Introduction to Flight Dynamics

A word from the author

Before I start the tutorial, I want to introduce myself. I studied mechanical engineering and mathematics, and I'm working in research. My focus is developing methods that can compute stable motions for complicated dynamic systems, like an airplane or a satellite, for examples.

But I'm not a pilot. Some of my friends are real-life pilots, so I only have second-hand knowledge of flying. In what follows, you will find mechanical explanations of terms used to make an accurate .AIR file, but I can not provide you with knowledge that involves flying the plane.

Since .AIR files are related to FS98 and to CFS, I chose a WWII jet aircraft, the Messerschmitt Me262 B-2/U-1. I hope you like it, since you will spend some time with it. The Messerschmitt's .AIR file, ME262B.AIR is locatedin the AIRCRAFT FACTORY 99 folder. If you wish, you may load it into FDE to follow the discussion.

*.AIR files are very complicated. Today we will introduce the most important settings, allowing you to create airplanes that fly well, accurately reflecting real-world flight dynamics. Every setting won't be explained (in fact, even we don't understand all of them), but we'll lead you through the most important, and you are encouraged to experiment with various settings.

Gather information

Collecting information about your aircraft is the first step in creating an accurate flight model. You may use many sources to gather data. For today's airplanes, you will find all of the information you need and more from the company that build this airplane. If you have access to the Internet, you will find most of the information at the company's Webpage. Your local library or bookshops also have good resources. Collect everything you can get. Beside technical specifications (length, top speed, etc.), try to find reports from pilots who fly your plane. Our example, the Messerschmitt Me262 B-2/U-1, is a difficult craft for gathering information, because it is very old and very rare. In fact, not more than two of them were built. Therefore, it may take some time to find useful information. After spending hours on the Internet and visiting several search engines, I collected the following data:

Length:	42.71 ft
Wing span:	41.01 ft
Weight:	10,279 lbs / 16,755 lbs
Power:	Two Junkers Jumo 109-004B, 1,984 lbs static thrust each.
Peak Performance:	835km/h at 6,000m, approx. 810km/h at sea level.

Next I visited a local library and left with a lot of technical information, including original drawings of the airplane‘s engines’ performance. This was enough technical information on the plane, but I still had no information about the plane‘s handling. Finally, I found an Internet discussion group dedicated to this airplane, and after asking for help, I was provided with the information I needed. For example:

Brakes and ground handling

The brakes were very poor, which made ground handling difficult.

Take-off and initial climb

All take-offs were running take-offs, due to the poor brakes. The ground roll was slightly longer than ordinarily required. The nose wheel could be lifted off at 100 mph IAS, and the take-off was made at about 120 mph in a nose-high attitude.

Before we start editing the .AIR file, prepare some useful helpers. Since we need to input very detailed information about the dimensions of the airplane, we need technical drawings of the plane. Typically, such drawings are difficult to obtain. I help myself with blueprints of the plane from above and from the side. Since we will need to measure some distances, I also keep a ruler handy. If you designed the airplane by yourself with FSFS or AF99, you can also make your blueprints from the visual model. For each of these drawings, we need to compute the scale of the picture.

For each picture, compute the scale by measuring the length of the blueprint fuselage with the ruler and then divide the actual fuselage length (in feet) by this number. For our example, the length of the fuselage on my blueprint was 22.7cm, so my scale is 42.71ft / 22.7cm = 1.88 ft/cm. If I want to know a specific length, say the length from the nose to the cockpit, I just measure it with the ruler and then multiply the length by 1.88ft/cm, and I get the distance between nose and cockpit in feet. You will also need a calculator that can calculate tangents (typically the [Tan] key) of an angle.

Last, you need a program that is capable of editing .AIR files. At the time I wrote this, I found two that satisfied me. The first one, called AirEd, was made by William Roth, and the second one, Flight Dynamic Editor, is from Abacus Software. Each has advantages and disadvantages that I won't discuss here. For the rest of this introduction, we'll use Abacus's Flight Dynamic Editor. Let's start with the fun.

Sitting on the ground

In this section we will edit everything we know about the physical dimensions and capabilities of the plane. Try to make this as accurate as possible, since small mistakes can screw up your plane. The main difference between this section and the next is that you typically will edit entries in this section just once, while you may edit entries in the next section several times. I won't explain every entry in this section. Some are self-explanatory, like "Wheel Brakes" or "Flaps," where you have to enter whether the plane has wheel brakes or flaps. It is good idea to look over the entries before you read further.

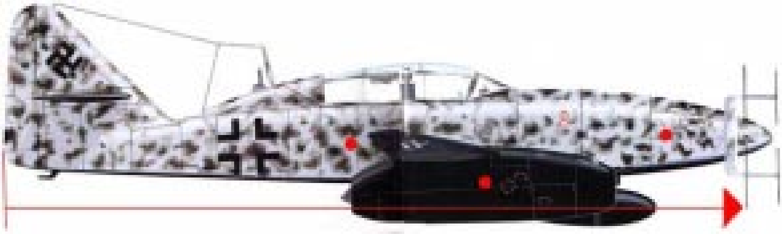
To understand some of the entries in the .AIR file, one should know something about mechanics. If you didn't study engineering, you may not be familiar with these terms. Regardless of your education, my aim is to help you understand the flight models, as easily as possible. I know a lot of people think that they are not able to understand "technical things." I don't believe that and will not let you go with such an excuse.

Center of gravity is the center of everything

Some entries in the .AIR file describe positions and dimensions of parts of the airplane. While we just need a unit (in feet, for example) to describe a length, we need a coordinate system to describe a position in 3-D space. Positions are always relative to something else. The coordinate system used in the .AIR file is relative to the aircraft's *Center of Gravity* (CoG). Since this term is also used in common language, most people have an idea what it means. But since the CoG is very important for our entries in the .AIR file, I will go more into detail here.

Assume that you want to balance your aircraft on the end of a needle. We have to know where to place our aircraft on that needle so that the airplane will not fall on the nose, tail or one of the wings. After we do this, we know that the aircraft‘s CoG lies on the vertical line that extends through the needle. See the vertical line in the figure.

We redo this two more times by placing the nose of the aircraft on the needle and one of its wingtips on the needle. Each time we draw a vertical line through the needle and the aircraft. Doing this, we will find that all three lines intersect at one point: the CoG of our aircraft. Obviously, we are not able to do this experiment, but this may provide you with a basic understanding of how to predict this point.



In practice, you have two ways to find this point when you don’t have the specifications for your aircraft. Either you try to guess it, if you believe that you have a good feeling for things like that, or you try to compute it. But how does one compute this? In fact, this is a very time consuming task even for an engineer, and you need very detailed information about the aircraft to do this exactly. Nevertheless, I will show you how to approximate this value. We start by subdividing our airplane into smaller pieces, which are more homogeneous than the whole plane. For my example these elements are: the two engines, the nose (containing the weapons) and the rest of the structure (fuselage, wings, elevator, etc.). Next we have to know or guess the weights of these subparts. For the Me262 B-2, I found:

Rest of structure = struc	2,068kg
Nose with weapons = nose	520kg
Two engines = eng	2,074kg
Empty weight = ew	2,068kg + 520kg + 2,074kg = 4,662kg (10,279lbs)

Now we make a little drawing with the longitudinal middle points of these parts. Take a look at the previous figure, the points are the middle point of my subparts. We are nearly finished now. After measuring the distance of our subparts from the tail (see figure) we can compute our longitudinal position of the CoG from the tail (*long(CoG)*), which is:

```
long(CoG) = (long(struc) * struc + long(nose)* nose + long(eng) * eng)
/ ew
```

Here *long(struc)* is the longitudinal distance between the middle point of *struc* and the tail, *struc* is the weight of the structure, *long(nose)* is the longitudinal distance between the middle point of the nose subpart from the tail, and so on. If you subdivide your plane into more parts, just extend the above formula.

Typically, airplanes are symmetric in the lateral direction, so you don't need to do this computation for the lateral direction. In this case, the lateral position of the CoG is right on the symmetry axis. I also never compute the vertical position, since the errors produced by guessing this position are small compared to the overall dimensions of the aircraft. After we include our CoG into the blueprint, we can start editing our .AIR file. Be sure that you set the CoG in FS or AF99 to the same point.

Entering your information

Open your .AIR file in the Flight Dynamic Editor. Click **File | Open,** select the aircraft you'd like to edit and click [Open].

The .AIR file is separated with section numbers. FDE displays the section number of the selected attribute on the right of the program window.

The Aircraft Description field allows you to enter data that appears in FS/CFS as a description of the aircraft.

The next entry, Aircraft Specifications, lets you input specifications of the aircraft. The default 737-400 of FS98, for example, has the following entries:

Wingspan:	94 ft, 9 in (28.88 m)
Max. Take-off Weight:	138,500 lbs (62,830 kg)
Engines:	Two CFM 56-3C-1 turbofans rated at 23,500 lbs (104.5 kN) static thrust ea.
Normal Cruise:	.74 Mach at 30,000 - 35,000 feet
Max. Speed:	340 kts IAS or .82 Mach (whichever is lower)
Range:	2,700 nm (5,000 km)
Stall Speed, Clean:	172 KIAS

In fact, you can enter anything here that you think is interesting to know about the aircraft. This entry does not change the behavior of the aircraft in the simulator.

The next section that is important is section 100, Aircraft Simulator Identifier. Here you have to enter: *sim1*. If you enter *sim99*, for example, the plane will not work in the simulator.

Adjusting the main dimensions

Main Wing

Scroll down to section 1204 of the .AIR file, Main Wing, and enter the following values:

- Under Main Wing Area, enter the area of the main wing in square feet.
- Under Main Wing Span, enter the span of the main wing, in inches.
- Under Main Wing Chord, enter the mean value for the main wing, in inches. You can compute this value by Chord(inches) = Area(square feet) / Span(inches) * 144.

- Under Main Wing Dihedral, enter the dihedral angle of the aircraft. Look at the above picture in order to find this value. The larger this angle is, the more the aircraft will be stabilized against rolling. The path of a body‘s motion (a satellite, for example) is stable if you can push the body a little bit out of the path and the body will return to it by itself. If an aircraft is stabilized against rolling, it will roll back to its default position (bottom down, cockpit up) when not pressed by external forces (such as the ailerons, for example). But you also have to think of another important point. The more the aircraft will be stabilized when flying upside up, the more it will be unstable if it flies upside down. So, for an airplane like the Extra300, it is good to avoid stabilizing it too much against rolling. In FDE, you can enter this value as the angle in degrees from horizontal.

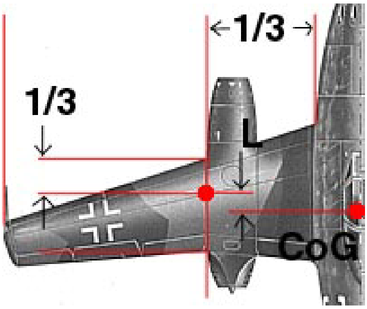
- The next value we will enter describes the lift of the main wing. It is referred to as Main Wing Efficiency in FDE. The larger this value is, the more lift will be produced by the main wing. The best way to edit this value is to find one of the stock FS98 or CFS aircraft that is comparable to your aircraft and use its value. We will use this entry later to adjust the climb rate of the aircraft. In the mechanical model of the simulator, this entry describes the profile of the main wing.

  A profile of the wing is such that the airflow under the wing goes a shorter way from the front to the end of the profile than the air flowing above the wing. This causes the air above the wing to have less pressure than the air under the wing. The pressure difference multiplied with the area of the wing equals the lift. In fact, the pressure difference is not constant in any direction of the wing, so the formula above is much too simple, but it will give you an idea by which values the lift is determined.

- The Main Wing Angle of Incidence, the next entry in the main wing section, is the longitudinal angle between the wing and the fuselage. Again, if you have no technical information about your plane, use a comparable aircraft to make a good initial choice here. For an aircraft to produce lift in level flight, this value must be a positive number. Typically, the fuselage of the aircraft should not be nose up or nose down while you are flying at cruise speed.

  If you find that your plane has its nose up during level flight at cruise speed, you must increase this value; if the nose points downward during level flight, decrease this value. Nevertheless, this is part of the fine tuning process of your aircraft, so don‘t fret over it now. In FDE you have to enter this value in degrees.

- Now we will enter the longitudinal position of the lift on the wing. You may wonder, since the lift is obviously produced over the whole wing, why we have to enter a position for that force (lift). If the simulator would really model the wing that way, you would never be able to fly your plane in real time, so in the model of the simulator the continuous lift of the whole wing is replace by a single force.



Therefore, we have to tell the sim where this force is located. The longitudinal position of the lift depends on the geometry of the wing and its profile. A good guess is to choose the profile that is 1/3 of the length of wing away from the fuselage, and then take the point that is 1/3 of the profile length away from the front of the wing. Take a look at the picture to understand. *L* is the value we want to know here. Enter this value in inches. The entry is named Main Wing Center of Lift Fore+/Aft- of C of G (inches).

- Last we will input whether our plane has winglets. A winglet is a small vertical extension at the tip of a wing, used to improve aerodynamics. Wings with winglets don’t produce as much turbulences at their tips as wings without winglets. If you add winglets to the simulator model, the wing will have more lift and less drag. “Winglet?“ is the FDE entry for this value.

Horizontal and Vertical Stabilizers

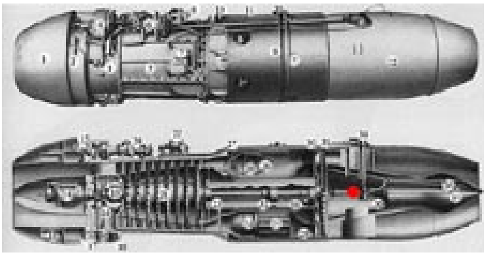
These sections are similar to the Main Wing section of the .AIR file, so I will not go into detail here. I‘ve just a few words to say about the Horizontal Stabilizer Efficiency Factor (section 1205). As for the main wing, you can control the lift with this value. I use it to trim an aircraft at its cruise speed. The idea is that the trim of the elevator should be neutral when your plane flies at cruise speed. If you find that your plane has its nose up while flying at cruise speed with a neutral trim, you can increase the efficiency value of the horizontal stabilizer.

Engines

- First, we have to specify which type of engine our aircraft has. Go to section 310, Engine Type, and enter “0“ for a piston engine, “1“ for a jet, “2“ for a glider or “3“ if you are building a helicopter.
- In Number of Engines (section 311), enter the number of engines. My Me262, for example, has two engines.
- Now we have to tell the simulator where our engines are located. This is done under Engine Locations (section 1002). All entries are relative to the CoG. This means that for Engine 1 Position Right+/ Left- C o G (inches), you have to enter the lateral distance between engine 1 and the CoG, in inches.

  Typically, an engine is not a single point, but in order to edit this entry you have to replace the engine with a single point. The question arises, which point shall we use? To understand this, we have to remember that we are talking about a simulator. The simulator replaces an engine with a single force that pushes forward. So, for a piston-engine aircraft, you have to choose the middle point of the propeller, and for a jet engine, the middle point between the exhaust cone and the combustion chamber.

  Look at the figure:



For a piston-engine aircraft you need to tell the simulator if the propeller drives with constant speed or is fixed to the engine under Propeller Type (section 330). For a jet, go to Jet Engine (section 600). I will not go more into details for the engines. If you are interested in this, I suggest you read a book about it. If you don’t want to do that, just copy this section from a plane that has nearly the same engine(s) as your aircraft and adjust the main values (horsepower, prop diameter, thrust and max. RPM).

Fuel tanks

First, we have to enter the specific weight of the fuel, in pounds per gallon. The associated entry is found in Fuel Weight per Gallon (section 312). In case of a piston-engine aircraft, this value is typically “6;“ for a jet, it is “6.6016.“

Next, enter the locations of the different fuel tanks. Flight Simulator can handle up to seven different fuel tanks: Center, left/right Main, left/right Aux, left/right Tip. In the .AIR file you will find four locations for the fuel tanks under Fuel Tank Locations (section 1003). Only four are listed, since the remaining three are located by changing the lateral value from right to left (*i.e.*, changing the entry from positive to negative or *vice versa*).

Again, all of these values are relative to the CoG and are measured in inches. Flight Simulator has two rules for handling the different tanks. All tanks on the left side contain fuel for engines on the left side, and all right-side fuel tanks feed engines on the right side of the aircraft. Nevertheless, if your plane just has tanks on the left side, the engines on the right side will still work. If more than one tank are on the left or right side, first the fuel from the Tip, then from Aux and then from the Main tank will be used. Several airplanes have rules that govern which tank shall be used first.

Today‘s jet airliners typically use tanks located toward the front first. My Me262 has two external tanks below the nose, plus one tank right before the cockpit and the one behind the cockpit. I found that if I first used just the drop tanks and the tank before the cockpit (as a modern jet would do), the plane crashes when I try to land. This is because the weight of the remaining nearly full fuel tank behind the cockpit causes the CoG of the plane+fueltank to be behind the main wheels.

I overcome the problem by assigning the drop tanks to the Aux tank, the tank before the cockpit to the Center tank and the tank behind the cockpit to the Main tank. This way, first the drop tanks and the tank behind the cockpit are used, causing the overall CoG to stay before the main gears.

Next enter the capacities (in gallons) of the different tanks in section 302, Fuel Capacity.

Placing the Aircraft in the Simulator

It's almost time to take our plane into the simulator. But first we need to enter two more sections so that we will be able to try our first take-off. The first time I tried FS, I wondered how the simulator knows if the plane hits the ground. You may think that this is fairly simple, since it would just determine if any of the boundaries of our model contact the ground. Since the visual model typically has a very complex shape, this is not possible to do in real time. So, the simulator uses a much more simplified model for this.

Aircraft Shape

- In section 1005, Scrape Points Position, you may enter up to three points of your aircraft. These three points describe a bounding box of our aircraft. If this box hits the ground at a certain time, the simulator decides if the plane crashed. The decision value is the entry Scrape Point Crash Factor. Take your blueprints and measure the longitudinal, vertical and lateral distance of the nose, the tail and the tip of the right wing from the CoG, in inches.
- Edit the corresponding entries in the .AIR file for the Front Scrape Point Right+/Left- C of G (inches) (lateral distance of the nose from the CoG, typically 0), Front Scrape Point Above+/Below- C of G (inches) (the vertical distance of the nose from the CoG), and so on. Typical values for the crash factors are: 262144 (FS98) or 393216 (CFS). The higher this value is, the less likely the aircraft is to crash.

Once I downloaded a Horten Go229 (Nurfluegel) from the Internet. Although the plane was flyable, I was not able to start it. The problem was that even at full thrust, the plane just slowly (1mph) rolled at the runway. The reason for this problem was that the author set the scrape points such that the bounding box was inside the earth when the plane was on the ground. Obviously, the plane couldn't start, since moving underground is impossible in FS.

Aircraft weight and maximum speed

- First we will enter the dry weight of the airplane. To be more precise, we will enter the zero-fuel (FS) / zero-fuel/zero-ammo (CFS) weight of the aircraft. This is not the manufacturer's empty weight. The simulator handles the total weight of the aircraft as follows. It takes the dry weight and adds the weight of fuel. In CFS it also adds the weight of the ammo to determine the overall weight of the plane. The single weight we want for FS98 is the dry weight. However, this is different from the empty weight from the manufacturer. The manufacturer's data for empty weight is completely empty, with no passengers, baggage, freight, weapons, oil or fuel. In FS98, the weight of the payload will have to be accounted for by adding them to the empty weight. Go to Main Dynamics (section 1101) and edit the entry Zero Fuel Weight. For my Me262, I computed this value to 10,279 lbs.

v Since we are already in section 1101, we will also set the maximum velocity of the aircraft. You need to input this value in knots, not mph or kmh. One knot = 1.1508 mph = 1.8520 km/h. The field you have to put this value in is named Vmo. The maximum speed is the speed at which the plane can fly without losing control. The maximum velocity controls the overspeed warning and is a scale for some of the dynamic values, like the pitch, roll and yaw inertias.

v The last entry associated with speed is the maximum mach number of the airplane. Although this value is not that important in FS or CFS, I want to write something about it because it is very important in the design of airplanes that are faster than 500mph. Such an airplane has a critical mach number, which is determined by its design. If the plane flies faster than this number, several problems can occur, which depend on the design of the aircraft. In some aircraft, for example, the controls freeze, and the pilot is not able to move any of the controls. If the plane flies much faster than its critical mach number, it may even crash. We enter this value in Max Speed (Mach) (section 316). The maximum mach number for the Me262 is 0.85, which means 85% of the speed of sound.

Landing gear

Most of us have witnessed the Dancing Betty phenomena: You install a new airplane in FS and as soon as you start, the plane seems to fall down, bounce on the runway and sometimes even crashes. To understand this, we have to know how FS puts an aircraft into the simulator. FS first reads two values from section 301 of the .AIR file (CoG above Ground and Fuselage Angle) to position the plane in the sim, and then it "releases" the plane. If the landing gear, described in section 1004, are not already on the ground, the plane will fall. It is also possible that the initial placement places the aircraft's wheels under the runway; in this case the plane will bounce up as soon as it is released.

- Use your blueprints to determine the longitudinal, vertical and lateral distance of each of the gears from the CoG, in inches. Enter these values under Landing Gear (section 1004). For example, the Main Gear Position Right+/Left- C of G (inches) = lateral distance of the main gear from the CoG in inches. You have six entries to edit for Main Gear and Center Gear. Main gears are typically the gears under the wing, and nose/tail gear is the nose gear or the tail gear (taildragger).

- Next go to section 301, Fuselage. First we will compute the fuselage angle, which can be calculated by the formula: FA = - arctan((NGPV - MGPV) / (NGPL - MGPL)) Note the minus sign. Here *FA* is the fuselage angle (in degrees), *NGPV* is Nose/Tail Gear Position Above+/Below- of CoG (in inches), *MGPV* is Main Gear Position Above+/Below- CoG (in inches), *NGPL* is Nose/Tail Gear Position, Fore+/Aft- of CoG (in inches), and *MGPL* Main Gear Position Fore+/Aft- CoG (in inches). This angle is used for the initial placement of the plane in the simulator; it does not affect its angle during flight.

- Next we enter the CoG above Ground entry in the Fuselage section (301). This value can also be computed. The formula is: CoG Above Ground = -(LBG * TAN(-FA) + HBG) * 1500. Here *HBG* is Main Gear Position Above+/Below- CoG (Section 1004-12) unless it's a taildragger, in which case *HBG* is Nose/Tail Gear Position Above+/Below CoG (Section 1004-24); *LBG* is Main Gear Position Fore+/Aft- CoG (Section 1004-16) unless it's a taildragger, in which case *LBG* is Nose/Tail Gear Position Fore+/Aft- C of G (Section 1004-28); *FA* is fuselage angle (Section 301-10), and *TAN* is the tangent of the angle inside the brackets (use your calculator to compute this value). Now our plane should no longer dance on the runway when it‘s placed in the simulator.

- Now we will edit the rest of the information for the landing gears. Return to section 1004. If your plane has retractable landing gears, set Type to “1.“ Furthermore, enter the front gear cycle times (the time the gear takes to extend or retract) under Gear 1 Cycle Time (seconds). Do the same for the left and right main gears. I typically set this value so that the landing gear lights turn to red at the same time the audio file for retracting ends. In FDE, beside the options of retractable (1) or not (0), you may also specify skid (2), floats (3) or skis(4).

- Next, enter whether the nose or tailgear is steerable. Not every plane has steerable wheels. Our example, the Me262, did not have steerable gear. Taxiing was accomplished by using the engines and the brakes. Enter this value for Steerable? (section 1004).

- Now go to section 1101 of the .AIR file, called Main Dynamics and edit the Braking Factor entry. This entry controls the maximum force of the landing gear brakes. Valid entries are between –32768 and 32767. The lower the entry is, the stronger will be your brakes. In fact, if you make them too strong, your plane can crash while braking. Examples 737: -25536, Learjet: -15536, Bf109G: 12000. Since I read that the Me262 had very poor brakes, I set this value to 18211.

- The last thing we have to do for the gears is to tell the simulator under which conditions the gears will crash and which forces the gear can absorb. In the real world, landing an aircraft causes an impact on the gears. Instead of these impacts, FS uses the impulse, which is the mass multiplied with the square of its velocity. Furthermore, it seems to use weights instead of forces.

  How is this applied to the landing gear? The model is rather simple. For each gear the simulator uses two weights—a minimum and a maximum—and a crash factor. If the actual force on the gear is bigger than the minimum and lower than the maximum weights, the contact between gear and runway is modeled with a spring and damper, causing descending oscillations. If it's below the minimum weight or bigger than the maximum weight, the gear jumps, which means the plane oscillates, but the motion is not damped. You need to understand this model if you encounter problems after you follow the next steps.

  Three values for each—the nose gear and the main gear—can be edited in section 1004, Landing Gear. These entries for the main gear are Main Gear Spring Loading Factor, Main Gear Damping Factor, Main Gear Crash Velocity. The first value, Main Gear Spring Loading Factor, is the maximum weight I talked about above. The second value, Main Gear Damping Factor, is the minimum weight. The last value is the crash factor.

  Set these values the following way:

	Main gear	Nose/tail gear
maximum weight	8 * minimum weight	7 * minimum weight
minimum weight	1/8 empty weight	½ empty weight
crash factor	500.000	500.000

Sometimes the first two values are really sensible. To check if my settings work, I fly three starts and three landings. For the first one I have a full fuel load, the second with 50% fuel and the last with 5% fuel. It took me some time to set the values right for our example, because the CoG of the Me262 is very close to the main gears and one of the main fuel tanks is far behind the main gears. With a 5% fuel load, very little force is applied on the front gear, causing the aircraft to bounce as soon as I tried to start. I overcome this by lowering the minimum weight value for the front gear so that the minimum weight = ¼ empty weight. In fact, if your plane bounces too much during takeoff and landing, try to lower the minimum values, not the maximum values.

That's it for this part of the tutorial. Now try your plane in the simulator and look at its handling. I typically found that the plane behaved nearly realistically at this point of editing the .AIR file and just need some fine-tuning to give it an overall good handling in the air.

Dynamics

This part of the flight dynamics introduction is quite different from the first part. Typically, you will edit entries we discussed in the first part once, but entries from this part more than once. Therefore, I grouped the entries here differently than those in the first part. Some are grouped by their mechanical meanings, like the five inertias, for example, and some to their associated dynamical meaning (pitch, yaw, roll). Nearly all of the values that control the dynamic aspects of the plane can only be set by comparing your plane with planes from FS98 or CFS.

Inertias (section 1101, Main Dynamics, and section 1001, Aerodynamics—Weight and Balance)

Inertias describe (roughly speaking) the likeliness of a body to rotate. If a plane has a large vertical inertia, for example, you need a rather big force to rotate the plane around the lateral axis through the CoG. FS and CFS use five inertias for predicting the aircraft's movement.

The first two can be found in section 1101, Main Dynamics. These are the vertical and lateral inertia. Before I explain how I determined these values for the Me262, I want to explain on which values inertias depends. Assume we rotate a small ball with mass (*m*) around a point (*p*) and the distance between the ball and the point (*p*) is *d,* then the inertia of the system is equal to md^2.

Actually, our airplane is not a single point, but this little example shows that the inertia is mostly predicted by the parts of the plane that are far away from the axis about which it rotates. Let's start with the vertical inertia. A comparable aircraft for my Me262 is the North American P-51d. If the Me262 would be a piston-engine aircraft with a single engine in the nose, we could easy compute the vertical inertia of the Me262 by taking the vertical inertia entry of the P-51 and dividing this value by the empty weight of the P-51d and multiplying the result with the empty weight of the Me262. Well, the 262 has two engines at the wings and none in the nose, so we can't make it this way. Remember our small example, that parts of the plane which are far away from the rotation line cause big inertias.

Since the P-51 had its engine in the nose and the Me262's engines are near the CoG, we can expect that the engines of Me262 will not cause a large vertical inertia. Since their weight was nearly half of the weight of the whole aircraft, I assumed that the 262 had a vertical inertia which is nearly as large as that of the P-51. Therefore, I set the vertical inertia to –121, which is the same value the P-51d has. The lower this value is, the larger is the inertia. This value also affects the turnrate.

Our next entry is the lateral inertia. This term describes how likely our aircraft will rotate around the vertical axis that goes through the CoG. In this case the engines of the Me262 will create a big inertia, since they are far away from the rotation axis. Therefore, I took the lateral value of the P-51, divided it by the empty weight of the P-51 and multiplied it with the empty weight of the Me262. The lower this value is, the larger is the inertia.

Now we'll look at section 1001, Aerodynamics—Weight and Balance. Here we find three inertias that describe the dynamic behavior of the plane. The lateral and vertical inertia are determined by the weight and geometric design of the aircraft. The three inertias in this section describe the likeliness of the plane to roll, pitch and yaw. These values also affect the turn rates of an airplane and the sensitivity to small forces. To be more precise, they control how much force you need to pitch, yaw or roll the plane. If these values are small, the plane will quickly react even to small changes of the associated control; if you set them high, the plane will react slowly. I read that the Me262 was a very sensible plane, so I took the values of the P-51 and divided them by 2. If you experience small oscillations around the longitudinal axis, increase the roll inertia. Use these values to give the plane a certain “feel“ (sensible, heavy).

Fuselage Drag Factor (section 1101, Main Dynamics)

Drag is the force that opposes the actual movement of the plane. It is caused by the air. The formula for drag is typically cv^2. Here c is the drag factor and v is the speed of the airplane. The drag factor is determined by the geometric design and size of the plane. The according entry is named Drag Coefficient—Zero Lift (section 1101). Again, start with a value you take from a similar aircraft here. You can use this value for several things.

First, it adjusts the maximum speed of the plane, but you will end with really big or low values if you try doing this. Second and more importantly, this value controls the speed loss during landing, after you turn your engines nearly down. If this value is low, you will find that the plane loses nearly no speed during level flight at low speed with the engines nearly turned off. Try to find reports from pilots to determine this value.

The Me262, for example, was known to stay in the air forever. In fact, the first American pilot who flew this plane said after the flight that he thought he‘d flown a perpetual plane, meaning the plane would fly forever without engines. I entered a small value here.

Landing gear pitch and drag (section 1101, Main Dynamics)

The Drag Coefficient – Landing Gear and Gear Pitch Factor values are located in Main Dynamics (section 1101). Extending the landing gear causes more drag on the airplane, which causes the nose to go down. For the drag, you can use a value from a similar aircraft. If you want to set the pitch value accurately, you will need a report from a pilot. Typical values for the pitch are between 0.02 and 0.05. The last value will cause a massive nose-down effect. If the landing gear is big and long, set the value for the pitch effect high, otherwise set it low. A large value for the drag helps during landing, since the plane reduces its speed faster.

Flaps (section 1101, Main Dynamics)

Landing flaps lower the stall speed of the plane. You can think of them as extensions of the main wings. Additionally they cause drag, which helps to slow the plane during landing. First we need to know to how many positions the flaps can be extended. The flaps of the Me262, for example, could be extended to 0°, 20°, 40° and 60°, giving four different positions. Go to Flaps Position (section 315) and fill in this number here.

Next, go back to section 1101 and enter the values for the Flaps Lift, Flaps Pitch Factor, Flaps Cycle Time and Drag Coefficient – Flaps. The flaps lift can be computed by the clean and dirty stall speed. Clean stall speed is the speed at which the plane stalls without any flaps, and a dirty stall occurs with full flaps applied. The formula is:

CLF is flap lift coefficient

W is gross weight (lbs)

S is wing area (sq feet)

VSC is stall speed clear (kts)

VSF is stall speed with flaps (kts)

$CLF = 294.46 * (W/S) * (VSF^{-2} - VSC^{-2})$

Thanks to Tom Goodrick for this formula. The value for flaps drag is typically around 0.1.

To predict the flaps pitch value you will need a report from a pilot. If this is not applicable, use the value of a similar aircraft's .AIR file. For the Me262, I set this value rather high, since I found in a report that massive trim was needed during landing. Positive values for any pitch entry means the nose goes down.

The flaps cycle time is the time it takes to fully extend or retract the flaps in seconds. If you don't have this information from the manufacturer, use a value between 4 (small aircraft) and 7 (big aircraft) for this entry.

Spoiler (section 1101, Main Dynamics)

Spoilers are simply brakes that can be applied while the plane is in the air. There are several possibilities why a plane needs brakes. Some planes simply accelerate too much when they dive. Since this can cause the plane to crash if it exceeds its critical mach number, it is good idea to have brakes, which raise the drag of the aircraft without impacting the control of the plane. Another possibility is that the plane should need very short runways. In this case, spoilers could help to stop the plane. Due to the variety of possible uses, there is no “correct“ spoiler appearance. Some of them are attached under the wing, some above the wing, some at the end of the wing, some even on the fuselage of the plane. In FS or CFS, three entries describe the spoilers.

This Drag Coefficient – Spoiler controls the drag on the plane when the spoiler is activated. Spoiler Lift controls how much lift is additionally produced by the spoilers. Spoiler Pitch Factor determines if the nose goes down (positive value) or up (negative value) while the spoilers are extended. In fact, there is no general rule how to handle these values. I will give you some examples. A spoiler attached above the wing will cause positive drag, nose down and more lift. Spoilers attached beneath the wing will cause positive drag, nose up and typically less lift. Spoilers attached to the fuselage (the Douglas AD-1 Skyraider, for example) typically increase the drag, but have no additional effect on the lift or pitch of the plane.

One drawback of this solution is that it can impact the airflow over the rudder and elevator. Again, there is no general rule for predicting these values. For a modern passenger airliner, set the value for the drag as high as for the drag of the flaps or slightly larger. Since these aircraft typically have spoilers attached above the main wing, the pitch factor should be positive (nose down) and also apply small lift (the default 737-400 has an error here: the value for the 737-400 is much too large).

If your plane has no spoiler, you can use these settings for something else. The idea is that you have three entries that affect lift, drag and pitch, which may be controlled by the pilot. In fact, a spoiler gauge can control the spoilers with a range between 0 and 16k, offering very fine control of the three dynamic entries. Some people use this to model an arrestor hook for planes that land on aircraft carriers. For example, Dino Cattaneo modeled the arrestor hook of an F-14 with the following values:

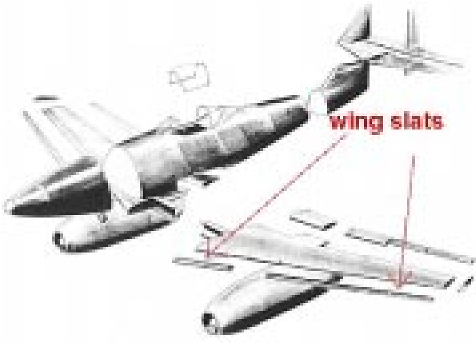
Drag Coefficient – Spoiler = 12.31641

Spoiler Pitch Factor = 0.0000

Spoiler Lift = 0.0000

In this case, it feels as if someone catches the tail of your aircraft when you apply the spoiler. It would be even better if we added some positive pitch.

Another possibility is to use these entries to design a VTOL airplane (vertical take-off and landing). This is achieved by rotating the engines. The English Harrier GR, for example, is designed like this. But this is more complicated, since you typically will need to lower the weight of the aircraft to make this work.



My Me262 had no spoilers, but it had wing slats. Wing slats extend at low speed and during very close turns, causing the flow of the air to stay laminar on the wing. Think of it as making the wing larger, which will cause the stall speed to go down. Beside the lift, wing slats will also produce slightly more drag and a nose up or down effect, which depends on the position of the center of lift on the main wing. If it is behind the CoG, the nose will go down; if it is before the CoG, the nose will go up. I used the following entries for the wing slats:

Drag Coefficient – Spoiler = 0.00293

Spoiler Pitch Factor = 0.03900000

Spoiler Lift = 0.621

Furthermore, I programmed a gauge that controlled the spoilers to depend on the airspeed and angle of attack.

The controls

Now we will start with the trickiest part of the .AIR file, the three controls: pitch, roll and yaw. For some entries in the .AIR file, I can only say what happens if you edit them, but I have no clue what they really are. Remember that all of this work was gathered by changing an entry, finding the difference, guessing what the entry might mean, trying to verify it, finding that your guess was wrong, changing the entry again, trying it again, etc. Most of the entries I'm unsure about are located in section 320. I suspect that they describe the dimensions and the placement of the three controls. The best advice I can give you for this section is to copy it from a plane that is as large as your plane is. If you are building a 747, take the values from the 737 and multiply every value in this section that ends with length or width with the quotient: length of 747 divided by length of 737.

Elevator and pitch (section 1101, Main Dynamics)

In section 1101, three entries determine the control of the elevator. The first one, Pitch Stability Factor2, controls the stability of the plane against pitching, which is movement around the lateral axis. Remember what I said before about stability: the lower this value is, the more the plane will try not to move around the lateral axis. The second entry is Pitch Damper. A damper is typically use to reduce oscillations. For the plane this means that if you set this value high, the plane will not oscillate when you end a turn, for example. Perhaps you might wonder what the difference is between pitch stability and pitch damper. The answer is that the stability factor controls the associated acceleration, while the damper affects the velocity. Consider as an example, if you find that your plane stalls at the beginning of a turn, but not during the turn, you need to increase the stability factor, since it accelerates too fast into the turn. If you find that your plane feels as if it is flying on a stick, but not in the air, you need to decrease the damper. Typically you will feel that you fly a very big plane if the value for the damper is set very high, and *vice versa*.

The Elevator Control Factor determines how fast the plane can turn. If your plane already stalls in a turn, you are not able to turn it faster by changing this value. The lower this value is, the faster the plane can rotate around the lateral axis. In order to set this value properly, you need to know the turn rate of the aircraft. One more thing you have to know about that entry is that it is modified by the Elevator Effectivity table (section 341). For CFS, this table contains seven pairs of values that describe a nonlinear function. The first value represents how much the control was moved by the pilot with the joystick ranging from -1 (maximum left) to 1 (maximum right).The second value is a factor that is multiplied by the respective control factor, *e.g.* Elevator Control Factor (section 1101).

In order to give you an example for this, assume that the Elevator Control Factor has a value of -1000.

Moving the joystick through 50% (.500000) of its range, you'd expect the effective force through the elevator to be .500000 x -1000 = -500.

If the table has a pair .500000, 0.875, then turning the joystick to 50% (.500000) yields a different value this being 0.875 x .500000 x -1000 = -437.5. If this entry is not present it is interpolated.

What can this be used for? Looking at the stock P-51D in CFS, you can see that the elevator is more effective if turned left, therefore left turns are faster. Furthermore, this can be used to adjust the sensitivity of joystick movement shortly before stall.

Ailerons and roll (section 1101, Main Dynamics)

The roll behavior and the ailerons are controlled by three entries in section 1101. These are Roll Center, Roll Stability Factor 1 and Aileron Control Factor. The first one determines the longitudinal offset of the roll center from the CoG, in inches. I never used a value different from 0 here, since the plane really starts to be very “complicated“ if this value is set to 10, for example. Give it a try.

The next entry, Roll Stability Factor 1, determines the stability (see elevator and pitch) of the plane if it’s rolling. The lower this value is, the higher the stability will be. The higher the stability is, the more the plane will accelerate in a roll.

The last entry, Aileron Control Factor, determines how fast the plane will roll. It is modified like the Elevator Control Factor (above) by a table (in section 342). Look at the Elevator and pitch section in order to understand how this works. The lower the value for the Aileron Control Factor, the faster the plane will roll.

Rudder and yaw (section 1101, Main Dynamics)

The entry for the maximum force of the rudder is named Rudder Control Factor. Unlike the two other control factors, the maximum force induced by the rudder is higher if this value is increased. The associated table is in section 343 (see Elevator and pitch for detailed information on that table).

The Yaw Slide Factor entry is very interesting. It determines whether the plane slides away if you bank the plane. The Me262 had a very nasty tendency to slide away during slow turns. Therefore, I set this value low (213), making the plane really difficult to land.

The next value, Yaw Stability Factor 3, determines the stability of the airplane against movements around the vertical axis. The higher this value is, the more stable the plane will be. If you set this value low, you may also experience oscillations at high speeds. My Me262 is known to oscillate at a frequency of 1Hz during high speeds. If I set this value to 55000, the plane started to oscillate at 720km/h; if set it to 57000, the plane started to oscillate at 760km/h. This may give you a hint how sensitive this entry is.

The last entry that is important for yaw is the Yaw Center, which describes the longitudinal center of rotation around the vertical axis. The value is measured in inches, and its sign means “+“ equals before and “-“ is behind the CoG.

Yaw Damper (section 1202, Yaw Damping Factor)

Unlike the pitch damper, this value is not part of the dynamical model of the simulator. The yaw damper is an active control that modern aircraft have. In FS98 and CFS, it can be controlled by a gauge and/or by the autopilot.