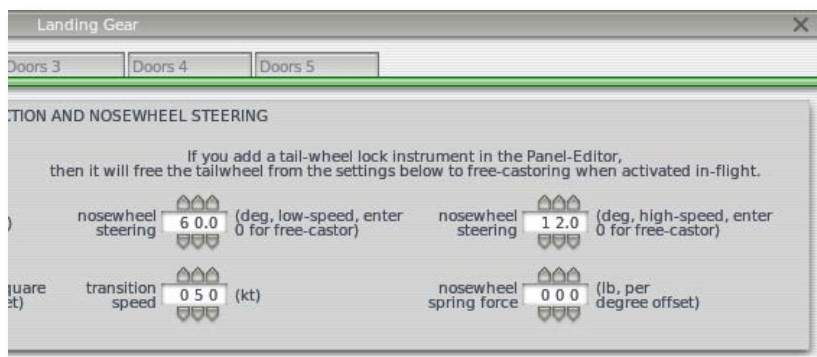


Figure 3.40: The steering and nosewheel settings

Beneath the low-speed nosewheel steering parameter is the transition speed. This is the speed in knots at which you can no longer steer using the brakes, tiller, or nosewheel steering, whichever the case may be, and must instead steer using the rudder. Above this speed, it would be unsafe to significantly deflect the steering controls.



Figure 3.41: The landing gear friction coefficients

Another important set of parameters impacting the aircraft's ground steering is the landing gear's coefficients of friction. These parameters, found in the bottom of the Gear Data tab, are shown in **Figure 3.41**. The rolling coefficient of friction (the box on the left) controls how much friction is produced by the weight of the airplane on the wheels when rolling on pavement. A value of 0.025 is typical, indicating that the drag of the wheels on the pavement is 0.025 times the weight of the aircraft when rolling. X-Plane will modify this value automatically when rolling on grass strips or off a runway.

The maximum coefficient of friction, the box on the right in **Figure 3.41**, controls the maximum amount of friction that the tires can generate, both by braking and from side loads.

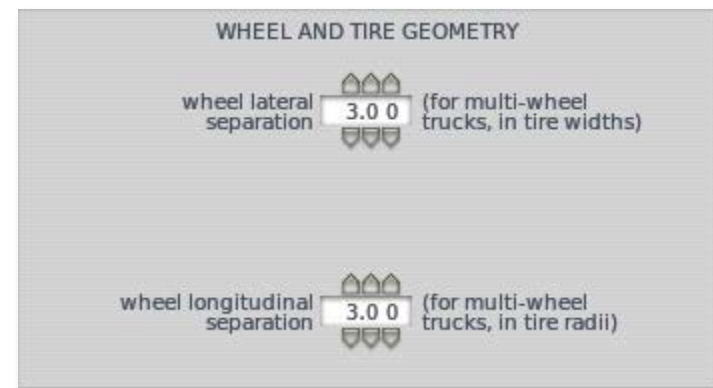


Figure 3.42: The wheel and tire geometry settings

The final gear parameters we will consider here are those controlling the wheel and tire geometry. **Figure 3.42** shows these controls, which are found in the middle of the Gear Data tab. The "wheel lateral separation" specifies the distance between wheels in a side-by-side configuration. This is measured in half-tire widths, from one tire's middle to the other's. Thus, a lateral separation ratio of 2 here puts the tires touching each other side by side.

The corresponding “wheel longitudinal separation” parameter sets the distance between wheels in an inline configuration. This is measured in tire radii (the distance from the center of the tire to its edge), from one tire’s middle to the other’s. Thus, a ratio of 2 here puts the tires touching along their edges as they rotate.

D. Designing Wheel Fairings and Skids

For each of your gears created in the Gear Loc tab of the Landing Gear dialog box, you can choose to add a streamlined fairing. Sometimes known as a wheel pant or spat, a fairing is designed to reduce the drag generated by a landing gear by presenting a streamlined surface for the air to interact with.

Before actually designing your fairings, you must tell Plane Maker which gears have them. This is done using the checkboxes in the bottom of the Gear Loc tab, as described in the section “**Setting the Gear’s Type, Size, and Position.**”

With at least one fairing specified in the Landing Gear dialog box, open the Wheel Fairings/Skids dialog boxes from the Standard menu. Each fairing you specified has its own tab here at the top of the dialog box. With one possible fairing per gear, and ten possible gears, that makes for a total of ten fairing tabs at the top of the dialog box.

Fairings are modeled just like the fuselage and the miscellaneous bodies; there is a Section, Top/Bottom, and Front/Back tab for each fairing. See the “**Shaping the Fuselage**” for information on using these tabs.

VI. Adding Other Surfaces and Bodies

In the previous sections, we’ve talked about creating a fuselage, a tail, wings, and a landing gear. What about everything else?

Some extra bodies have their own special dialog boxes for modeling. These include engine pylons, engine nacelles, weapons, and slung loads. All other extra bodies, like external fuel tanks, get no such special dialog boxes; instead, they are modeled in the Miscellaneous Bodies dialog box, described in the section “**Adding Other Bodies to the Fuselage.**”

For information on adding weapons and slung loads to an aircraft, see the section “**Creating and Adding Weapons**” in Chapter 7.

For information on engine pylons and engine nacelles, read on to the following sections of the manual.

A. Adding Engine Nacelles

An engine in X-Plane is primarily a point from which thrust is generated: propellers are no more than spinning, thrust-producing blades, jet engines are no more than points from which thrust is produced, and so on. To create the body of the engine (like the tip of the propeller or the body of a jet engine), you must add an engine nacelle. **Figure 3.43** shows the parts of a propeller and a jet engine which would be modeled as nacelles in Plane Maker. Like every surface in X-Plane, these nacelles will have both visual and aerodynamic consequences. Note that it only really makes sense to create the nacelles *after* you have created the engines themselves, as described in the section “**Creating the Engines**” of Chapter 4.

The Engine Nacelles dialog box is used to model these bodies. Bodies here are created just like the fuselage and the miscellaneous bodies; for more information, see the sections “**Shaping the Fuselage**” and “**Adding Other Bodies to the Fuselage**” previously in this chapter.



Figure 3.43: Parts of the engines modeled as nacelles (thanks to Wikimedia Commons user [Delatorre](#) for the jet engine photo)

There are eight tabs at the top of this dialog box, corresponding to the maximum of eight engines you can specify in the Engine Specs dialog box. For each engine you want to build a nacelle on, check the box at the top of the tab reading “aircraft has a nacelle over this engine,” as seen in **Figure 3.44**. This box cannot be checked for engines the aircraft does not have. For instance, if the aircraft has two engines, the third tab at the top of this dialog box cannot have its “aircraft has a nacelle over this engine” box checked.

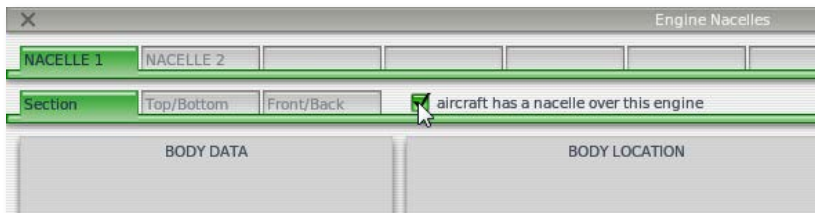


Figure 3.44: The “aircraft has a nacelle over this engine” checkbox

Note that *unlike* in the creation of the fuselage and miscellaneous bodies, each station’s distance behind the

reference point (found in each nacelle’s Section tab, above the white gridded box used to create the sections) are set *relative to the engine itself*—not relative to the aircraft’s reference point. This makes sense; the nacelles are attached to a particular engine, not to the aircraft as a whole.

Figure 3.45 shows a wireframe view of a nacelle, side-by-side with its skinned counterpart. Note the large black dot on the left side of the nacelle in the wireframe view. This is the position specified for the engine itself; it is the “center of thrust” for the engine. This point serves as the reference point for this nacelle.

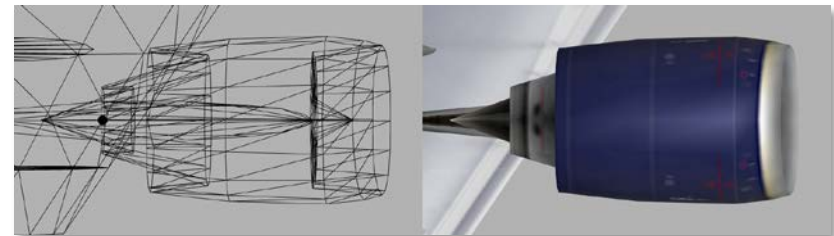


Figure 3.45: An engine nacelle, seen both in wireframe and textured views

B. Adding Engine Pylons

Engine pylons—the hardpoints of an aircraft designed to have engines mounted to them—are modeled using the Engine Pylons dialog box, launched from the Standard menu. (Note that it only really makes sense to create the pylons *after* you have created the engines themselves, as described in the section “**Creating the Engines**” of Chapter 4.)

Modeling a pylon is very similar to modeling a wing—a pylon just ends up being a short, stubby, oddly shaped wing, which might itself be attached to a real wing. In light of this, the controls found in the Engine Pylons dialog box are identical to those in the Wings dialog box, with a couple exceptions. For information on using the standard wing controls, see the

section “Shaping the Wings” above.



Figure 3.46: An Airbus A380's engine pylon (thanks to Wikimedia Commons user [David.Monniaux](#) for the photo)

The most important thing to note is that *unlike* in the creation of a wing, each pylon is place with respect to the engine to which it is (assumedly) attached—it is *not* placed relative to the aircraft's reference point. Since engines in Plane Maker are just points from which thrust is generated, this works well.

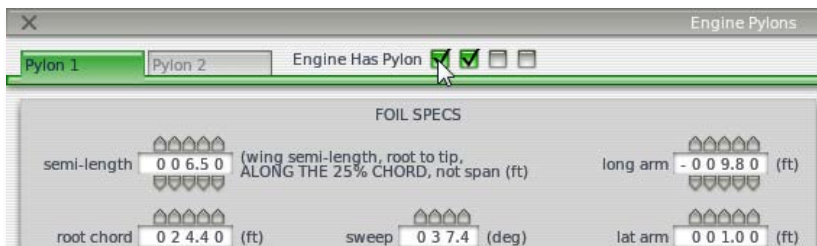


Figure 3.47: The “engine has pylon” checkbox

Up to two pylon designs can be created for each aircraft. To apply a pylon design to a certain engine, check the box corresponding to that engine at the top of that pylon's tab, as seen in **Figure 3.47**. These engines are numbered as they are in the Engine Specs dialog box; the engine on the far left in the Location tab of that dialog box corresponds to the checkbox on the far left here, and so on.

VII. Setting the Location of the Tow Hook, Winching Hooks, Boarding Door, and Refueling Port

A few miscellaneous features of the aircraft's body are set up using the Viewpoint dialog box, launched from the Standard menu. In the Viewpoint dialog box's Default tab, the position of the aircraft's tow hook, winching hook, refueling port, and boarding door can be specified using standard position controls, as described in the “**Fundamental Concepts**” section at the beginning of this chapter.

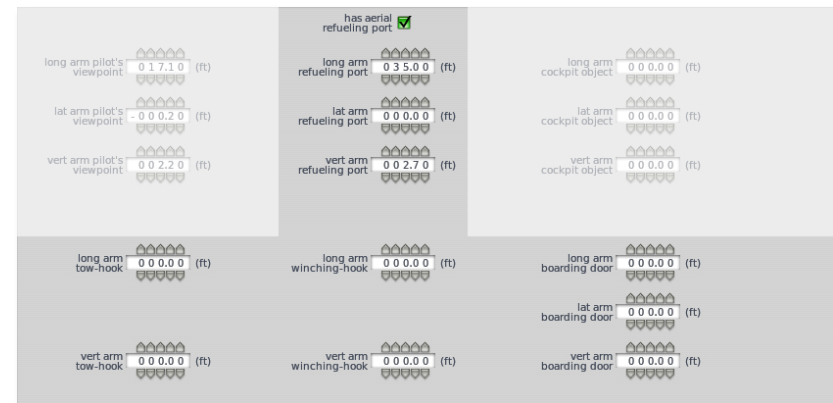


Figure 3.48: The refueling port, tow hook, winching hook, and boarding door settings in the Default tab of the Viewport dialog box

The position of these features of the body will only be visible when using the wireframe view (toggled using the spacebar). There, they will be represented as large black dots, just like the point representing the aircraft's center of gravity.

Note that both the winching hook and the tow hook must be centered laterally along the aircraft's body, so they do not have a "lat arm" parameter.

4. Working with the Aircraft's Systems

An aircraft's systems include electrical, hydraulic, fuel, avionics, flight control, and propulsion sub-systems. In addition to influencing the flight model as appropriate, these systems can be set to fail in X-Plane, allowing pilots to practice dealing with contingencies.

I. Creating the Engines

The aircraft's engine, along with any related propellers, thrusters, and so on constitute its propulsion sub-system.

To begin creating an aircraft's engine, open the Standard menu and click Engine Specs. The Location tab of the Engine Specs dialog box is the best place to start. There, you can set the number, type, location, and other properties of both the engines and propellers. The parameters available here will vary depending on what type of engine(s) you choose.

To begin, set the number of engines present on the aircraft using the box at the top of the dialog box. A number of columns will appear, one for each engine you specified. Use the drop down menu at the top of each column to set the type of each engine. The engine type will determine what further parameters are available for the engines. It will also affect, among other things, the sounds produced by the engine and the fuel flow it draws.

The following types of engines are available here:

- carb recip—an internal combustion, reciprocating (piston) engine used to drive a propeller. It uses a carburetor to mix air with fuel at low pressure.
- injected recip— an internal combustion, reciprocating (piston) engine used to drive a propeller. It uses a fuel injector to mix air with fuel at high pressure. Fuel-

injected engines are for more common today than carbureted ones, due partly to their increased reliability.

- turboprop (free)—an internal combustion, gas turbine engine used to drive a propeller. Gas turbines are more reliable than reciprocating engines. A free turboprop engine is one whose power turbine is not geared to the gas turbine's compressor, allowing the propeller to operate independent of the compressor speed. This is the most common turboprop design.
- turboprop (fixed) —an internal combustion, gas turbine engine used to drive a propeller whose power turbine is geared to the compressor.
- electric—an engine that draws electrical power from fuel cells, solar panels, or the like and uses it to drive a propeller.
- low bypass jet—an internal combustion, gas turbine engine with a low ratio of air coming into the engine and bypassing the engine core compared to the amount of air passing through the core. Low-bypass turbofans are, in general, more fuel efficient than turbojets but less efficient than high-bypass turbofans. Low-bypass turbofans are often used in jet fighters in conjunction with an afterburner.
- high bypass jet—an internal combustion, gas turbine engine which has a high ratio of air coming into the engine and bypassing the engine core compared to the amount of air passing through the core. High-bypass turbofans are more fuel efficient than low-bypass ones, but generally have a lower top speed and greater weight.
- rocket—a reaction engine which harnesses the acceleration of mass shooting out of its exhaust nozzle as propulsion.
- tip rocket—a rocket engine typically attached to the tip of a helicopter's rotors, used to turn the rotors without the use of a tail rotor.

The following steps to set up an aircraft's engines will depend in large part on which engine type(s) you selected. There are,

however, a few features that all engine types have in common.

A. Features Shared by All Engine Types

Regardless of the engine type selected in the Location tab, a few characteristics of the engine must be set. These include the engine's location, its fuel consumption properties, and the altitudes at which it performs best.

i. Location

All engine types must have a position specified in the Location tab. This is done using the standard position controls (as described in the section “**Fundamental Concepts**” of Chapter 3), plus a vertical and side cant. Positive values for the vertical cant will cause the engine to point upward. Positive values for the side cant will cause the engine to angle right (clockwise) when viewing the aircraft from above.

All engine types also have the option to be vectored, using the checkbox beneath the side cant parameter.

ii. Throttle Settings

In addition to their location, all engines must have a few characteristics of their throttle set. These are found the Description tab of the Engine Specs dialog box, in the General Engine Specs box there. **Figure 4.1** shows the parameters relevant to most engine types.

The first of these are the maximum forward and maximum reverse throttle. These control the maximum throttle available in X-Plane with all engines operative (at sea level in standard atmosphere). This can, among other things, be used to fine-tune an engine's performance to match measured performance in the real world. It is not uncommon to use a

maximum throttle of, say, 0.80 in order to match an engine's real-world performance, as manufacturers will often keep an engine within 75 or 80% of the nominal power to ensure safe, reliable performance. Allowing over 100% power also makes sense when leaving some reserve power for emergency operations.

Note that all engine specifications in Plane Maker are set with respect to full throttle. Thus, if you move the maximum throttle away from 1.00, the engine characteristics set throughout Plane Maker will not match the performance in X-Plane. This isn't necessarily a problem, but you should keep it in mind.

GENERAL ENGINE SPECS	
max forwards throttle	1.00
max reverse throttle	0.50
max emergency throttle	1.00
lo idle adjust	1.00
hi idle adjust	1.00
go to BETA below this throttle setting	0.00 (ratio)
go to REVERSE below this throttle setting	0.00 (ratio)
turbine (free-turbine and jet) spoolup time	0.10 (sec)

Figure 4.1: Throttle settings in the Description tab's General Engine Specs box

For engines that cannot be set in reverse, the maximum reverse throttle will be zero.

Beneath the “max forwards” and “max reverse throttle”

parameters is the maximum emergency throttle, which sets the maximum throttle available when an engine failure has occurred.

Next are the low and high idle adjustment boxes. Plane Maker will automatically estimate where the engine idles, both in a low-idle situation and a high-idle one. Use this box to change the idle speed, as a ratio of the default Plane Maker estimate.

Beneath the idle adjustments is the “go to Beta below this throttle setting” box. In engines that feature reverse thrust, the Beta range serves to maintain a constant RPM while varying the blade pitch, allowing finer control of the aircraft's speed while on the ground. Use this parameter box to set the ratio of the joystick's throttle at which to switch into Beta conditions. For instance, if you wanted to go to Beta when the joystick was at 25% of its throttle range, you would set this box to 0.25.

Beneath the “go to Beta” box is the “go to reverse thrust below this throttle setting.” In engines capable of it, reverse thrust pushes the aircraft backward—quite useful when trying to land a large aircraft in a short distance. Just like the corresponding Beta parameter above, this is set as a ratio of the joystick's throttle. Both Beta and reverse modes are virtually ubiquitous in both turboprops and jet engines. Likewise, they are uncommon in reciprocating engines.

The final setting in the Description tab which may be applicable to both propeller-driving and jet engines is the “turbine spool-up time,” seen in the bottom of **Figure 4.1**. This number is determined by the amount of inertia the engine has, and is applicable only to turbine engines, such as turboprops and jets. It is a measure of how long it takes the low-pressure compressor (N_1) to speed up to its maximum when the throttle is brought instantly from idle to full. In X-Plane, the actual spool-up time will be affected by atmospheric conditions, the weight of the propeller (if applicable), and the time it takes the pilot to advance the throttle.

iii. Critical Altitude and FADEC Characteristics

Without modification, most engines put out less power the higher they go. The thinner air at high altitudes simply provides less oxygen to burn. Because of this, most aircraft have a critical altitude—a height above sea level above which they can no longer produce full power. At altitudes below this, full power is still available. **Figure 4.2** shows the Critical Altitude box, found at the top of the Engine Specs dialog box's Description tab. In that box, the “critical altitude” setting is specified in feet above mean sea level.

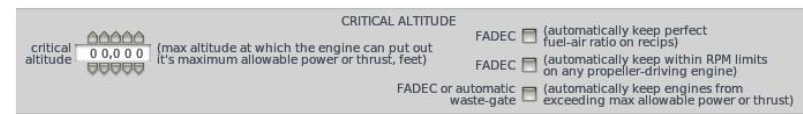


Figure 4.2: The Critical Altitude box in the Description tab of the Engine Specs dialog box

To the right of the critical altitude parameter box are three checkboxes for adding a FADEC, a **F**ull **A**uthority **D**igital **E**ngine **C**ontrol. A FADEC system is designed to control all aspects of the engine's performance. One advantage to having a FADEC is that, on reciprocating engines, it can maintain the perfect fuel-to-air ratio, allowing for greater performance and cleaner exhaust. The FADEC can also keep a propeller-driving engine within its safe RPM limits, as the second checkbox down in **Figure 4.2** notes. Finally, a FADEC can keep the engine from exceeding the maximum allowable thrust, as the final checkbox in **Figure 4.2** notes. This can also be done by the automatic wastegate in a turbocharger—in this case, the same box should be checked.

iv. Boost Characteristics

All combustion engines (both jet and reciprocating) can have a boost applied to them. This can come in two forms: an anti-detonant, or a nitrous oxide (N_2O) boost. When an anti-

detonant is injected into an engine, the engine's combustion chamber is cooled, increasing the density of the gases in the engine and increasing the engine's compression ratio. It also serves to cool the engine, allowing it to run at a higher RPM than it otherwise would be able to. Nitrous oxide, on the other hand, decomposes quickly when it is injected into an engine. When it does, it increases the amount of oxygen available during combustion. Like an anti-detonant, the vaporization of N_2O also cools the engine.

To tell Plane Maker that your aircraft has a boost, go to the Engine Specs dialog box's Description tab. There, in the bottom right of the box labeled "Prop Engine Specs," are the two parameters for boost. Note that, although these are found in the Prop Engine Specs box, they apply to all engines in X-Plane.

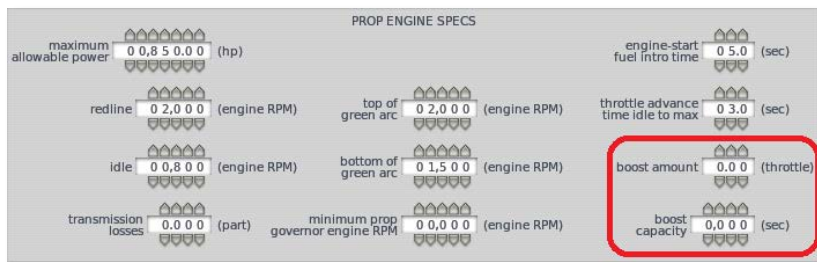


Figure 4.3: The boost settings, found in the Description tab of the Engine Specs dialog box

X-Plane will not differentiate between the source of your boost, whether anti-detonant or nitrous oxide. Instead, it just needs to know how much of a boost your method gives. Set the "boost amount" box to the amount of boost you get from the engine, as a ratio to the normal, non-boosted engine's performance. Thus, if your nitrous oxide system increased the power of your engine by 50%, you would set the "boost amount" parameter to 0.50.

Next, set the "boost capacity" box to the length of time, in seconds, that you can use your boost before it runs out.

To use the boost in X-Plane, simply push the throttle to its the maximum; the boost will automatically kick in.

v. Specific Fuel Consumption

After setting up the basic characteristics of a propeller or jet engine, you can set the engine's specific fuel consumption. One box in the SFC/Sound tab (which is itself found in the Engine Specs dialog box) is labeled "Reciprocating or Turboprop Specific Fuel Consumption," as seen in **Figure 4.4**. Another is labeled "Jet Engine Specific Fuel Consumption." These boxes are identical except for the types of engines they affect.

Using these boxes, you can define the engines' specific fuel consumption (SFC)—that is, the amount of fuel burned per hour per engine horsepower. This should be set for two altitudes, one low and one high, and each altitude should have a half-power and full power SFC.

For propeller-driving engines, the measurement used here is the brake specific fuel consumption (BSFC), entered in the "Reciprocating or Turboprop" box. This is calculated as fuel flow divided by horsepower (as measured at the engine's output shaft, before any transmission losses occur).

For jet engines, the thrust specific fuel consumption (TSFC) is used, and it is entered in the "Jet Engine" box. TSFC is calculated as fuel flow divided by thrust.

In most cases, the "lo altitude for prop engines" (the low altitude at which you'll specify the SFC) is zero feet above mean sea level. The "hi altitude for prop engines" may be your cruise altitude, but it doesn't have to be. Both these controls are found in the left half of the Reciprocating or Turboprop SFC box.

RECIPROCATING OR TURBOPROP SPECIFIC FUEL CONSUMPTION

lo altitude for prop engines 0 0,0 0 0 (ft)	lo altitude half power SFC 0 0.4 0 0 (/hr)
	lo altitude max power SFC 0 0.4 0 0 (/hr)
hi altitude for prop engines 1 0,0 0 0 (ft)	hi altitude half power SFC 0 0.4 0 0 (/hr)
	hi altitude max power SFC 0 0.4 0 0 (/hr)
idle FF 0.2 5 (ratio to max)	

Figure 4.4: The reciprocating or turboprop specific fuel consumption

In the right half of each box, the “half power SFC” for each altitude should be set to the specific fuel consumption in pounds of fuel per hour per horsepower of the engine *when the engine is at half power*. For instance, if a given engine burned 100 pounds of fuel per hour, and it had a 200 horsepower engine, it would burn 0.5 pounds per hour per horsepower. If that was the fuel consumption at your low altitude at half power, you would enter 0.500 in the “lo altitude half power SFC” box.

The “max power SFC” box works the same, but it specifies the fuel consumption at full power for each altitude.

Finally, in the bottom of the SFC box is the engine’s fuel flow at idle, as a ratio of the aircraft’s maximum fuel flow. If your aircraft used 0.1 times the fuel at idle as it does at full power, you would enter 0.10 here.

Note that specific fuel consumption in rocket engines is much simpler than in combustion engines; the SFC parameter found in the bottom right of the Engine Specs dialog box’s Description tab applies at all altitudes, at all power settings, for rockets. It defines the pounds of fuel burned per hour for each pound of the engine’s thrust. Note also that the specific fuel consumption is the *inverse* of the engine’s specific impulse (I_{sp}), the number usually discussed in relation to a rocket’s fuel consumption.

B. Working with Engines That Turn Propellers

Both of the reciprocating engines, as well as the turboprop, electric, and tip rocket engines all are used to turn propellers (or rotors, as the case may be). In this case, you must specify the number of propellers and their features using the Location tab of the Engine Specs dialog box.

Near the top of the dialog box, right beneath the engine number and type settings, are the settings for the number and type of propellers. In nearly all cases, there will be one propeller per engine.

The following types of propellers are available in Plane Maker:

- fixed—a propeller whose angle of attack (or blade pitch) is fixed.
- constant RPM—often referred to as a “constant speed” or “variable pitch” propeller, this propeller will change the blades’ pitch in order to generate greater thrust while keeping a constant number of revolutions **per minute** (RPM).
- manual pitch—a propeller whose pitch is adjusted manually by the pilot.
- main rotor—a large, overhead rotor used in helicopters, held roughly parallel to the ground, which varies its thrust to maintain a constant RPM.
- constant tip Mach—a propeller which adjusts its speed so that its tips always move at a constant Mach

number, usually resulting in a more efficient flight than constant RPM propellers.

- tail rotor—a smaller rotor used in helicopters, held roughly perpendicular to the ground.
- lift fan—a downward-facing fan, such as is used in the F-35 Lightning II to facilitate vertical takeoff and landing.
- VTOL cyclic—a large rotor in the style of a standard helicopter rotor. It varies its power in order to maintain constant RPM, but it can also change the direction of its thrust in order to facilitate vertical takeoff and landing.

Each propeller you specified will have its own column of settings, just like each engine does; the propeller settings will be integrated to the engine settings columns.



Figure 4.5: Some basic propeller settings

Beneath the propeller number and type settings is the “number of blades” control, as seen in **Figure 4.5**. This number can be set independently for each propeller. Immediately to the right of the number of blades is the direction of spin, also in **Figure 4.5**. This is set either to clockwise (CW) or counterclockwise (CCW), as seen when looking at the aircraft from behind.

To the right of the blade direction setting are three checkboxes, seen in **Figure 4.5**. The “engine clutched” and “prop clutched” boxes are used with helicopters and autogyros, respectively.

The final checkbox in **Figure 4.5**, labeled “prop ducted,” is used with ducted fans—propellers mounted inside a cylindrical shroud. Ducted fans are also found in Fenestron tail rotors and lift fans ([as in the F-35B](#)). A very straightforward ducted fan is

found in the Martin Jetpack, as in **Figure 4.6**.



Figure 4.6: The Martin Jetpack, with its ducted fans (thanks to Flickr user [martinjetpack](#) for the photo)

Beneath the engine's location controls are the propeller settings, as seen in **Figure 4.7**.

The first of the propeller specifications, the prop radius, sets the distance in feet from the center of the propeller to the tip of one of its blades.

Beneath the prop radius are the settings for the propeller's width. The “root chord” parameter (the left one of the pair) sets the width of the propeller in inches at its base, where it meets the aircraft body. The tip chord, likewise, is the width in inches at the propeller's tip, where it is farthest from its mounting place on the aircraft.

The minimum and maximum pitch set the range, in degrees, over which the blade can change its angle of attack (pitch). This angle is measured at the propeller's tip. Constant-RPM and manual pitch propellers, among other propeller types, vary their blade pitch to achieve a desired thrust at a constant rotational speed. Set the minimum pitch using the box on the left and the maximum using the one on the right. Typically, the minimum pitch is zero degrees, meaning the blades are “flat” against the wind they are moving into.

Figure 4.7: The propeller specifications, found in the bottom of the Location tab

Beneath the pitch parameters is the “design RPM” parameter. This sets the speed, in revolutions per minute, that the propeller is optimized for.

Next are the “design spd acf, prop” settings. The first (on the left) is the speed of the air, in knots, that the propeller is optimized to have passing through it. For airplanes, this is approximately equal to the forward speed of the plane that you

want to optimize for plus half the propwash. For helicopters, it should be the half the propwash only, since a helicopter’s forward speed is only a small component of the airflow into the rotor from above.

The second parameter, the design speed of the propeller, is the maximum airspeed, in knots, of the propeller at its tip. If the propeller would otherwise exceed this speed, X-Plane will sweep it back in order to stay at or below this speed. For propellers that should not be swept back, simply enter a very large number here.

Based on the radius, design RPM, and design speed of the propeller, Plane Maker will automatically calculate an angle of attack for the length of the propeller. To modify this angle of attack, see the section “**Customizing the Propeller**” below.

The final setting for propellers in the Location tab is the engine-to-gear ratio, found at the bottom of the dialog box. This is the number of times the engine rotates for each rotation of the propeller. This is most commonly set to 1.000: for each rotation of the engine, the propeller rotates once.

i. Setting the Engine Details

After setting the engine’s location and the basic features of its propeller, you can set the details of its engine performance, such as its horsepower and the RPM for various modes.

Most of these details for a propeller-driving engine are set in the box labeled “Prop Engine Specs,” located in the Engine Specs dialog box’s Description tab and shown in **Figure 4.8**. Other engine details, like the maximum throttle and the critical altitude, are common to all engine types, and are described in the section “**Features Shared by All Engine Types**” above.

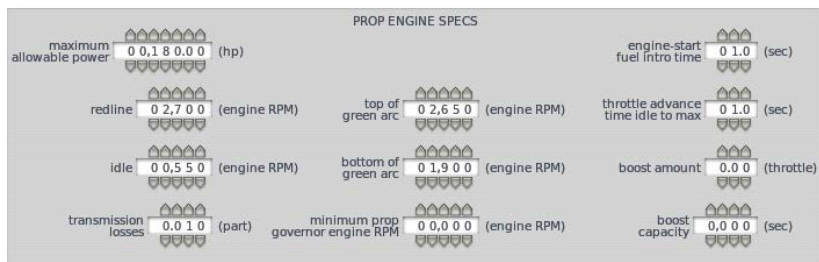


Figure 4.8: The Prop Engine Specs box, found in the Description tab of the Engine Specs dialog box

In the upper left of this box is the engine's maximum allowable power. This is the maximum horsepower output at sea level with standard atmosphere.

Beneath the "maximum allowable power" control are the RPM values at which the engine redlines and idles. The redline RPM sets the maximum allowable rotations per minute for the engine, and the idle RPM sets the speed at which the engine turns when the throttle is set to zero. Reciprocating engines typically redline between 2,000 and 3,000 RPM.

Beneath the redline and idle RPMs is the "transmission losses" parameter. All aircraft lose some power in the transference of energy from the engine to the actual turning of the propeller; this is power lost to the transmission. The "transmission losses" box sets this loss as a ratio to the full power coming from the engine. Thus, a value of 1.000 here would mean that 100% of the power from the engine is lost in the transmission. Airplanes typically have losses between 0.00 and 0.02.

Note that the "transmission losses" value should include all drags on the engine, including any generators, belts, chain drives, etc. which take away from the engine's output.

The center column of the Prop Engine Specs box has three boxes, corresponding to three different engine RPM limits. The top box, "top of green arc," sets the maximum engine RPM that can be set using the prop control in X-Plane—the

maximum RPM seen under normal operation. This should probably be close to the engine redline RPM set to the left.

Beneath the "top of green arc" box is the "bottom of green arc" parameter. This sets the minimum engine RPM that can be set using the prop control in X-Plane.

The final RPM limit here is the "minimum prop governor engine RPM," found at the bottom of the center column of values. This parameter sets the lowest RPM that can be obtained in X-Plane by pulling the prop control back. This does not take into account reverse, Beta, or feathered modes. For these, you will simply set the propeller pitch using the controls in the bottom of the General Engine Specs box to the left and X-Plane will automatically calculate an appropriate RPM. (For information on setting these pitches, see the section "**Customizing the Propeller**" below.)

In the column to the right of the engine RPM limits are a few miscellaneous settings. The top one, "engine-start fuel intro time" sets the time (in seconds) it takes fuel introduction to go from zero fuel flowing into the engines to the idle amount during the engine's start process.

Beneath the "fuel intro time" is the "throttle advance time idle to max" parameter. This sets the time in seconds that it takes the engine to go from idle to full torque if the throttle is commanded instantly from idle to full. For turboprops, this is the amount of time it takes the low-pressure compressor (N_1) to bring in torque when the throttle is brought to its maximum.

Note that the final settings in the Prop Engine Specs box, both of which deal with the boost, are described in the section "**Boost Characteristics**" above.

ii. Customizing the Propeller

The propeller is initially created in the Location tab of the

Engine Specs dialog box. As discussed in the section “**Working with Engines That Turn Propellers**” above, the Location tab specifies the propeller’s size, pitch, and design RPM. In many aircraft, though, there is much more to the propeller than that.

In the far left of the Description tab in the Engine Specs dialog is a box labeled General Engine Specs. The top half of the box deals with the throttle settings of many or all types of engines, and is thus described in the section “**Throttle Settings**” above. The bottom half, however, is all about propellers.

feathered pitch of prop	7 9.0	(deg)
beta pitch of prop	- 1 0.0	(deg)
reverse pitch of prop	- 2 0.0	(deg)
prop mass ratio	1.0 0	(compared to solid aluminum)
tip weights on ROTORS	0.0 0 0	(pounds, each)
tip mach at 100% power	0.0 0	(for constant-mach props)
tip mach at 50% power	0.0 0	(for constant-mach props)

Figure 4.9: The bottom half of the General Engine Specs box

The first characteristic of a propeller that can be set is the feathered pitch of the prop, as seen at the top of **Figure 4.9**. This sets the pitch of the propeller, in degrees, when it is

feathered. A featherable propeller is one whose blades can be rotated to be parallel to the air flowing over them. In the case of engine failure, feathering a propeller reduces the drag it generates by a huge amount. For instance, **Figure 4.10** shows a C-130 Hercules with the blades of its propellers angled to attack the wind with as small a profile as possible; its propellers are feathered.



Figure 4.10: A C-130 Hercules with its propellers feathered

Beneath the feathered pitch of the propeller is its Beta pitch, seen in **Figure 4.9**. This sets the pitch of the propeller, in degrees, when it is in its Beta range. In engines that feature it, the Beta range serves to maintain a constant RPM while varying the blade pitch, allowing finer control of the aircraft’s speed while on the ground.

Next in **Figure 4.9** is the “reverse pitch of prop” setting. Like the previous parameters, this defines the pitch of the propeller, in degrees, when it is in reverse-thrust mode.

The “propeller mass ratio” parameter determines the density of the propeller, which affects how easily the propeller speeds up and slows down. This is set as a ratio to the density of solid aluminum. Aluminum has a density of 2700 kg per cubic meter, so if your propeller had a density of, say, 1000 kg/m³, you would set this to $1000 / 2700 = 0.37$.

The next parameter down in **Figure 4.9**, “tip weights on rotors,” is used in helicopters and VTOLs only.

The final two parameters in the General Engine Specs box are for constant-Mach propellers. These set the speed of the propeller’s tip at full and half throttle, respectively, as a ratio of the speed of sound. X-Plane will automatically interpolate between these values at other throttle settings.

At this point, most of the characteristics of the propeller have been set, from its pitch settings to its weight. What we have not yet discussed is fine-tuning the shape of the propeller. For instance, in our discussion of the Location tab, we set the width of the propeller at its root and tip, and we set the length of the propeller’s blades. What about the width of all the points in between? We also have not touched on the twist of the propeller, the angle of incidence for each “slice” of the propeller.

Each of these shape settings is controlled by the Propeller tab of the Engine Specs dialog box, as shown in **Figure 4.11**.

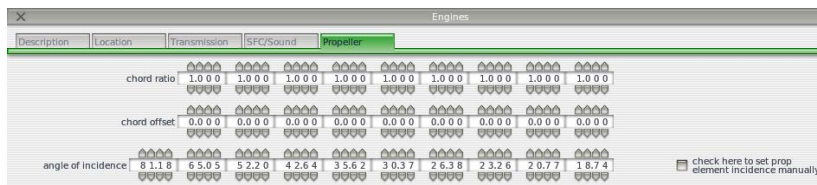


Figure 4.11: The Propeller tab of the Engine Specs dialog box

Each blade of the propeller is broken into nine pieces, and

each piece has three parameters that can be set. These parameters are the chord ratio, chord offset, and angle of incidence, as seen in **Figure 4.12**.

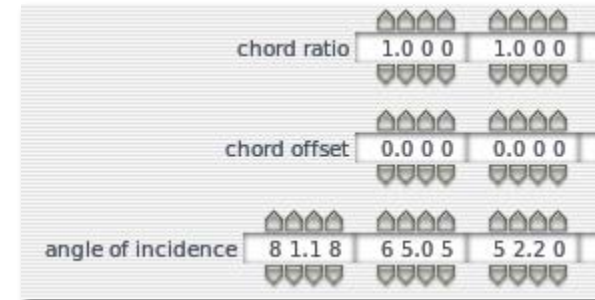


Figure 4.12: The three settings for each slice of the propeller

The “chord ratio” parameter controls the width of each slice of the propeller. This is set as a ratio of the default width of each chord, which Plane Maker finds by linearly interpolating between the root and tip width.

The “chord offset” parameter sets the amount up or down that the center of each propeller piece is shifted. This is set as a ratio of the chord width. For instance, if a certain section of the propeller needed to be shifted in the opposite direction from the way the propeller turns by one-tenth the width of the propeller at that point, you would set that piece’s chord offset to 0.100.

The last option available in the Propeller tab is the angle of incidence for each piece. By default, Plane Maker will calculate an appropriate angle of incidence based on the radius, design RPM, and design speed of the propeller. To modify the angle of incidence, first check the box labeled “check here to set prop element incidence manually.”

The final element of the propeller’s shape which we have yet to set is its cross-sectional shape (the airfoil it uses). To define this, open the Airfoils dialog from the Expert menu. The first tab at the top of the dialog box, labeled Props, is used for the

propeller's airfoils. For information on using the controls in the Airfoils dialog box, see the section “**Setting a Wing's Airfoils**” in Chapter 3.

iii. Setting Up Solar Cells

If solar cells on the wings are to be used (in part or in whole) to power an electric engine, the two solar power settings in the SFC/Sound tab must be set appropriately. Shown in **Figure 4.13**, these are the solar cell coverage on the wing, as a ratio of the whole wing area, and the solar cell efficiency, as a ratio of perfect efficiency.

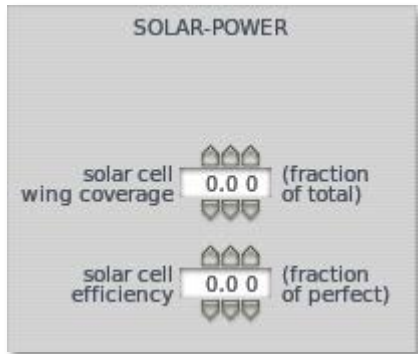


Figure 4.13: The solar panel settings

Most solar cells have an efficiency between 5% and 20% (a ratio to perfect efficiency of between 0.05 and 0.20). At noon, the sun puts out about 1400 watts of power per square meter in space, which is reduced to about 1000 watts per square meter at sea level. A good guess for middling altitudes is 1100 watts from the sun. The equation to find the power in watts available from the solar cells is:

$$\text{Wings surface area} \times \text{Solar cell coverage} \times \text{Solar cell efficiency} \times \text{Power coming from the sun}$$

Divide this number by 760 to convert the power in watts to horsepower.

C. Working with Jet Engines

Jet engines are much simpler to set up in Plane Maker than propeller-driving engines. Use the Location tab of the Engine Specs dialog box to set the position of the center of the engine's thrust (as described in the section “**Features Shared by All Engine Types**” above). For a jet engine, this center of thrust is usually the exhaust. Check the “vectors” box in that tab if the engine will vector.

After setting the engine's location, you can set the details of its performance, such as its thrust characteristics and N_1 speed, using the Engine Specs dialog's Description tab.

The Description tab's “Jet Engine Specs” box, seen in **Figure 4.14**, controls the relevant parameters here.

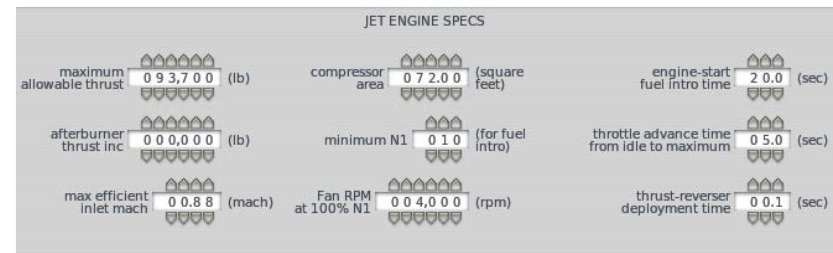


Figure 4.14: The Description tab's Jet Engine Specs box

The parameter in the upper left, the engine's maximum allowable thrust, defines the thrust output at 100% N_1 (the low-pressure compressor) speed, as measured under standard atmospheric conditions. Note that many engine manufacturers rate their engines at their takeoff thrust, which is often not 100% N_1 . Thus, the thrust specifications from a manufacturer may be under-rated.

Beneath the maximum allowable thrust is the “afterburner thrust inc,” the increase in thrust provided by the afterburner. This will be added to the value in the “maximum allowable thrust” field when the afterburner is at full power.

Beneath the afterburner increase is the “max efficient inlet Mach,” the maximum speed as a proportion of the speed of sound at which the inlet can pass air into the engines efficiently. The geometry of any intake will allow it to funnel air into the engine only up to a certain speed; past that, the force of shock waves hitting the inlet make it much, much less efficient. Many real aircraft have variable intake geometries as a means of counteracting this effect and extending the maximum efficient inlet speed.

At the top of the middle column in the Jet Engine Specs box is the compressor area, given in square feet. Specifically, this is the frontal area of the engine compressor, calculated as π times the radius of the compressor for engines with the whole of their (round) compressors open to drag effects. The compressor’s frontal area only has a significant effect on drag at low throttle settings.

Beneath the compressor area is the minimum N_1 for fuel introduction, set as a percentage of N_1 ’s maximum speed. If fuel is introduced into the engine prior to this speed, a hot start (a start that exceeds the maximum temperature the engine is designed to handle) may ensue. Beneath the minimum N_1 is the fan RPM at 100% N_1 , measured in rotations per minute.

At the top of the far right column in the Jet Engine Specs box is the “engine-start fuel intro time”—the time, in seconds, that it takes to go from no fuel to idle fuel flow during the engine’s starting process.

Beneath the fuel intro time is the “throttle advance time from idle to maximum.” This sets the time in seconds that it takes the engine to go from idle to full torque if the throttle is commanded instantly from idle to full. It is, more accurately, the time it takes N_1 to bring in torque when the throttle is moved to full.

The final parameter in the Jet Engine Specs box is the thrust-

reverser deployment time, the time in seconds that it takes the thrust reverser to deploy and retract.

D. Working with Rocket Engines

Rocket engines, like jets, are quite simple to set up in Plane Maker. Use the Location tab of the Engine Specs dialog box to set the position of the center of the engine’s thrust (as described in the section “**Features Shared by All Engine Types**” above). For a jet engine, this center of thrust is usually the center of the exhaust nozzle. Check the “vectors” box in that tab if the engine will vector.

After setting the rocket engine’s location, you can set its other characteristics using the “Rocket Engine Specs” box (seen in **Figure 4.15**), located in the Description tab of the Engine Specs dialog box.

ROCKET ENGINE SPECS at sea level, optimum altitude, and vacuum

thrust	0,0 5 5,8 5 0,0	0,0 5 7,8 5 0,0	0,0 4 6,8 5 0,0 (lb)	nozzle exit area	0 0 8.0 (square feet)
optimum altitude	0 6 0,0 0 0			SFC	1 5.2 0 (/hr)

Figure 4.15: The Rocket Engine Specs portion of the Description tab

Here, there are three parameter boxes for thrust. From left to right, these set the maximum thrust of the rocket engine, in pounds,

- at sea level,
- at the engine’s design altitude, and
- in a vacuum.

In X-Plane, the engine can put out full thrust in all three conditions, though real rockets are not always able to do so.

Beneath the three thrust settings is the engine’s optimum

altitude, the altitude at which the rocket achieves maximum thrust, in feet above mean sea level.

In the upper right of the Rocket Engine Specs box is the “nozzle exit area” parameter, the size of the exhaust nozzle. This is used only to calculate how large an exhaust flame to display in X-Plane.

The final parameter in the Rocket Engine Specs box is the engine’s specific fuel consumption (SFC). Specific fuel consumption in rocket engines is much simpler than in combustion engines; this parameter applies at all altitudes, at all power settings. It defines the pounds of fuel burned per hour for each pound of the engine’s thrust. Note that the specific fuel consumption is the *inverse* of the engine’s specific impulse (I_{sp}), the number usually discussed in relation to a rocket’s fuel consumption.

E. Working with Twin- and Multi-Engine Aircraft

Creating multiple engines in Plane Maker is quite straightforward; in the Location tab, each engine has its position defined independently (as described in the “**Location**” section above), as well as its propeller characteristics, if applicable, as described in the “**Customizing the Propeller**” section above. Engines of the same type (propeller-driving, jet, or rocket) are assumed to have the same characteristics—that is, all propeller-driving engines on an aircraft will have the same maximum allowable horsepower, the same redline RPM, and so on.

The only thing significantly different about setting up multiple engines is the use of the Engine Specs dialog’s Transmission tab. This, of course, applies only to engines that turn propellers.

Most aircraft designs will have one transmission per engine. Thus, a single-engine aircraft will have a single transmission, a

twin-engine aircraft will have two transmissions, and so on. Exceptions are designs which use a common transmission to connect multiple engines to multiple propellers, as seen in the V-22 Osprey, as well as helicopter designs, where all rotors are geared together.

The number of transmissions is defined in the far left of the Transmission tab, seen in **Figure 4.16**.

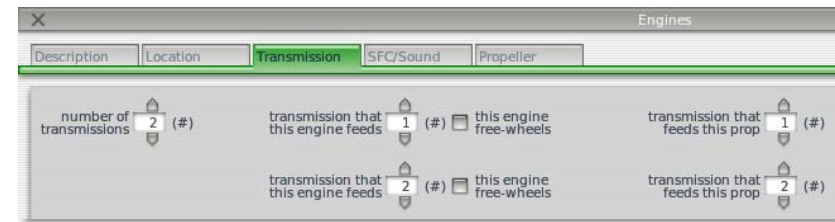


Figure 4.16: The Engine Specs dialog’s Transmission tab

To the right of the “number of transmissions” parameter are the transmission settings for each engine and each propeller; engine settings are in the center of the window, and propeller settings are on the right. With multiple engines created in the Location tab, there will be one row of settings for each engine. Note that the topmost engine here corresponds to the leftmost engine in the Location tab, and the topmost propeller here corresponds to the leftmost propeller in the Location tab.

Each engine can drive one transmission, as defined in the “transmission that this engine feeds” box. Each propeller, in turn, can be driven by one transmission (set in the “transmission that feeds this prop” box). Thus, in a twin-engine plane, the port-side engine might feed transmission 1, and the port-side propeller would be fed by transmission 1. The starboard-side engine, then, would feed transmission 2, and the starboard-side propeller would be fed by transmission 2.

II. Setting Up Electrical, Hydraulic, and Pressurization Systems

The electrical and hydraulic sub-systems of an aircraft are used to drive instruments, lighting, and flight controls. The pressurization system keeps the air pressure in the cabin at a comfortable level. These systems are modeled in Plane Maker using the Systems dialog box, found in the Standard menu.

A. Configuring the Electrical System

The electrical system is configured using the Systems dialog box. The Electrical tab sets the sources of electrical power, as well as the number of buses and inverters, so it is a good place to start when setting up the system.

Note that the aircraft will have one battery for every battery button present on the 2-D instrument panel, and one generator for every generator button on the panel.

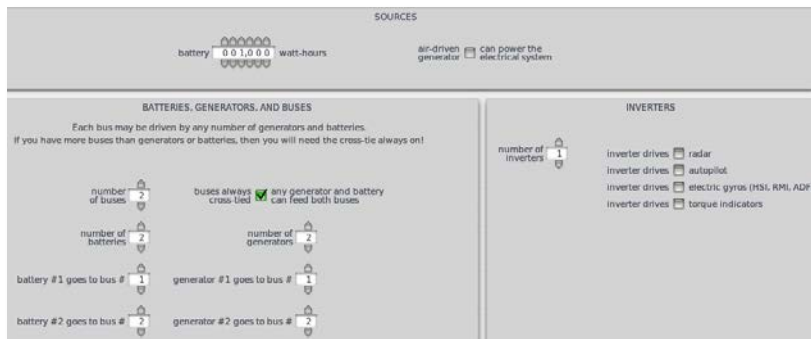


Figure 4.17: The Systems dialog's Electrical tab

In the Sources box, the parameter on the left sets the battery's capacity, measured in watt-hours. The battery will only be considered if more amperage is required by your electronics than is available from the generator, as might occur in a generator failure or when taxiing in some aircraft. A good

estimate for light aircraft is a 1,000 watt-hour battery.

If the aircraft also has an air-driven backup generator to power the electrical system, check the box on the right side of the Sources portion of the dialog box.

An aircraft will often have several different electrical distribution networks, called buses. These buses are often separated and powered by separate generators and batteries so that the failure of one bus will not cause electrical failure across the rest of the aircraft. In this case, a switch inside the aircraft will “tie” the buses together so that the still-working buses can power the failed ones.

Set the number of buses, batteries, and generators using the corresponding parameters in the “Batteries, Generators, and Buses” portion of the dialog box. If you have more than one bus, specify which bus each battery and generator feeds using the input boxes at the bottom of the “Batteries, Generators, and Buses” box. Finally, if the buses are always tied, check the box labeled “buses always cross-tied.” In this case, all engines and batteries will feed all buses.

Finally, the “Inverters” box in the Electrical tab specifies the number of power inverters and which systems are connected to them. Inverters are most commonly used for backup power, turning DC power from the batter into AC power for (most) electronics.

With the backbone of the electrical system configured, you can use the Systems dialog's Bus 1 and Bus 2 tabs to specify how much amperage each electrically-powered subsystem requires and from which bus it draws its power. To the right of each subsystem's label are up to four checkboxes, corresponding to buses 1 through 4 (with buses 1 and 2 corresponding to the top two checkboxes and buses 3 and 4 to the bottom two checkboxes). For instance, in **Figure 4.18**, the de-icing subsystem's window heater is drawing 6 amps from bus 1.

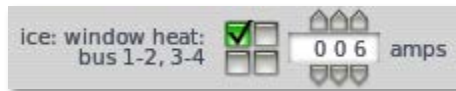


Figure 4.18: A single electrical subsystem, drawing 6 amperes from bus 1

In addition to the subsystems, there may be a base load on each of the buses—that is, some number of amps drawn at all times, regardless of what other electronics are powered on. The base load for each bus is set in the upper left of the Bus 1 tab. Note that generator loads will be affected by the bus that each system is attached to, and the amperage drawn from it.

If the bus powering a system fails in X-Plane—that is, if the battery and generator for the bus are off, the bus cross-tie is off, and there is no APU running for the bus—that system will fail.

B. Configuring the Hydraulics System

The hydraulics system is configured in the Systems dialog's General tab. Here, the boxes labeled “Hydraulic Sources” and “Hydraulic Systems that Depend on Hydraulic Sources” represent the basics of the hydraulic system.

X-Plane can model up to four hydraulic pumps: one powered by the electrical system, one powered by a ram air turbine, and two powered by the engine. Check the boxes in the Hydraulic Sources portion of the General tab corresponding to the pumps your aircraft uses.

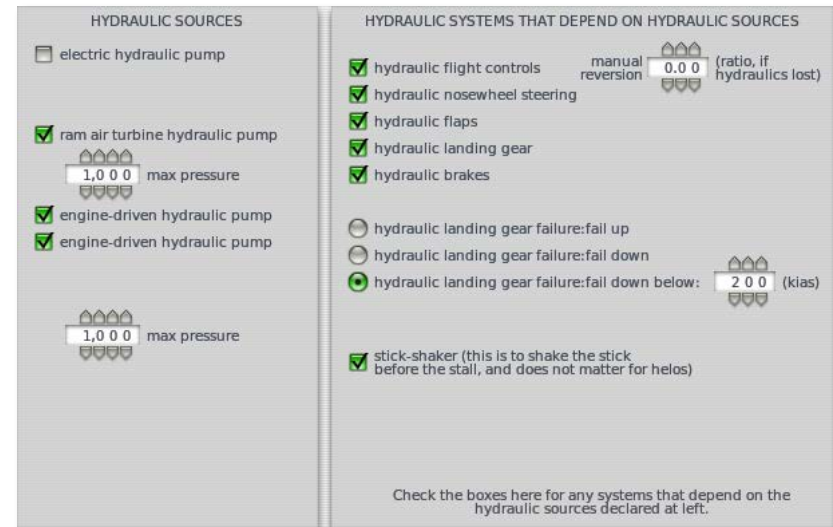


Figure 4.19: The “Hydraulic Sources” and “Hydraulic Systems that Depend on Hydraulic Sources” boxes of the Systems dialog's General tab

Each type of pump has a different max pressure, set beneath the pump's checkbox. The units on the maximum pressure are not specified; the hydraulics modeling is not detailed enough for the units to matter, so they can be anything. The only thing that matters here is the ratio between the different pumps, and it only matters then in the case of failure.

To the right of the hydraulic sources are the systems that depend on the hydraulics. If the hydraulic pumps fail, the systems represented by each checked box will also fail.

Most of the systems here are self-explanatory. The final one, the stick shaker, is a device that rapidly vibrates the control yoke as the aircraft approaches a stall. In X-Plane, this is indicated by a loud noise. If the stick shaker box is checked near the bottom of the “Hydraulic Systems that Depend on Hydraulic Sources” box, the stick shaker will fail along with the hydraulic system.

The box labeled “manual reversion” controls the extent to which, following a hydraulic system failure, the flight controls continue to operate. This is set as a ratio of their normal full operation.

The group of settings in the middle specifies how the landing gear fails in the event of a hydraulic failure. If the landing gear depends on hydraulics, it can have one of three behaviors in the event of failure: it can remain retracted, remain extended, or extend and remain there *if* the craft’s indicated airspeed is below a certain threshold. Select the radio button appropriate for your aircraft here. If the “fail down below...” option is selected, you must also set the threshold speed, in knots indicated airspeed.

C. Configuring the Pressurization System

An aircraft’s pressurization system is set up using the Pressurization box (seen in **Figure 4.20**) found in the General tab of the Systems dialog box. There, use the “maximum allowable pressurization” field to set the cabin pressure that the system is capable of providing, measured in pounds per square inch (psi). Standard atmosphere on Earth is 14.7 psi at sea level.



Figure 4.20: The Pressurization box, found in the General tab of the Systems dialog box

To the right of the maximum allowable pressurization is the emergency pressurization altitude. When the “dump to emer alt” button is pressed in the aircraft’s panel in X-Plane, this is the altitude that the pressurization system will match.

Checking the top box on the far right, labeled “auto-manage pressurization,” will cause X-Plane to control the

pressurization, maintaining the air pressure of 7,500 feet above mean sea level until the maximum allowable pressurization is reached.

Checking the bottom box on the far right, labeled “dump pressure below 1000 ft,” will cause the pressurization system to equalize pressure with the outside air when the altimeter reads 1000 feet.

III. Configuring the Avionics System

The avionics system is comprised of the electronics used on an aircraft, including the systems used for navigation, communication, and the monitoring of other systems’ performance. Most of the avionics setup in X-Plane is performed when designing the panel, as described in Chapter 5, **Creating an Instrument Panel**. However, the “back-end” (such as specifications for how the instrument displays work) are set using the Systems dialog box, launched from the Standard menu. Later, when designing the instrument panel, you will add the specific instruments your aircraft uses.

A. Configuring Instrument Performance Ranges, Display Limits, and Colors

Prior to adding the instruments themselves (again, as described in Chapter 5, **Creating an Instrument Panel**), you can configure the instrumentation’s “back end,” the features of the instruments which will change based on your aircraft’s specifications. This includes performance ranges, which are set in terms of red-line, yellow, and green ranges. Additionally, it includes the instruments’ display limits, such as the maximum speed displayed by the airspeed indicator.

The aircraft’s performance ranges are set using the Limits 1 and Limits 2 tab of the Systems dialog box (found in the Standard menu). These tabs are used to set the operational

and limiting temperatures, pressures, voltages, etc. of various systems on the aircraft. This information should be available in the aircraft's Pilot's Operating Handbook (POH). Note that this information is not used in the flight model; it controls only what the instruments display.

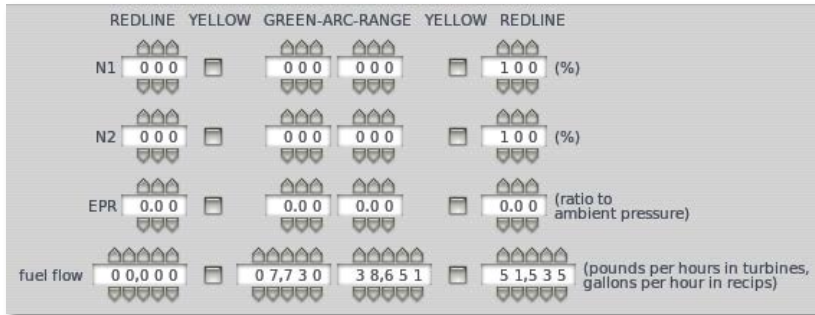


Figure 4.21: The columns for redline, yellow, and green ranges in the Limits tab

In addition to setting the red, yellow, and green ranges for the aircraft's systems, the Limits 1 and Limits 2 tabs determine the units used in displaying torque, temperature, and power.

To configure the colors used in the instrument displays, open the Systems dialog box from the Standard menu and select the Arc Colors tab. Here, you can set the (decimal) RGB values for each of the three standard ranges. By default, the "green" arc has an RGB value of (0, 1, 0), the "yellow" arc a value of (1, 1, 0), and the red a value of (1, 0, 0).

Finally, you can set the range of values displayed by opening the Limits dialog box from the Standard menu. Here, two tabs are used for setting the range of values displayed on "round" instruments and two tabs are used for digital instruments.

In the case of round instruments, check the box next to a measurement (such as VVI, ITT, N₁, etc.) to set (in order from left to right):

- the minimum value displayed,

- the maximum values displayed,
- the angle on the dial at which the minimum value is displayed, and
- the angle on the dial at which the maximum value is displayed.

In setting the angles, 0 degrees is the top of the instrument. Angles can be positive or negative, and can even be greater than 360 if you would like the dial to wrap around.

To use a different (compressed) scale for the high-end of an instrument's range, check the box on the right of the angle settings labeled "halve over." Then, beginning at the value you select, the scale will be halved, so it will take 2 units to move the instrument hand the same amount that 1 unit moves it at the low end of the scale. This is most often used in the airspeed indicators of high-speed airplanes, where it allows a greater range of speeds to be "compressed" into the display.

In the case of digital instruments, checking the box for a measurement allows you to set the offset, scale, and the number of digits used in displaying that measurement. The offset is a value added to the X-Plane value when displaying this measurement in the panel (this may be positive or negative). The scaling value will be multiplied by the X-Plane value to determine the number displayed in the instrument panel. The "digits" value determines the total number of digits used in displaying this measurement, while the "decimals" value determines only the number of decimals used.

B. Setting V-Speeds and G Limits

In addition to red, green, and yellow ranges, the instruments need standard operating markings. These include "v-speeds" (such as the maximum cruise speed, stall speed, and so on), as well as g limits. With the exception of the g limits, these will not be factored into the flight model; they may, however, be used in the airspeed indicator. To set these, open the

Viewpoint dialog box from the Standard menu. There, on the left side of the Default tab, you can set the following:

- V_{mca} , the minimum speed below which you can still steer the aircraft with one engine disabled and the other at full throttle
- V_{so} , the speed below which the airplane will stall with the flaps deployed
- V_s , the speed below which the airplane will stall with the flaps retracted
- V_{yse} , the optimal climb speed with one engine disabled
- V_{fe-m} , the maximum allowable speed for fully extended flaps
- V_{fe-1} , the maximum allowable speed for first-notch flaps
- V_{le} , the maximum allowable speed for extended gear
- V_{no} , the maximum allowable speed for normal operation
- V_{ne} , the maximum allowable speed (the craft's airframe will fail if this speed is exceeded by more than about 25%)
- M_{mo} , the maximum allowable Mach number
- Positive g limit, the maximum allowable positive g load (the craft's airframe will fail if this limit is exceeded by more than about 50%)
- Negative g limit, the maximum allowable negative g load

Note that, unless noted, all values above are in knots.

If you cannot find official g limit values, 4.0 is a good guess for most general aviation aircraft. At g loads more than 50% above these values, if the appropriate settings are enabled in X-Plane, structural damage will occur—probably in the form of a wing being torn off!

Note that, depending on your engine configuration, some of the values listed above may not be visible. Any of these markings can be left off the instruments by simply setting their values to zero. Note also that, though X-Plane does not take these speeds into account for performance prediction, it may use them for niceties like the plane's starting speed when selecting an approach.

C. Configuring the Autopilot

Configuration of the autopilot is done separately from other instruments. The source of the autopilot's attitude and heading readings, as well as various levels of alerts, are configured in the General tab of the Systems dialog box, in the top section of the dialog box labeled "Autopilot."



Figure 4.22: The Autopilot box, found in the General tab of the Systems dialog box

IV. Configuring the Starter



Figure 4.23: The Starter box found in the General tab of the Systems dialog box

The engine's starter is very simple to configure. X-Plane comes good defaults for the starter and battery strength, but you can increase or decrease the starter strength as a ratio of X-Plane's default. To do so, use the "starter strength ratio" parameter, located in the "Starter" box of the Systems dialog's General tab, and seen in **Figure 4.23**. Additionally, you can

choose whether your starter is electric or air-driven.

V. Configuring the Fuel System

The aircraft's fuel system is configured using the Weight & Balance dialog box, launched from the Standard menu. To begin setting it up, go to the Weight tab and enter the maximum amount of fuel, in pounds, that the aircraft can carry into the "fuel load" parameter box.

Next, move to the Tanks tab. In this tab, there are nine fuel tanks able to be added. Each tank holds a ratio of the aircraft's maximum fuel, which is set using the "tank #x ratio" input box. The total of all tanks' ratios must add up to 1.000. For instance, if an aircraft had two fuel tanks, one in each wing, each tank might hold 0.5 of the total fuel.

Use the "fuel pump pressure" setting to set the relative pressure of the fuel tanks. This will determine which tanks are emptied first if more than one is selected. For instance, If tank 1 should empty a little bit before tank 2 and long before tank 3 when all 3 tanks are selected, you might set their fuel pump pressures as in **Table 4.1**.

Tank 1	20 psi
Tank 2	17 psi
Tank 3	10 psi

Table 4.1: Relative fuel pump pressures

Finally, the fuel tanks can be placed on the aircraft using the standard position controls (as described in the "**Fundamental Concepts**" section of Chapter 3). X-Plane considers the inertial properties of slinging fuel around at various distances from the aircraft's center of gravity, so placing the fuel tanks in the correct location is important in making sure the craft handles correctly. Note that, when placing fuel tanks, you are really only placing the tanks' center of gravity; X-Plane assumes the tanks are physically large enough to hold the

weight of fuel you have specified.

Note also that the fuel tank selectors in the instrument panel will select left and right tanks based on the physical locations you specify here.

5. Creating an Instrument Panel

Creating a basic 2-D instrument panel in Plane Maker is as easy as choosing a panel background image and dragging the instruments you want where you want them. Creating panels that use generic (user-created) instruments are more complicated, as are 3-D panels; both generic instruments and 3-D panels are beyond the scope of this manual, and will thus be discussed only briefly.

I. Introduction to Panel Creation

With the aircraft whose panel you want to design open, open the Standard menu and click Panel: 2-D. The panel design dialog box will appear.

This window is made up of a number of different sections. The buttons in the toolbar at the top of the screen (labeled 1 in **Figure 5.1**) perform a variety of functions; mouse over each button to get a description as well as the keyboard shortcut that does the same thing, where available. For instance, mousing over the far left button, whose icon is a floppy disk, tells us that this button saves the file, and that you can also save by pressing Ctrl + s.

Two groups of information panes lie on the left and right of the screen, respectively. On the left is the Instrument List, which is combined with the Preview, Description, and Properties panes, and on the right is the Hierarchy, combined with the Key Frames pane. These left and right groups can be displayed or hidden by clicking the large Instrument List and Hierarchy buttons at the top of the screen, respectively.

Creation of an instrument panel, then proceeds this way. First, find the instrument you're looking for in the instrument list (labeled 2 in **Figure 5.1**) and click on it. For instance, in

Figure 5.1, the general aviation altimeter, whose filename is alt_GA.png, is selected. With an instrument selected, you can see what it will look like in the Preview tab (labeled 3 in **Figure 5.1**). Beneath this is the Description tab (labeled 4 in **Figure 5.1**), which details what the selected instrument does.



Figure 5.1: The panel design dialog box with its various parts numbered

Having found the instrument you're looking for, click it in the instrument list and drag it into the layout pane, labeled 5 in **Figure 5.1**. Doing so will cause the instrument to also be listed in the hierarchy pane, labeled 6 in **Figure 5.1**. With an instrument in the panel, click on it to select it; selecting an instrument in either the layout or the hierarchy pane will cause it to be selected in both.

When an instrument has been added to the panel layout, it will appear in the Hierarchy pane. You can select an instrument

from the layout pane by clicking its name here. Additionally, you can set its status to visible or invisible by clicking the eye icon to the left of it, and you can set it to locked or unlocked (that is, unmovable or movable) by clicking the padlock icon.

When an instrument is selected in the layout and hierarchy panes, the Properties tab (labeled 7 in **Figure 5.1**) will display its settings. This includes what lighting is used on the instrument, which electrical bus the instrument is on, and what Tool Tip (if any) will be displayed when the Show Instrument Descriptions setting is activated and it is moused over in X-Plane. The comment property is simply for use in designing and will have no effect in X-Plane.

To select multiple instruments in either the hierarchy pane or the layout pane, hold down either the Control or Shift keys and click the desired instrument. To group instruments together in the hierarchy pane, select them and press the G key. With a group created, you can also click and drag other instruments into the group in the hierarchy pane.

With an instrument selected, you can drag it around to reposition it, or use the arrow keys to move it by very small amounts. If there is more than one instrument in the panel, guide lines will appear to which the instrument will “snap,” allowing you to align instruments perfectly.

Use the = and - keys or your mouse wheel to zoom in and out in the layout pane. To pan your view of the panel left and right, you can right click (or hold the Control key and left click) on the panel and drag it; alternatively, you can use the left, right, up, and down arrow keys to “nudge” the panel each direction, and press Shift with an arrow key to jump to the far edge in a given direction. Press the Alt key to view each instrument’s index (duplicates of a single instrument will have different indices in order to differentiate them). Click and drag anywhere in the layout pane to form a box that selects multiple instruments. To delete an instrument, select it and hit the Backspace key.

If two instruments are placed on top of one another in the layout pane, the instrument closest to the bottom of the list in the hierarchy pane will be displayed on top of the instruments higher up the list. To change an instrument’s name, double-click it in the hierarchy pane and type its new name.

Finally, in the very bottom of the window is the status bar (labeled 8 in **Figure 5.1**). Here, you can see the level of zoom for the panel layout pane, the name and position of the currently selected instrument, the object’s size (as a ratio compared to its original size), and whether the instrument uses the copilot’s pitot tube.

II. Setting a Panel Background

Before beginning the layout, you may want to create the background image that your panel will use. Plane Maker will supply a default panel image based on your cockpit type setting in the Viewpoint dialog box (e.g., General Aviation, Airliner, Fighter, etc.), but you may want a different image for a number of reasons. Many aircraft designers today use a panel that is around 1600 pixels wide so that the panel is usable at lower resolutions (e.g., 1024 x 768), but it also shines at high resolutions (e.g., 1920 x 1080). Note that the panel is limited to a maximum of 2048 x 2048 pixels, and a minimum of 1024 x 1024 pixels, but the image does not have to be square.

Panel backgrounds in Plane Maker can follow one of two naming conventions. The old convention is simply to name the image “Panel.png” (without the quotes, of course). As of version 9, Plane Maker will still work with a panel named this way. The new convention, and the one you should use when creating new aircraft, is to name the image to match the “cockpit” setting in Plane Maker’s Viewpoint dialog box.

For instance, if the cockpit setting in the Viewpoint dialog were set to General Aviation, the panel image would be named Panel_General.png. If it were instead set to Airliner, the image

would be named Panel_Airliner.png.

The official names for panels are the same as in the folder Resources/bitmaps/cockpit/-PANELS-/ and are:

- Panel_General.png
- Panel_Airliner.png
- Panel_Fighter.png
- Panel_Glider.png
- Panel_Helo.png
- Panel_Autogyro.png
- Panel_General_IFR.png
- Panel_Autogyro_Twin.png
- Panel_Fighter_IFR.png

In order for Plane Maker to find your background, you must (re)name it using one of these conventions and save it in the following folder:

[Your aircraft folder here]\cockpit\ -PANELS-\

Thus, the panel image for X-Plane 9's Cessna 172 SP is in the following folder:

X-Plane 9\Aircraft\General Aviation\Cessna
172SP\cockpit\ -PANELS-\

With your panel image has been saved to the correct folder, it should appear the next time you open the Panel dialog in Plane Maker. With the panel loaded, you can begin dragging and dropping instruments from the list into your cockpit.

III. Sliders in the Panel

Normally, a switch in the X-Plane panel is either on or off, and going between the two states is instantaneous. For instance, as far as X-Plane is concerned, an aircraft's landing gear is either all the way up (with the background dataref sim/cockpit2/controls/gear_handle_down set to 0) or all the way down (with said dataref set to 1). Thus, the landing gear switch in the instrument panel is either all the way up or all the

way down. However, it may be desirable to animate the transition between these states; one might like to specify to X-Plane how long an animation should take. This is where sliders come in.

Basic sliders are designed for animations that X-Plane does not have a native mechanism for. The dataref for a slider can be used to animate an object or a generic instrument (or anything else, for that matter).

Sliders consist of a couple sets of datarefs and some Plane Maker settings.

- sim/cockpit2/switches/custom_slider_on is an array of 24 Boolean values for switches that "control" slider animations. You set these datarefs using Generic Instruments (for example, the rotary switch).
- sim/flightmodel2/misc/custom_slider_ratio is an array of 24 ratios that slowly move from 0 to 1 (and back) over time whenever the custom_slider_on switches are changed.
- sim/operation/slider_01 through sim/operation/slider_20 are 20 commands that toggle the custom_slider_on datarefs. This lets users bind keyboard or joystick commands to the various actions. You can also use these with manipulators to drive your animations in 3-D.

Each of the 24 sliders has a cycle time, as seen in **Figure 5.2**, which is set in the Sliders tab of Plane Maker's Systems dialog box. This controls how long it takes the ratio variable to move from its current value to the value of the switch.



Figure 5.2: The cycle time settings for a single slider

Essentially, the sliders act as a time-delay mechanism, running a sequence of ratios over a set amount of time when a source switch is set. This lets you create animation sequences where

a user sees the entire sequence.

For example, consider a staircase for a regional jet which needed to deploy over the course of 10 seconds. To make this happen in X-Plane, we would do the following:

- Create a staircase switch on our 2-D panel (using the generic rotary instrument) using `sim/cockpit2/switches/custom_slider_on[0]`
- Attach a 3-D staircase to the aircraft as a misc. object that animates based on `sim/flightmodel2/misc/custom_slider_ratio[0]`. It would animate from 0 to 1.
- Add a “command slider” to the instrument panel. This is labeled “`but_command_slider`” in the “buttons” folder of the panel design dialog’s instrument list (labeled 2 in **Figure 5.1**).
- Set the cycle time for that slider to 10 seconds in the Sliders tab of Plane Maker’s Systems dialog box.

If you have more than one slider in your instrument panel, you can figure out which number each one is assigned by opening the panel design dialog and pressing the Alt key (Option in Mac OS X). Small green numbers will appear on each duplicated instrument, as seen in **Figure 5.3**. For instance, in **Figure 5.3**, the cycle time for the slider on the far right would be set using the “#3 time” parameter in the Systems dialog’s Sliders tab.



Figure 5.3: Three sliders in an instrument panel, whose numbers are displayed by pressing the Alt (Option) key

It is also possible to create an animation sequence for parts of the aircraft which you do not want tied to an actual switch in the instrument panel. For instance, you might want to animate

the landing light housing unfolding from the wing when the lights are turned on. In this case, you would not want to tie the landing light cockpit switch to `sim/cockpit2/switches/slider_on` because changing the switch would trigger the animation without actually turning on the landing lights!

To account for this, the slider system allows you to pick *any* dataref as a “source” for a slider; the `slider_on` datarefs are merely a default. Thus, in the case of the landing lights, you would simply need to choose the real landing light switch dataref (`sim/cockpit2/switches/landing_lights_on`) as the source for your sliders. Then, when the landing lights are turned on, the slider will be triggered and the landing lights will work as they should.

To select a custom dataref for a slider, simply open the Systems dialog’s Sliders tab, check the box labeled “dataref” next to the slider which you would like to use, then box next to the text field below the dataref checkbox. A dialog box will appear that allows you to choose which dataref you will link to.

Note: If you are using custom-assigned sliders, you should begin with slider #24 and move to lower numbers as needed, since actual sliders in the instrument panel (`but_command_slider`) will be numbered beginning at 1.

Then, in the case of the landing lights, you would set the sliders up this way:

- In the instrument panel, there would be a normal landing light switch.
- Slider #24 would have a cycle time of 5 seconds, with the dataref checkbox on, and a dataref of “`sim/cockpit2/switches/landing_lights_on`”.
- In a misc. object for the aircraft there would be a key-framed animation based on `sim/flightmodel2/misc/custom_slider_ratio[0]` that animates the landing light housing.

IV. Generic (Custom) Instruments

For information on creating your own instruments using X-Plane's "generic" instruments, please see the [Generic Instruments Wiki entry](#).

V. Creating a 3-D Panel

Working with 3-D objects in general, and 3-D instrument panels in particular, is a subject for advanced aircraft design. For information on using 3-D objects in general with X-Plane aircraft files, see the section "Creating 3-D Objects for an Aircraft" in Chapter 8. For information on 3-D panel creation in particular, see the [3-D Panel Wiki page](#).

6. Modifying an Aircraft's Properties

Some properties of an aircraft do not fit into the category of its systems, its body, and so on. Examples of these include the aircraft's tail number, the location of its lights, its weight and balance, and the sounds the aircraft produces.

I. Setting the Identification Information

An aircraft's identification information is set using the Viewpoint dialog box, launched from Plane Maker's Standard menu. There, the Default tab is used to set the aircraft's unique tail number, found in the upper left of the window. This tail number will be used both for air traffic control communications and for the tail number "instrument" available in the aircraft's instrument panel. To the right of the tail number is the name of the aircraft file's author and a description of the aircraft being modeled.

Beneath the aircraft's description is the International Civil Aviation Organization (ICAO) code for the aircraft. Note that the ICAO designator for a particular model aircraft may be found using the [ICAO Aircraft Type Designator search](#). Finally, to the right of the ICAO code is the aircraft's call sign for use by air traffic control. If this is left blank, the aircraft's tail number will be used. Note that as of X-Plane 9, the ICAO code and call sign have no direct effect on the simulator. They may be useful, however, when using plug-ins for flying online such as XSquawkbox.

II. Customizing the Aircraft's Sounds

By default, X-Plane uses a set of sounds which vary depending on the engine type and the type of aircraft. Note that the aircraft type is specified in the Viewpoint dialog box.

There, near the bottom of the window in the Default tab is the "cockpit" drop-down menu. Selecting "Airliner" there will cause X-Plane to use sounds for a large jet, whereas selecting "General Aviation" there will cause it to use sounds appropriate to a small, propeller-driven airplane, and so on.

The simplest means of customizing an aircraft's sounds, then, is to simply select a different cockpit type in the Viewpoint dialog box. However, you might have recordings of your specific aircraft which you would like to use. In this case, you would need to create a folder called "sounds" (without quotes, of course) and place it inside your aircraft's folder. Then, you need only create a folder structure in your aircraft's sounds folder which mirrors the structure found in the default sounds folder.

First, then, one must understand the structure of the default sounds directory. The default sounds are located in the folder:

`X-Plane 9\Resources\sounds`

In this folder are the following subfolders:

- "alert," which contains sounds for altitude warnings, system failures, and navigation alerts, among other things.
- "contact," which contains sounds for crashing into the ground, and touching down on the water, as well as for the rolling and skidding wheels on pavement.
- "engine," which contains sounds for the many different kinds of engines modeled in X-Plane.
- "radio chatter," which contains communications between aircraft and ATC. Note that this is the only set of sounds which apply globally and may not be customized by a particular aircraft.
- "systems," which contains sounds for the humming of the APU and avionics, the moving of flaps and gears, and the firing of guns and flares.
- "weather," which contains sounds for thunder, wind, and rain.

Each subfolder contains a number of WAV (uncompressed audio) files corresponding to the different sounds that would be heard in X-Plane.

To use custom sounds, then—that is, sounds which override the default ones—you would create a subfolder in your aircraft's sounds folder to match the structure of the default sounds folder, then name your WAV files with your aircraft's name as a prefix, like this:

[.acf file name] [name of .wav file to replace] .wav

For instance, if your aircraft file was called "MyCessna.acf" and you wanted to use a custom altitude alert sound for your aircraft, it would need to be located here:

[Your aircraft folder] \sounds\alert\MyCessna
altitude_alert.wav

Note that the sample rate of the WAV files you wish to use should be 22.050 kHz. You can likely set your recording device to this sample rate before you begin capturing your sounds. Alternatively, an audio editor (such as the excellent, free, cross-platform [Audacity](#)) can be used to change the sample rate.

When using custom wind sounds (saved as [your aircraft directory] \sounds\weather\[.acf file name] wind.wav), X-Plane will scale the volume of the recorded sound depending on the speed at which your aircraft is flying. In order to do so, you must set the knots indicated airspeed at which the wind sound was recorded. This is located in the Engine Specs dialog's SFC/Sound tab; in the bottom third of this window on the far left is the setting labeled "speed that wind sound was recorded at."

Likewise, engine sounds (stored in [your aircraft directory] \sounds\engine\) are scaled in both volume and pitch based on the engine speed at which they were recorded. The bottom of the Engine Specs dialog's SFC/Sound tab houses the settings for the RPM or N_1 speed at which engine

and propeller sounds were recorded.

III. Setting the View Properties

When flying in X-Plane, the pilot's inside-the-cockpit view is fixed at some point on the aircraft. To set this point for your aircraft, open the Viewpoint dialog box from the Standard menu. It will open to the Default tab. There, in the left-center of the window, are the "long," "lat," and "vert" arms of the pilot's viewpoint. These are standard position controls, as discussed in the section "Fundamental Concepts" of Chapter 3. The pilot's viewpoint, then, is set with respect to the aircraft's reference point.

IV. Configuring the Lights

An aircraft's lighting consists of external lights (including navigation lights, landing lights, and rotating beacons) and internal lights (located in the cockpit, illuminating the instrument panel).

The Ext Lights tab, found in the Viewpoint dialog box, is used to turn on and off the different types of external lights, and it also controls the location and intensity of those lights. Note that, in order to clearly see the location of your external lights when you add them, you may want to select the "Show with day/night textures" option from the Special menu, thus displaying the aircraft as it will be seen in night lighting.

The Int Lights tab, on the other hand, is used to set the color and intensity of the panel and cockpit lighting.

A. Configuring External Lights

In the Ext Lights tab of the Viewpoint dialog box, the checkboxes found directly above the numeric input boxes control whether the aircraft has that light. An aircraft may have

up to two landing lights (corresponding to the two check boxes labeled “landlight”), two rotating beacons (corresponding to the check boxes labeled “rotbeacon”), and so on. These check boxes are seen at the top of **Figure 6.1**.

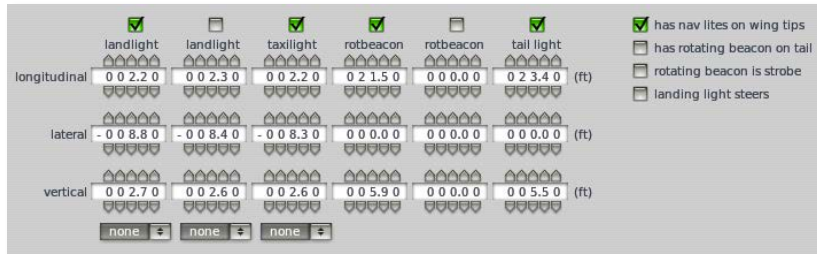


Figure 6.1: Settings for the location of external lights, found in the Ext Lights tab of the Viewpoint dialog box

Beneath each light’s check box are three boxes to set the light’s location, which comprise the standard position controls in Plane Maker (as discussed in the section “Fundamental Concepts” in Chapter 3). Normally, each light’s location is set relative to the aircraft’s reference point. The two landing lights or the taxi light, however, may have their position set relative to a landing gear (useful for lights which should be attached to the gear). Selecting a gear using the drop-down menu controls seen at the bottom of **Figure 6.1** will cause the gear’s position to be set relative to that landing gear.

Near the bottom of the Ext Lights tab are a number of settings for the landing light, as seen in **Figure 6.2**. The light’s intensity is set as a ratio of the default using the “landing light power.” A power setting of 1.00 will give the default intensity, and a power setting of 2.00 will give a double-intensity light, and so on.

Beneath the intensity control is the landing light’s angular width setting. Here, a value of 20 degrees is a good default, but a thinner or wider beam may be used.



Figure 6.2: Settings for landing light width, direction, and intensity

To the right of the landing light power setting is the light’s heading (its lateral angle, measured in degrees). Using a negative value here will point the light left, and using a positive value will point it right.

Finally, beneath the landing light’s heading control is the parameter determining its pitch (its vertical angle, in degrees). A negative value here will point the landing light down, whereas a positive value will point it up. A pitch of -5 degrees is a good default.

B. Configuring Internal Lights

Internal lights (the lights in the aircraft’s cockpit and on the panel) are configured using the Int Lights tab of the Viewpoint dialog box. This tab is divided into two parts. The left part of the window sets the color of the various cabin lights in the 2-D cockpit view, while the right controls a number of features in the 3-D cockpit view.

In the left part of the screen, the color of the 2-D panel’s lights are set using RGB decimals. Thus, a value of 0, 0, 0 (red, green, blue) is full black, and a value of 1, 1, 1 is full white. The lights which may be configured here are as follows:

- the floodlight, the light broadly illuminating the whole of the instrument panel,
- the side view night lighting, and
- the three panel spotlights.

The 2-D panel's flood light intensity can be modified using a panel overlay image. The floodlight is named using the 2-D panel image name plus the extension "-1". For instance, the floodlight overlay in X-Plane 9's default Boeing 777 is stored as:

```
B777-200 British Airways\Cockpit\-PANELS-\
Panel_Airliner-1.png
```

This panel overlay image must be a gray-scale PNG with no alpha (transparency) channel of the same size as the main panel. The PNG must have its -1 shadow layer changed from RGB+alpha to gray-scale, no alpha. In this form, white indicates more shadow, while black indicates no shadow. Thus, if you wanted the flood light to brightly and evenly light the entire panel, you would use an all-black image.

Similarly to the floodlight, the panel spotlights are created using a spotlight overlay image. These overlays are stored in the standard panel directory and are named with your panel image's name plus the extension "-2", "-3", or "-4", for overlays 1, 2, and 3.

For instance, panel spotlight 2 in X-Plane 9's default Boeing 777 is stored as:

```
B777-200 British Airways\Cockpit\-PANELS-\
Panel_Airliner-3.png
```

In the case of both the spotlights and the floodlight, the actual color of the light is simply set using the Int Lights tab of the Viewpoint dialog, using the controls seen in **Figure 6.3**.

In the right portion of the Int Lights tab are the 3-D cockpit lighting settings. A 3-D cockpit has 3 lights, each of which have a color, width, size, pitch, heading, and an associated dataref.

As in the case of the 2-D lights, the color of the 3-D panel's lights are set using RGB decimal. The RGB controls for each of the three cockpit lights are located in the top left of the 3-D

Cockpit Lighting box. Here, as in the 2-D panel, a value of 0, 0, 0 (red, green, blue) corresponds to full black, and a value of 1, 1, 1 is full white.

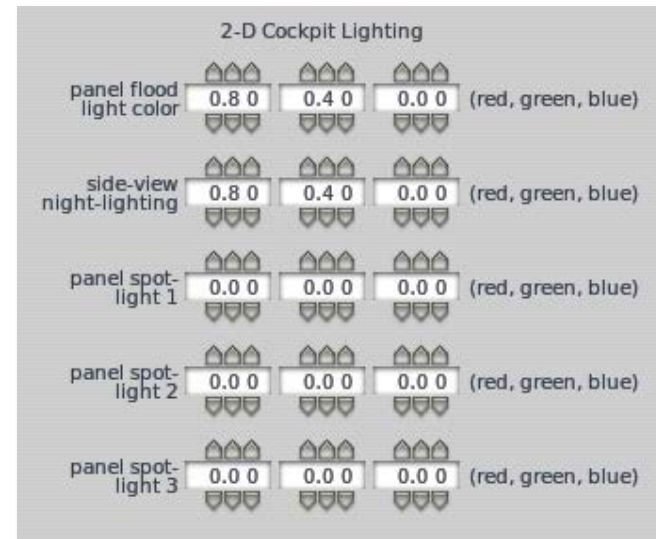


Figure 6.3: Color settings for panel lighting in the 2-D cockpit

Once you set the lights' colors, moving to wireframe view (by pressing the spacebar) will allow you to see the lights' positions. Note that any light set to full black will be turned off again.

To the right of the lights' color settings are the locations of each light, set using the standard location controls (as discussed in the section "Fundamental Concepts" of Chapter 3).

Beneath the color and location controls are the width, size, pitch, and heading controls. Setting a width of zero degrees makes a light omnidirectional; any other setting makes the light directional.

The size of the light is set as a ratio to the default. Past a given

distance, the light shines at half brightness; increasing the size will increase the distance at which this occurs.

A light's pitch is set relative to the aircraft's nose. A pitch of zero degrees indicates the light is pointing directly forward, while a pitch of -90 degrees indicates it is pointing directly down. For the light's heading, on the other hand, positive values indicate the light is pointing to starboard, while negative values indicate it is pointing to port.

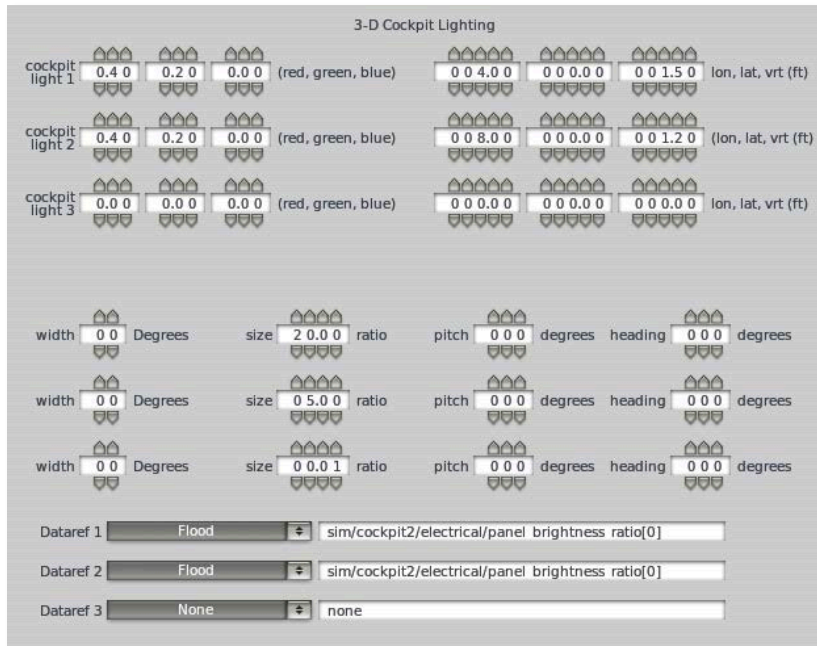


Figure 6.4: Color, direction, size, and related datarefs for lighting in the 3-D cockpit

Finally, the brightness of each cockpit light in the 3-D panel is linked to a dataref. The drop-down menu allows you to select from the most commonly used datarefs, such as the spotlights and floodlight, or you can select a custom dataref by typing it in the text box.

Note that the Misc Objects dialog box (found in the Standard

menu) is used to turn this internal 3-D lighting on or off a given 3-D object. The cockpit object will have interior 3-D lighting applied when the “Cockpit object gets interior lighting” box is checked there. Other objects will have this lighting applied to them when their lighting mode is set to “inside” using the drop-down boxes on the right.

V. Setting the Weight and Balance

To set the aircraft's weight and balance, open the Weight & Balance dialog box from the Standard menu. There, you can set the center of gravity, the empty and maximum weights, as well as the positions of slung loads and fuel tanks.

A. Setting the Center of Gravity

The aircraft's center of gravity (CG) is set using only the longitudinal and vertical parameters of the standard location controls; that is, it has only a distance behind and above the reference point. In X-Plane, the user may move the center of gravity forward or aft. In light of this, three longitudinal positions are defined for the center of gravity. The first, seen on the far left in **Figure 6.5**, is the forward limit (the farthest forward the CG may move). The middle value is the center of gravity's default longitudinal position, and the value on the far right is the aft limit (the farthest back that the CG may move).

The vertical position of the center of gravity stays constant no matter how the CG is moved. Thus, there is only one “vert CG” value to set.

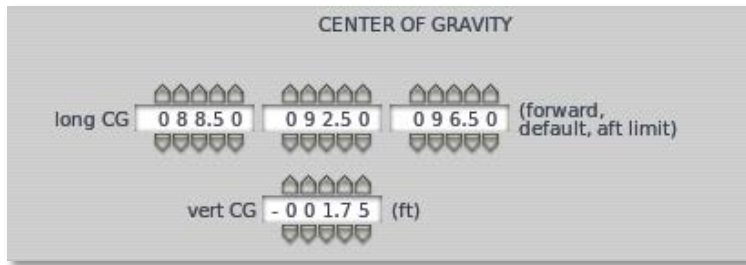


Figure 6.5: The center of gravity settings, located in the Weight & Balance dialog box

B. Setting the Weights

Most of the weight characteristics, located in the bottom left of the Weight & Balance dialog's Weight tab, are self-explanatory.

The empty weight is the weight of the aircraft when empty of fuel or payload, but with oil and other fixed weight on board. The fuel load is the total weight of fuel that the aircraft can carry. The jet-assisted takeoff (JATO) weight is the weight added by the thrust-adding rockets.

The jettisonable load is the maximum weight that can be jettisoned from the aircraft. This may include bombs, water for forest fires, slung loads, cargo pushed out the back of a plane, and so on. When using a jettisonable load, check the appropriate boxes to the right, as seen in **Figure 6.6**, to indicate the nature of the jettisonable load. For more on using slung loads, see the section "Creating and Adding Weapons" in Chapter 7.

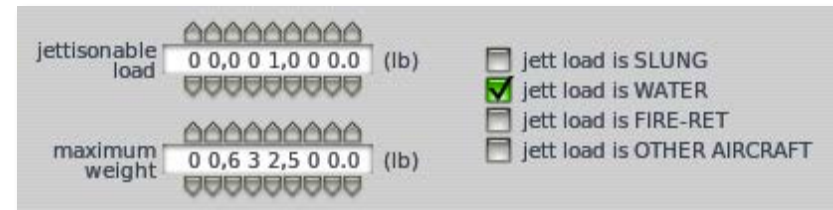


Figure 6.6: The jettisonable load settings in the Weight & Balance dialog box

Beneath the jettisonable load setting, the maximum weight value defines the weight above which the aircraft cannot take off (the maximum takeoff weight, or MTOW).

Next, the weight-shift weight is the amount of weight that can shift around based on control input, as in a hang glider. This portion of the aircraft's total weight will be shifted in X-Plane. When using a nonzero weight shift, you will be able to set the distance, in feet, that the weight can move both laterally and longitudinally using the Weight Shift box to the right.

The displaced weight value should be zero for airplanes, but it may be nonzero for blimps, zeppelins, or dirigibles. When using a nonzero displaced weight, you can adjust the portion of the total displaced weight that the buoyancy of the craft can scale across using the "displacement adjust ratio" value to the right. For instance, if the buoyancy control can scale from 80% to 120% of the displaced weight value, this would be 0.2. Additionally, you can set the distance above the reference point for the center of buoyancy using the "vertical center of displaced air" value.

Note that the weight and location of the fuel tanks can be set as described in the section "Configuring the Fuel System" of Chapter 4.

7. Modeling Additional Features of an Aircraft

Plane Maker can model a large number of features of an aircraft which, though not strictly required to get an aircraft off the ground, add to the simulation's realism in a significant way. These features include weapons, slung loads, rockets for a jet-assisted takeoff, and artificial stability systems.

I. Creating and Adding Weapons

Built into Plane Maker is a robust weapon creation tool, which can be used to create guns, missiles, bombs, drop-tanks, and lasers. These weapons are stored as .wpn files. The geometry of a WPN object is set in a way similar to the fuselage and miscellaneous bodies, and the WPN may be textured similarly to these other bodies. Once a weapon has been created, it can be attached to the aircraft similarly to other bodies.

A. Building Weapons

To begin creating a weapon, open the Expert menu and launch the Build Weapons dialog box. It will open to the General tab.

There, using the buttons in the upper left, you can choose to either modify an existing weapon (by clicking Load Weapon) or create a new one (by clicking New Weapon). The weapon file must be saved using the Save Weapon button here; saving the aircraft file will not save changes to the weapon file.



Figure 7.1: File editing controls in the Build Weapons dialog box

When creating a weapon, first select its type in the Weapon Specs box on the left. Types of weapons available are:

- laser, a mock combat laser which does no damage, but instead simply indicates a hit; this weapon fires perfectly straight and instantaneously, with no ammo limit
- death laser, a true combat laser which destroys its target; this weapon fires perfectly straight and instantaneously, with no ammo limit
- gun, a simple machine gun with limited ammo and limited accuracy
- rockets (unguided), a rocket launcher for firing X-Plane's default rockets
- air-to-air missile (heat-seeking), a missile for air combat which passively tracks and follows a target using the infrared radiation emitted by the target
- air-to-air missile (FAF self radar guide), a missile for air combat which tracks and follows a target using the target's radar signature
- air-to-air missile (FAF your radar guide), a missile for air combat which tracks and follows a target using your own aircraft's reading of the target's radar signature; to guide this type of missile, the target must remain in front of the firing aircraft
- air-to-ground missile (TV-guided), a missile for attacking ground targets which is guided from the cockpit of the firing aircraft

- air-to-ground missile (GPS), a missile for attacking ground targets based on the targets' GPS location
- air-to-ground bomb (GPS), a bomb for attacking ground targets based on the targets' GPS location
- air-to-ground bomb (laser guided), a bomb for attacking ground targets based on a laser signal from the firing aircraft
- air-to-ground bomb (TV-guided), a bomb for attacking ground targets which is guided from the cockpit of the firing aircraft
- air-to-ground bomb (free-fall), a bomb for attacking ground targets which is unguided
- drop tank, an external fuel tank which can be dropped from the aircraft; fuel will automatically burn from this tank before the aircraft's internal tanks are used

To use a texture with the weapon, simply store a PNG file named *[WPN file name].png* in the same directory as your .wpn file. The texture must be draped over the weapon using the Body Texture box, found in the Geometry tab of the Build Weapons dialog box. There, you can specify the top, left, right, and bottom portions of the *[WPN file name].png* file to use on both the left and right of the weapon. For more information on texturing objects in Plane Maker using these controls, see the section “**Fine-Tuning a Paint Job**” in Chapter 8.

B. Attaching Weapons

Having created a weapon using the Build Weapons dialog box, you can arm an aircraft with to 24 weapons using the Default Weapons dialog (found in Plane Maker's Expert menu). These weapons will be present on the aircraft each time you open it in X-Plane.

In order to add a weapon, click the small square to the right of the location controls, as seen in **Figure 7.2**.



Figure 7.2: Launching the Open Weapon dialog box, from Plane Maker's Default Weapons dialog box

Navigate to your weapon file's directory and select it. Then, use the standard position controls (as described in the section “**Fundamental Concepts**” of Chapter 3) to position the weapon on the aircraft.

If the weapon is attached to a moving surface, such as a flight control or a landing gear, select that part of the aircraft in the “attach” drop-down menu.

Finally, if the weapon is located inside the aircraft and thus does not change the craft's aerodynamics except by adding weight, check the box labeled “internal.”

After saving your aircraft file, your weapons will be loaded with the aircraft in X-Plane.

II. Creating and Adding Slung Loads

Objects such as vehicles, cargo containers, or even other aircraft can be “slung” from an aircraft (most often a helicopter).

Objects used as slung loads are simply standard X-Plane OBJ files with a weight specified. To specify a weight in an already existing OBJ file, open the file in a text editor (Notepad, Emacs, TextEdit, etc.) and scroll to the end of the file. There, just before the lines

```
end
object
```

add the following:

```
slung_load_weight x
```

(where x is the weight in pounds for the object).

Thus, for an object weighing 500 pounds, the .obj text file looks like this:

```
. . .
slung_load_weight 500
end
object
```

To use a slung load in X-Plane, you must first use Plane Maker specify the weight able to be slung from the craft. This is done in the Weight & Balance dialog box (found in the Standard menu). There, the maximum weight for a slung load is set as a “jettisonable load” weight. After setting this weight, check the box to the right labeled “jett load is slung,” indicating that this weight is available for use with a slung load.



Figure 7.3: Setting the jettisonable load weight as a slung load

With the jettisonable load set up, the box in the upper right labeled Slung Load Location will be usable, as seen in **Figure 7.4**. There, you can use the standard location controls (described in the section “**Fundamental Concepts**” of Chapter 3) to define the slung load should attach to the aircraft. Then, set the slung load cable length, the length of the line between the aircraft and the slung load, and the load will be ready to use in X-Plane.

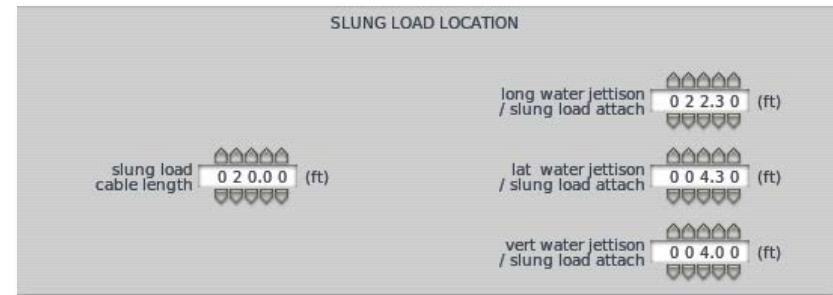


Figure 7.4: The slung load location controls

With a slung load enabled in Plane Maker, open the aircraft in X-Plane. There, in the Aircraft menu, open the Weight and Fuel menu. In the Fuel/Payload tab there, drag the “jettison weight” slider up to match the weight of the slung load object you will use. Then, click the small box near the bottom of the window labeled “slung load object,” navigate to the directory containing your slung load object, and select it. When you close out of the dialog box, the slung load will be attached to your aircraft and you will be ready to fly.

8. Modifying the Appearance of an Aircraft

An aircraft in Plane Maker may have a paint job applied to it by telling Plane Maker how to drape an image file over its model, or you can use 3-D objects (as might be created in Blender, Maya, 3ds Max, etc.) attached to various points of the aircraft to achieve a much higher quality appearance.

I. Creating a Basic Paint Job

The effects achievable by draping 2-D image files over a 3-D, Plane Maker-created aircraft model are perfectly acceptable, albeit not as impressive looking as what can be done with 3-D modeling tools. Creating a basic paint job in this way requires only Plane Maker and the image editor of your choice.

Before beginning, be sure that your ACF model is in its final or near-final form; changing the shape of the fuselage, the wings, etc. later would require you to modify the image file used in your paint texture, possibly in significant ways.

We will be working primarily in the Visual Texture Regions dialog box, which is launched from the Expert menu. This dialog is used to specify which portions of your PNG texture images will be draped over each body of your aircraft. You can use the tabs along the top of this window combined with the radio buttons on the left to select which specific part you will edit. You can click and drag the regions covered by a part using the large box in the center of the window. Additionally, if you plan to use two image files in your aircraft's textures, you can check the box next to a part labeled "use second texture." In that case, the area of the texture image available for draping over that part will come from the second texture rather than the default one.

For instance, if you wanted the entire top half of the default image file for your aircraft to be draped over the left side of your fuselage, you would:

1. Select the Fuselage tab at the top of the dialog box,
2. Click the radio button labeled "edit left side of body," and
3. Click and drag the flashing red box until it was around the entire top half of the image.

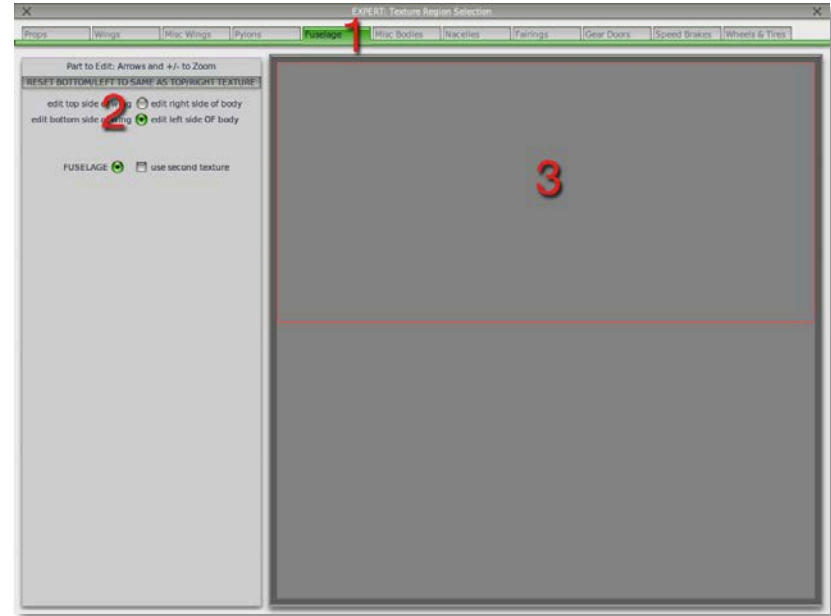


Figure 8.1: Editing the portion of the image used to texture the left side of the fuselage

Ideally, once your aircraft model is ready to use, you will set the regions of your texture to use with each part of the aircraft, then let X-Plane create a "starting-point" texture map, which will be divided according to the geometry of your aircraft's parts and your settings in the Visual Texture Regions dialog box. This starting-point can be opened in your image editor of choice and recolored or blended with a photo of your aircraft.

To create this starting-point texture, open the Special menu and click Output Texture Map Starting Points. This will create

one or two PNG files, depending on your use of the “use second texture” checkboxes. For instance, **Figure 8.2** shows the starting-point image file created for a Van’s RV-7. If you have not changed the locations of your aircraft’s bodies using the Visual Texture Regions, X-Plane will use the default locations, sizes, and shapes for each of your aircraft’s pieces.

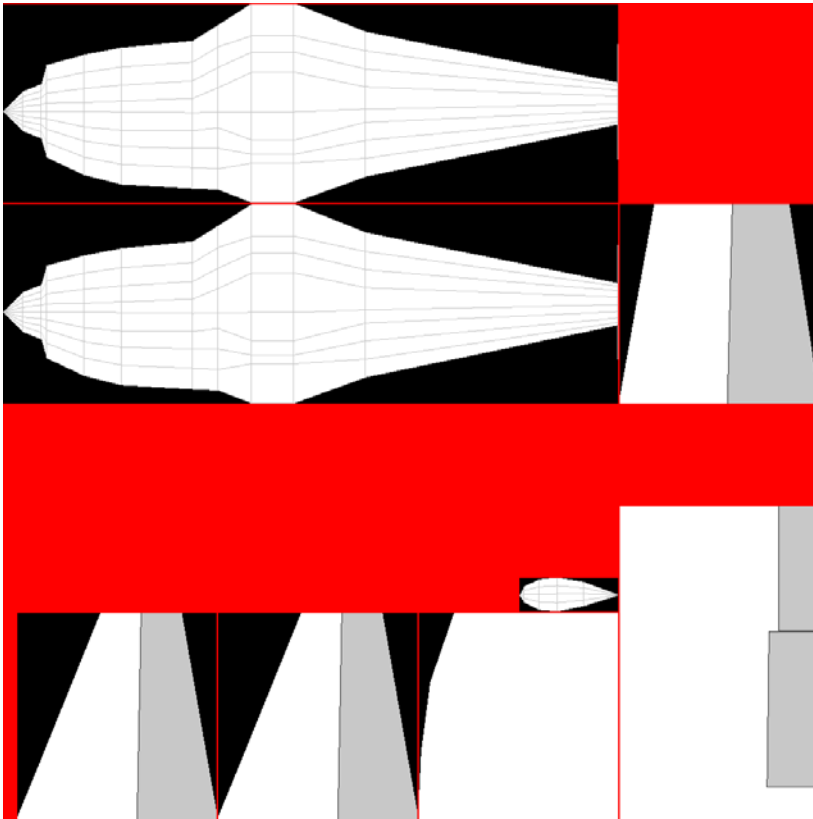


Figure 8.2: An example of the starting-point image file used in texturing an aircraft

These image file(s) will be saved in your aircraft's folder with the proper names. The first image (or the only one, as the case may be) will be called `[ACF file name].paint.png`. The second image, where applicable, will be called `[ACF file name].paint2.png`. Note that in order for Plane Maker and X-

Plane to find the image textures, they must keep these names.

Note that images used with an aircraft file must have dimensions (in pixels) that are a power of two. For instance, the image could have a resolution of 512 x 2048, 1024 x 1024, 2048 x 1024, and so on, with a maximum resolution of 2048 x 2048. The files that Plane Maker outputs will abide by these rules.

Using the starting-point images from Plane Maker, you can create painted or photo-realistic textures. After modifying the image files, open the Special menu and click Reload Textures (or press the T key) to refresh the textures from your files.

For a step-by-step guide to creating a simple photo-realistic texture, see [this tutorial](#) on the X-Plane Wiki.

A. Fine-Tuning a Paint Job

As discussed in the section above, the Visual Texture Regions dialog box can be used to modify the portion of your texture image used for each part of the aircraft. Modifying these regions using the mouse, however, will always be limited in precision.

To gain fine control over the texture regions used for a part of the aircraft, use the Body Texture controls found throughout Plane Maker (for instance, in the windows for creating the fuselage, miscellaneous bodies, wings, wheels and tires, engine nacelles, and weapons).

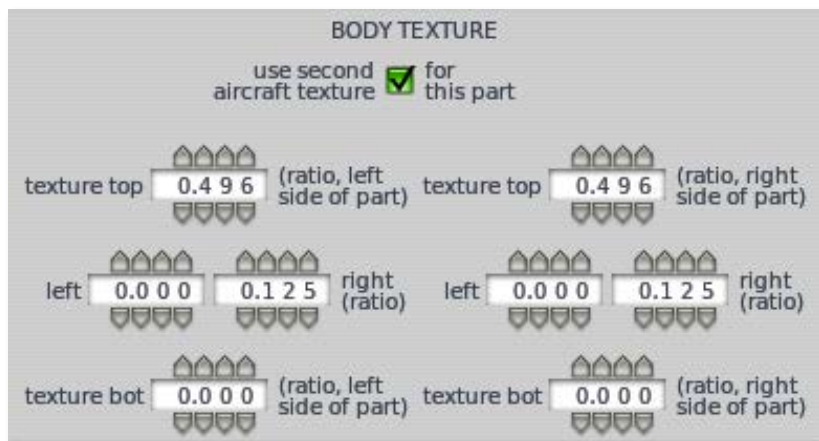


Figure 8.3: The Body Texture controls, used for fine-tuning the portion of the texture draped over a given part

In the Body Texture box are two groups of four input boxes. The four boxes on the left specify the portion of the texture file to use with the left side of this part of the aircraft, while the four boxes on the right control the right side of the part. Each side has a top, left, right, and bottom coordinate, which is specified as a decimal portion of the width or height of the texture. Note that the “origin” here is the bottom left corner of your image file. Thus, if a body on the aircraft had its texture region set as follows, it would use the bottom left quarter of the texture:

- Top = 0.5
- Left = 0.0
- Right = 0.5
- Bottom = 0.0

Use these controls to fine-tune the placement of a texture, or to ensure that parts are not overlapping.

II. Adding a Livery

A livery is a second set of paint textures that can be selected in X-Plane by opening the Aircraft menu and clicking Open

Livery. To use an image (such as an alternate version of your normal texture image) as a livery, save it with the same name as the original paint texture (that is, as `[ACF file name]_paint.png` and `[ACF file name]_paint2.png`), but place it in a directory with a path like this:

`[Aircraft folder]\liveries\[Name of livery]\`

For instance, the complete path for an aircraft's second livery might be:

`X-Plane 9\Aircraft\Bonanza A36\livery\
Red with accents\A36_paint.png`

Compare this to the location of the default paint scheme, which would be:

`X-Plane 9\Aircraft\Bonanza A36\
A36_paint.png`

Note that you must use the same placement of the aircraft's parts in each of your liveries; that is, the fuselage, wings, wheels, etc. must all be in the same place, respectively, in each image.

To view and edit a different livery in Plane Maker, go to the File menu and select Open Livery.

If you save the aircraft file after loading a certain livery, that livery will automatically be applied when you open the aircraft in X-Plane in the future.

III. Creating 3-D Objects for an Aircraft

In X-Plane, high-quality 3-D objects may be used as overlays for parts of the aircraft, for 3-D cockpits, or for elements of the scenery.

In the case of aircraft objects, only the Plane Maker-created .acf file can be used in the flight model. X-Plane uses this file only to determine the aircraft's flight characteristics. Because

of this, the ACF format is highly specialized and could never be used as a sort of all-purpose modeling format.

While Plane Maker is perfectly adequate for entering the design of the plane—it is reliable and easy to use—Plane Maker is *not* a 3-D modeling program. Instead, it is used to simply lay out the basic aerodynamic shapes and properties of an aircraft. This results in a model that looks okay, but not great. Plane Maker *cannot* make the complex model required for a 3-D cockpit, and it cannot create a highly detailed model of the craft as a whole to overlay the basic Plane-Maker model from which flight physics are calculated.

Instead, you can use a 3-D modeling program (such as 3ds Max, Blender, Google SketchUp, or AC3D) to create these objects. You can use any modeler able to export to the X-Plane OBJ file format. Many of the more popular modelers have plug-ins available to enable this; even if your modeler does not support it, you may be able to export to AC3D and save to an OBJ from there. Note, however, that the X-Plane OBJ format is *not* the same as the Alias OBJ format.

Regardless of which modeler you use, note that in order to use the OBJ with X-Plane, the file must use one texture per object.

You can find plug-ins for exporting from AC3D [on the X-Plane Wiki](#). For exporting from Blender or SketchUp, see Jonathan Harris' plug-ins [on his site](#). For danklaue's updated Xplane2Blender script, see its [X-Plane.org Download page](#).

The easiest way to get started modeling an aircraft is to let Plane Maker create a starting point OBJ for you. To do this, first create the ACF version of the craft in Plane Maker. Then, open the Special menu and click "Generate OBJ from Aircraft." Plane Maker will create a file called "aircraft.obj" in your top-level X-Plane directory. This OBJ can then be imported into your modeling program for further editing.

Note that, in the export, Plane Maker will ignore any parts of

the aircraft set to invisible. If you want all parts of the aircraft in your exported OBJ, open the Invisible Parts dialog box from the Special menu and click the "Show all parts" button.

IV. Attaching 3-D Objects

Having created .obj files for X-Plane per the proceeding section, you can add objects to your aircraft file in one of two ways. The 3-D cockpit object will automatically be added to the aircraft when it is saved as [ACF file name]_cockpit.obj in the top level of the aircraft's directory. Other objects must be manually added to the aircraft using the Miscellaneous Objects dialog box.

While miscellaneous objects can use a texture file with any name they specify (so long as the OBJ file references it), the 3-D cockpit must use a texture named [ACF file name]_cockpit_texture.png, and it must be stored in the aircraft's top-level directory.

Miscellaneous objects (all OBJ files which are not [ACF file name]_cockpit.obj) must be stored in your aircraft directory, in a subdirectory called "objects."



Figure 8.4: Controls for adding a miscellaneous object

With the miscellaneous objects saved in the correct location, open the Miscellaneous Objects dialog box from the Standard menu. Using the two tabs in this dialog, you can attach up to 24 objects to the aircraft. To place an object in a given "slot" here, first click the small square in the left-center of the window. This will open a standard "Open File" dialog box, where you can navigate to your aircraft's "objects" folder and select an OBJ file.

With the object loaded, you can use the standard position

controls (as described in the section “**Fundamental Concepts**” of Chapter 3) found here to change the object’s location and heading. Some aircraft designers, however, prefer to have the relative positioning of each piece of the aircraft set in their 3-D modeler, thus bypassing the positioning in Plane Maker.

Attaching a miscellaneous object to a part of the aircraft (using the drop-down menus on the far right) will cause the object to track the movement of that part. This is useful, for instance, when an object needs to move up and down with an aileron.

Finally, note that the lighting used on a given 3-D object depends on the lighting settings here. The cockpit object will have interior 3-D lighting (as described in the section “Configuring Internal Lights” of Chapter 6) applied when the “Cockpit object gets interior lighting” box, near the bottom the screen, is checked. Other objects will have lighting applied to them based on the drop-down lighting menu on the right side of the screen.

In X-Plane, interior light from the aircraft is applied only to the objects set to be “inside.” Objects whose lighting is set to “glass” will be drawn last and will be excluded from shadow calculations. Note that only objects tagged as glass will be drawn as properly translucent. This means that cockpit objects that might otherwise include windows should be split apart in a 3-D modeler so that the glass windows are a separate object from the rest of the cockpit.

A. 3-D Object “Bouncers”

Plane Maker supports up to 14 “bouncers,” objects which can move around in the cockpit based on the aircraft’s turning and acceleration. These might be maps, pets, people, or snacks. To use a bouncer, you add an OBJ to the cockpit as usual, as a miscellaneous object. Then, after telling Plane Maker that you are using this bouncer, you can use a plug-in to animate

this object based on the bouncer’s datarefs.

To input this bouncer’s features in Plane Maker, open the Systems dialog box from the Standard menu. There, open the Bouncers tab. For each bouncer you intend to use, check the box labeled “has this bouncer.” Check the “bouncer can float freely” box if this object is not tied down; in this case, X-Plane will not constrain its motion in the vertical axis.

Then, indicate how much acceleration (in g-force units) the bouncer experiences when the aircraft’s engine is redlined. Input the spring and damping constants for the longitudinal, lateral, and vertical axes, which will determine how forcefully the object is held in place. Finally, set the maximum travel, in meters, as the farthest the bouncer is allowed to move before X-Plane simply stops it.

With the bouncer thus configured in the Systems dialog, you can create a plug-in to move the object by reading from the following datarefs:

- `sim/flightmodel2/misc/bouncer_x`, the lateral offset in meters from default for this bouncer
- `sim/flightmodel2/misc/bouncer_y`, the vertical offset in meters from default for this bouncer
- `sim/flightmodel2/misc/bouncer_z`, the longitudinal offset in meters from default for this bouncer

V. Changing the Visibility an Aircraft’s Parts

When using 3-D objects created in a modeling program such as AC3D or Blender, you may want *only* the OBJ versions of a given part on the aircraft to be visible. This might be the case if, for instance, the Plane Maker-created ACF version of your fuselage was poking through the much prettier OBJ version in places. Or, you may have exported a starting-place OBJ of the entire aircraft and modified it in your 3-D modeler from there. In this case, there is no reason for the Plane Maker version of the aircraft to compete with the modeler-created one.

To handle these situations, Plane Maker allows you to make parts of the aircraft invisible. Using the Invisible Parts dialog box, found in the Expert menu, you can simply check the boxes next to any parts you don't want drawn, or use the "Show all parts" and "Hide all parts" buttons to quickly change all the parts. Regardless of their visibility, X-Plane will still calculate physics on all the aircraft's parts.

9. Performing a Test Flight

At some point—any point you choose, really—you will need to bring your aircraft into X-Plane and test it out. A typical test flight might include:

- checking all control surface movements (by switching to an external view and giving full deflection in each direction for all controls),
- noting the aircraft's ability to fly straight-and-level (how much trim it requires, etc.),
- confirming that the center of gravity feels like it is where it should be, and
- checking the lift and drag vectors (by pressing the keyboard's / key by default) and confirming that they appear as expected.

Ideally, when performing a test flight, you will have enough experience with the real-world version of the aircraft to know how it *should* feel. Following a test flight, your goal is to be able to go back into Plane Maker and track down the source of any inaccuracies.

When modifying the flight model to match real-world performance, be careful that you do not modify your aircraft in a way that ignores the real-world meaning of the parameters you are changing. Even in the (unlikely) event that this is an acceptable fix at the moment, you risk degrading the quality of your aircraft in future versions of X-Plane.

For instance, suppose that, for some reason, your plane feels sluggish when turning. You might try increasing the area of the control surfaces, knowing that you had already matched the size of the real-world control surfaces, and find that the problem goes away.

This is absolutely not way to go about changing the plane's flight characteristics in X-Plane. The control surfaces' area

does not simply represent a variable that can be changed to affect how a plane turns. The surface area must match the way the real-life airplane is built. If you increase the area, straying from reality, to “fix” a problem, what you really do is create a new problem later when X-Plane goes to simulate your model.

Simply put, if you put *intentional errors* into your plane's flight model to compensate for limitations of the simulator, any future improvement in the simulation accuracy of X-Plane is almost guaranteed to make your plane fly *worse* in the future.

10. Distributing an Aircraft

Once an aircraft is complete, you probably want to distribute it on the Web. To do so, make sure you have a single folder that contains your airplane (the .acf file, objects, textures, and so on). That folder might have many sub-folders, such as “cockpit_3d” or “airfoils.” Many aircraft dependencies (including 3-D cockpits, airfoils, and objects) are not guaranteed to work correctly unless they are in the correct sub-folders inside your aircraft folder. Also be sure your ACF file has a recognizable name!

With your aircraft folder ready to go, compress the whole folder into a .zip file. Windows users can do so by right-clicking on the folder, moving the mouse down to “Send to,” and selecting “Compressed (zipped) folder.” Mac users can right-click (or Option-click) on the folder and chose “Compress [*folder name*].”

With your ZIP file ready to go, all that’s left is to upload the aircraft. X-Plane.org is a great place to do so. You can create a free account, then [upload your file](#). This is a great way to let others see your design. You could even do this for commercial purposes, like letting the world test-fly your company’s new airplane design... at zero cost to you!

Glossary of Terms

.acf file—an aircraft file for use with X-Plane.

Aileron—control surfaces mounted on an airplane's wings which move in opposite directions to roll the craft.

Airfoil—the cross-sectional shape of a wing. Different airfoils have different lift and drag properties at different speeds and angles of attack.

Aspect ratio—the ratio of a wing's length to its chord width. A low aspect ratio results in short, stubby wings, while a high aspect ratio results in long, narrow wings.

Blade pitch (propellers)—a propeller's angle of attack, the angle at which it meets the air. Variable pitch propellers are able to rotate the propeller's blades along their long axis, thus changing their pitch.

Chord—the line connecting the leading edge of an airfoil to the trailing edge.

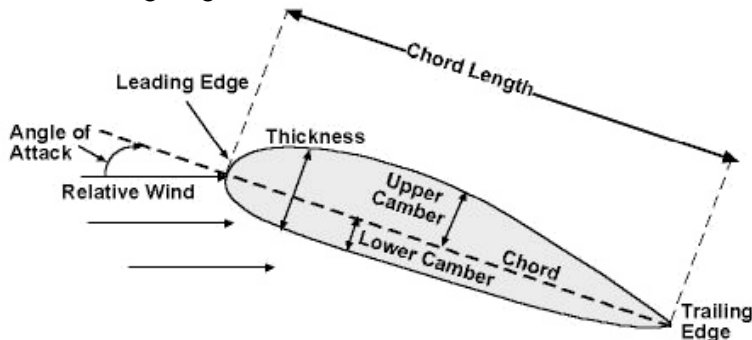


Figure 0.1: A diagram indicating the chord length on a wing's cross-section (the airfoil)

Chord length—the distance between the leading and trailing edges of an aircraft's airfoil.

Dihedral (wings)—the upward or downward angle of the wings when viewing the aircraft from head-on, as seen in Figure 0.2.



Figure 0.2: Wing dihedral, the upward angle of the wings, illustrated (thanks to Wikimedia Commons user [Steelpillow](#) for the image)

Elevator—control surfaces mounted on an airplane's horizontal stabilizer (a part of the tail) which move together to change the pitch of the airplane.

Flap—a control surface mounted on the trailing edge of a wing (the edge facing toward the tail of the aircraft) which is extended in order to lower the airplane's stalling speed and increase the drag acting on it.

Incidence (wings)—the upward or downward angle of the wings, when viewed from the side of the aircraft, as seen in Figure 0.3.

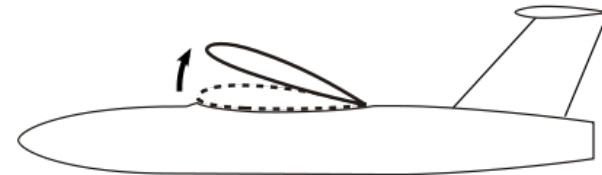


Figure 0.3: Variable wing incidence illustrated on a high-wing plane (thanks to Wikimedia Commons user [Steelpillow](#) for the image)

Livery—a certain paint scheme for an aircraft. Different liveries can be selected in X-Plane to give an aircraft a different paint job.

Pylon—a hard point on an aircraft, where things like engines or weapons can be mounted.



Figure 0.4: An Airbus A380's engine pylon (thanks to Wikimedia Commons user [David.Monniaux](#) for the photo)

Reference point—the arbitrary point of the aircraft around which nearly all objects' positions are set.

Root (of a wing)—the part of an aircraft's wing which is closest to the fuselage (body) of the aircraft.

Rudder—control surfaces mounted on an aircraft's vertical stabilizer (a part of the tail) which move in opposite directions to change the yaw of the craft.

Slat—control surfaces mounted to the leading edge of a wing which extend to allow the aircraft to operate at a higher angle of attack, useful when near stall speeds.

Speedbrake—

Standard atmosphere—the International Civil Aviation Organization (ICAO) defines the standard atmosphere at mean sea level to be 15°C (59°C) with 1 atmosphere air pressure.

Sweep (wings)—the angle forward or backward that the wing points, when seen from above, as seen in **Figure 0.5**.

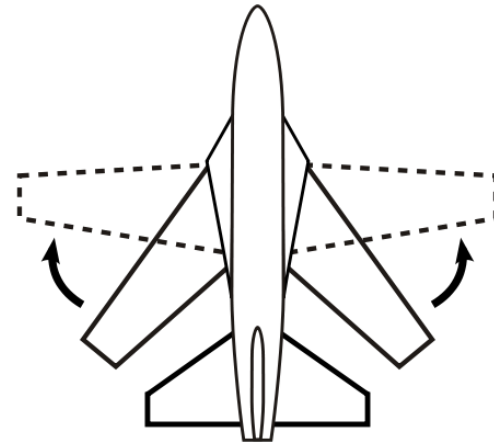


Figure 0.5: Variable wing sweep illustrated (thanks to Wikimedia Commons user [Steelpillow](#) for the image)

Tip (of a wing)— the part of an aircraft's wing which is farthest from the fuselage (body) of the aircraft.