King Air B200 Tutorial Part II

Weight & Balance

by

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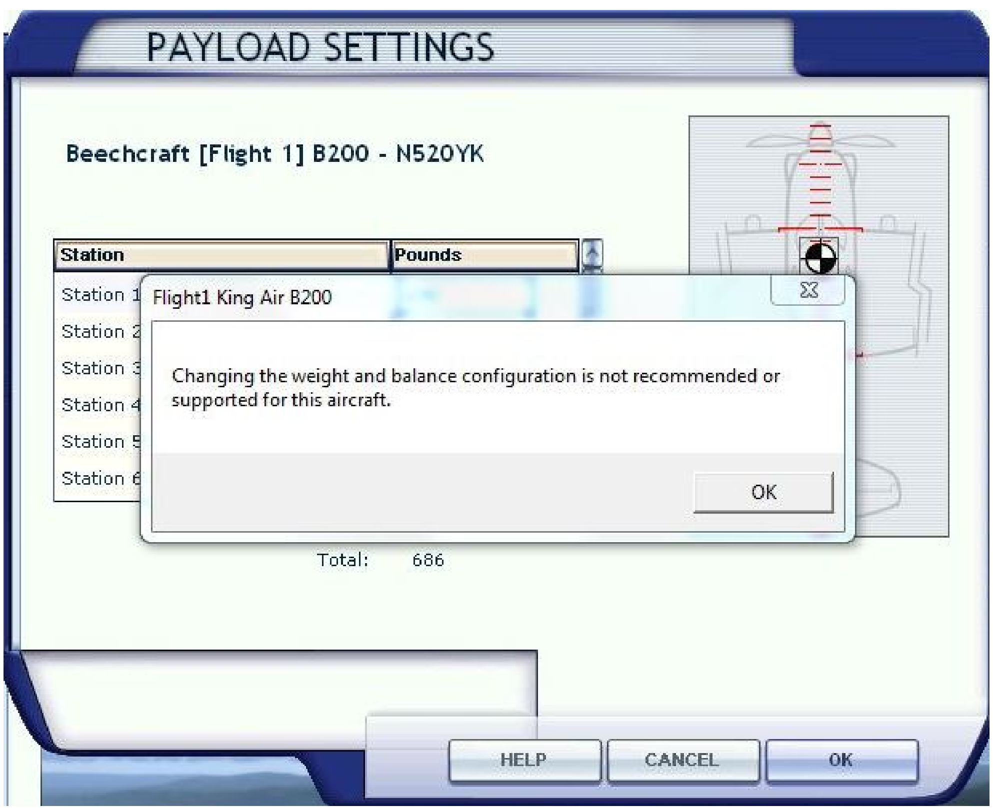
INTRODUCTION AND OBJECTIVES

Welcome to the Beech King Air B200 Flight Tutorial Part II, which is intended for use only with the Flight1 Beechcraft Super King Air B200 product available at www.flight1.com.

As you've probably already surmised by reading the title page, this tutorial will focus on the proper arrangement of weight within the aircraft so as to remain within the center of gravity limitations (balance) established for the Beechcraft Super King Air B200.

It's worth mentioning again that the aircraft being simulated here is an early-80s model B200 with the Blackhawk Modifications XP52 engine upgrade package along with Raisbeck Engineering dual aft body strakes and BLR winglets, so the performance will be radically different from a stock B200. For that reason, please refer to the performance data that came with your Flight1 Super King Air B200, rather than a commercially available B200 Pilot's Operating Handbook. Likewise, the cabin configuration is slightly different from a stock King Air, so you should use only the weight and balance worksheet contained in this tutorial.

By now, you've probably seen the warning that pops up whenever you enter the payload interface while the Flight1 Beechcraft Super King Air B200 is selected. In case you haven't, it looks like this:



In the past, Flight1 has been called upon to assist users who reported various add-on aircraft to be unflyable, only to discover after many hours of troubleshooting that the user had entered payload

values that were wildly unrealistic. The warning is there to remind users that if they don't know *exactly* what they're doing in changing the payload values, they shouldn't be in there making changes.
With that in mind, the goal of this tutorial is, quite simply, to inform the user about good weight and balance practices as they are applied to the B200, and to make it relatively "safe" to click through that warning and adjust the Flight1 Super King Air B200's payload. In short, I'm going to give you enough information to make you dangerous. No, not to me, or to anybody else. Just to you, and your own enjoyment of flight simulation as a hobby. Therefore, Flight1 will not support any of the procedures outlined in this tutorial, and you should not expect the developer's help in the forums if you render your King Air unflyable.

Don't worry, I won't leave you hanging. The last part of this tutorial will give you the steps to recover your default weight and balance.

BEFORE WE GET STARTED

It's important that you use the FSX "Fuel and Payload" interface for all changes to the Flight1 Super King Air B200 payload.

<u>IMPORTANT:</u> Don't, under any circumstances, edit the aircraft.cfg file. Don't. I mean it.

A FEW TERMS YOU NEED TO KNOW

Approved Loading Envelope – The range of weights and centers of gravity that are within the operating limits of the airplane.

Arm – The distance between a designated point on the aircraft and the center of gravity of an object loaded onto that aircraft.

Basic Empty Weight – The weight of an empty airplane including full engine oil and unusable fuel. This value is used for determining all loading data. In the real world, Basic Empty Weight would be determined by actually weighing the empty aircraft. The Basic Empty Weight of the Flight1 King Air B200 is 7,538 pounds.

Center of Gravity (CG) – The point at which all of the weight of an aircraft is considered concentrated.

CG Limits – The extreme center of gravity locations within which the aircraft must be operated.

Datum – A vertical plane perpendicular to the longitudinal axis of the aircraft from which fore and aft measurements are taken for weight and balance purposes.

Empty Weight – The weight of an empty aircraft before any oil or fuel has been added. In FSX, this term is used interchangeably with Basic Empty Weight, which is not the case in the real world.

Landing Weight – The weight of the aircraft at landing touchdown.

Maximum Ramp Weight – The heaviest weight permitted by aircraft limitations. The maximum ramp weight of the B200 is 12,590 pounds.

Moment – A measure of the rotational tendency of a weight about a specific line, mathematically equal to the product of object's weight and arm. This value is divided by 100 for ease of calculation, so on the worksheet, you'll see it as "Moment/100".

Payload – The weight of the occupants, fuel, and cargo.

PPH – Pounds Per Hour.

Ramp Weight – The weight of the aircraft at engine start, assuming all payload is aboard.

Standard Empty Weight – The basic empty weight of the aircraft as set by the manufacturer.

Station – The longitudinal distance from a given point to the datum, expressed in inches.

Takeoff Weight – The weight of the aircraft at liftoff from the runway.

Unusable Fuel – The fuel remaining in the fuel tanks after all usable fuel has been consumed or removed.

Usable Fuel – The portion of the total fuel which is available for consumption.

Useful Load – The difference between ramp weight and basic empty weight.

Zero Fuel Weight – The aircraft ramp weight minus the weight of the usable fuel onboard. The maximum zero fuel weight of the B200 is 11,000 pounds.

WEIGHTS YOU NEED TO KNOW, AND OTHER USEFUL NUMBERS

Maximum Ramp Weight	12,590 pounds
Maximum Takeoff Weight	12,500 pounds
Maximum Landing Weight	12,500 pounds
Maximum Zero Fuel Weight	11,000 pounds
Basic Empty Weight	7,538 pounds
Maximum Weight in Baggage Compartment	370 pounds
Aft CG Limit (aft of datum)	196.4 inches
Forward CG Limit at maximum takeoff weight (aft of datum)	185.0 inches
Forward CG Limit at 11,279 pounds or less (aft of datum)	181.0 inches

Note that between 12,500 pounds and 11,279 pounds, there is a straight line variation between 185.0 inches and 181.0 inches. In other words, if the airplane's weight is below 11,279 pounds, the forward limit of the CG is 181.0 inches, but if it's greater than 11,279 pounds, the forward CG limit moves aft. In practical terms, we need to consult the Weight and Balance Diagram if the weight is greater than 11,279 pounds and the calculated CG value is less than 185.0. (If that doesn't make sense to you, you'll see what I mean when we get to the Weight and Balance Diagram.)

ESTABLISHING THE BASICS

Part of the paperwork that comes with the real airplane is a Basic Empty Weight and Balance Form, and it's from this form that you'd get the key pieces of information for performing weight and balance calculations: Basic Empty Weight and Basic Empty Moment/100.

Obtaining this information is a complicated process that begins with draining all the usable fuel from the tanks and ensuring that the engine oil is fully topped up. It is possible to weigh the airplane with full fuel tanks, but it adds a layer of complexity to the process.

The empty airplane is then placed on three scales. It can be set on jacks (there is a jack point under the nose and one under each wing) or on its wheels.

Once on the scales, the plane must be leveled. If on jacks, the plane is leveled by adjusting the jacks. If on its wheels, the airplane is leveled by increasing or decreasing the air in either the landing gear struts or the tires.

All of this is done inside a hangar where there are less likely to be air currents that may move the airplane while it is being weighed.

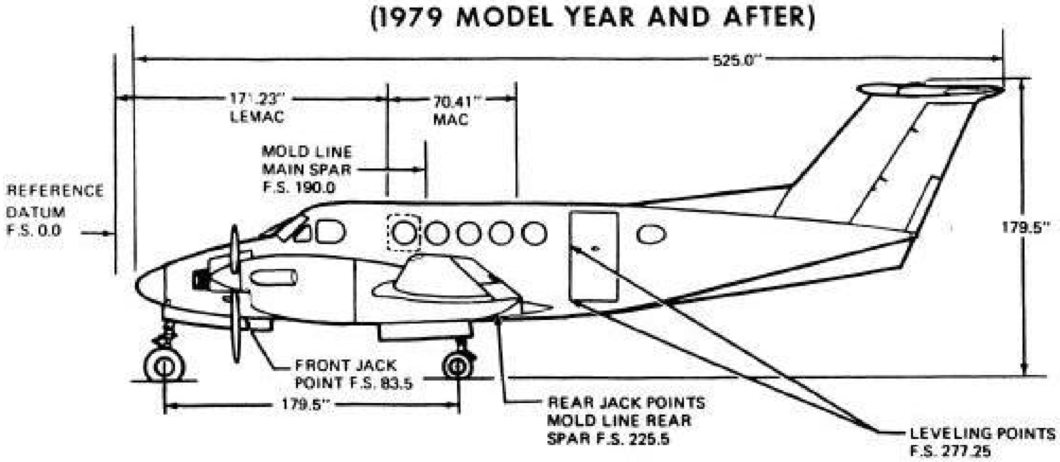
Now, obviously, we can't actually do any of this inside the sim, but the Basic Empty Weight is specified in the [WEIGHT_AND_BALANCE] section of the aircraft.cfg file, and I've taken the liberty of calculating the Basic Empty Moment/100 for you. It's 14545. (Yes, I know, the value for empty_weight_pitch_MOI is also in the aircraft.cfg file, but as best as I can determine, this value is not the moment we're looking for. I totally just waved my hand and did the Jedi Mind Trick, too.)

For those of you who absolutely *must* know how I came to the Basic Empty Moment/100 for the Basic Empty Weight, I'll explain it at the end of this tutorial.

In the mean time, let's take a look at our airplane and the way it's laid out.

DIMENSIONAL AND LOADING DATA

(1979 MODEL YEAR AND AFTER)

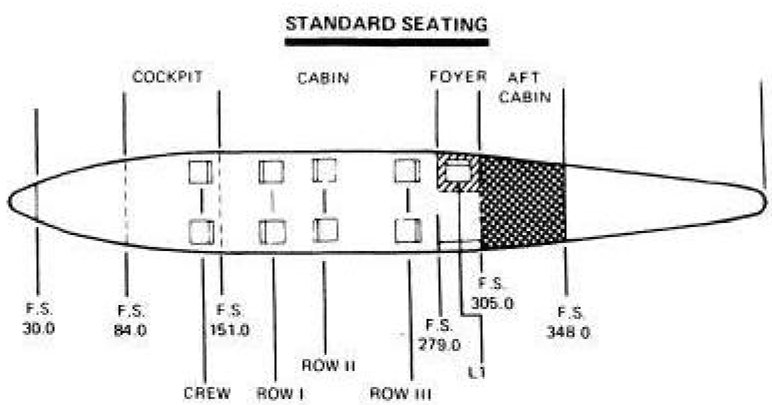


There are quite a few lines and arrows here, but we're only going to talk about some of them. First, notice that each of the illustrated points has the designation "F.S." followed by a number. This is the Fuselage Station, and the number represents the number of inches aft of the Reference Datum. Oddly enough, the Reference Datum is actually several inches forward of the physical nose of the airplane.

That's right. All our weight and balance calculations will be based on a point that isn't physically on the airplane.

Okay, that's not exactly true. The Reference Datum is based on the front jack point, and my guess is that its location has to do with simplifying our calculations, since it's easier to work with all positive numbers than a mix of positive and negative numbers, as it would be if we put the reference datum at a middle point on the airplane where there might later be changes that prompt us to redo our math.

The fuselage station number is important! Everything we put on the airplane will have one, and the F.S. number varies with the location of the object. When we multiply the F.S. number by the weight of the object (and for our purposes here, people are "objects"), the product is the Moment of that particular object. When we add all of the Moments of all the objects on board the airplane and the Basic Empty Moment of the airplane itself, we'll get a loaded Moment. When we divide that loaded Moment by the total weight of the airplane with everything aboard, we'll get the location of the airplane's Center of Gravity. Clear as milk, right?



Okay, maybe this will help. In this diagram, notice that the various bulkheads in the airplane have F.S. numbers, and within each compartment, the seats will also have a F.S. number based on where it's actually bolted to the airplane. They're not shown on this diagram because the seats will be in slightly different places from airplane to airplane.

Time for an example: You're flying solo with no baggage, so the only thing we need to do is calculate the moment of your weight added to the airplane. Let's assume you weigh 170 pounds. We can see from the diagram above that the crew seats in the cockpit are located between F.S. 84 and F.S. 151. As it happens, the seats are at F.S. 129. We multiply the pilot's weight by the F.S. number of the seat to get the Moment.

(Pilot's Weight)*(Pilot's Seat F.S.) = (Pilot's Moment)
170 (lbs) * 129 (inches) = 21930

Pretty simple, right? Now, to make our calculations even easier, we divide the Moment by 100 and round to the nearest whole number to get 219.

When we calculate the load in the airplane, we'll do that same thing for all the people and cargo we're putting aboard, total all the weights to determine Zero Fuel Weight, and all the Moments to determine Zero Fuel Moment. Then, we'll add the weight and moment of the fuel onboard at takeoff and what we expect it to be at landing, then make sure the Moment/100 with takeoff and landing fuel is within the CG limits at the respective weights. Confused? Let's break that down.

STEP BY STEP

Step 1: Calculate the Zero-Fuel Weight. Enter the weights of the people in each seat in the worksheet on the left side of page 8. Note that the last two lines (at F.S. 326) are labeled "Baggage/Jump". You may enter the half the weight of the baggage or the weight of one additional passenger in each spot, but the maximum weight for these two positions combined is 370 pounds. Enter the sum of the weights in the ZFW line of the worksheet.

CAUTION
Zero Fuel Weight must not exceed 11,000 pounds.

Step 2: Determine the Zero Fuel Moment/100. Use the Cabin Loading table to determine the Moment/100 for each position loaded in Step 1, and enter the values on the ZFW line of the worksheet.

CABIN LOADING

Weight in lbs>		80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240
Crew	F.S.129	103	116	129	142	155	168	181	194	206	219	232	245	258	271	284	297	310
Chair	F.S.176	141	158	176	194	211	229	246	264	282	299	317	334	352	370	387	405	422
Chair	F.S.214	171	193	214	235	257	278	300	321	342	364	385	407	428	449	471	492	514
Chair	F.S.253	202	228	253	278	304	329	354	378	405	430	455	481	506	531	557	582	607
Jump	F.S.326	261	293	326	359	391	424	456	489	522	554	587	619	652	685	717	750	782

Step 3: Enter the fuel weight and moment/100. Using the Fuel Weights and Moments table on the right side of Page 8, determine the weight and moment/100 of the fuel to be entered in the FSX "Fuel and Payload" interface and enter the values on the Fuel line of the Weight and Balance Worksheet.

Step 4. Calculate the Ramp Condition. Enter the sum of the ZFW and Fuel weights in the weight column on the Ramp Condition line of the Weight and Balance Worksheet. Enter the sum of the ZFW and Fuel moments/100 in the moment/100 column of the Ramp Condition line.

CAUTION
The Ramp Condition Weight must not exceed 12,590 pounds.

WEIGHT AND BALANCE WORKSHEET

	Weight	Arm	Moment/100
BEW	7538		14545
Captain	______	129	______
First Officer	______	129	______
Aft Facing - L	______	176	______
Aft Facing - R	______	176	______
Aft Facing - L	______	214	______
Aft Facing - R	______	214	______
Fwd Facing - L	______	253	______
Fwd Facing - R	______	253	______
Baggage/Jump	______	326	______
Baggage/Jump	______	326	______
ZFW	______		______
Fuel	______		______
Ramp Condition	______		______
Less Taxi Fuel	90		138
Takeoff Condition	______		______
Less Fuel to Destination	______		______
Landing Condition	______		______
CG in inches	______ Takeoff		______ Landing

FUEL WEIGHTS AND MOMENTS

WEIGHT	MOMENT/100
67	103
134	206
201	319
268	443
335	567
402	693
469	819
536	946
603	1071
670	1196
737	1319
804	1443
871	1566
938	1690
1005	1815
1072	1939
1139	2064
1206	2188
1273	2313
1340	2437
1407	2562
1474	2687
1541	2812
1608	2938
1675	3063
1742	3188
1809	3312
1876	3437
1943	3562
2010	3688
2077	3811
2144	3936
2211	4062
2278	4187
2345	4312
2412	4443
2479	4570
2546	4700
2586	4776
2680	4963
2747	5097
2814	5231
2881	5366
2948	5501
3015	5638
3082	5773
3149	5909
3216	6046
3283	6184
3350	6323
3417	6462
3484	6602
3551	6743
3618	6881
3645	6936

STEP BY STEP (continued)

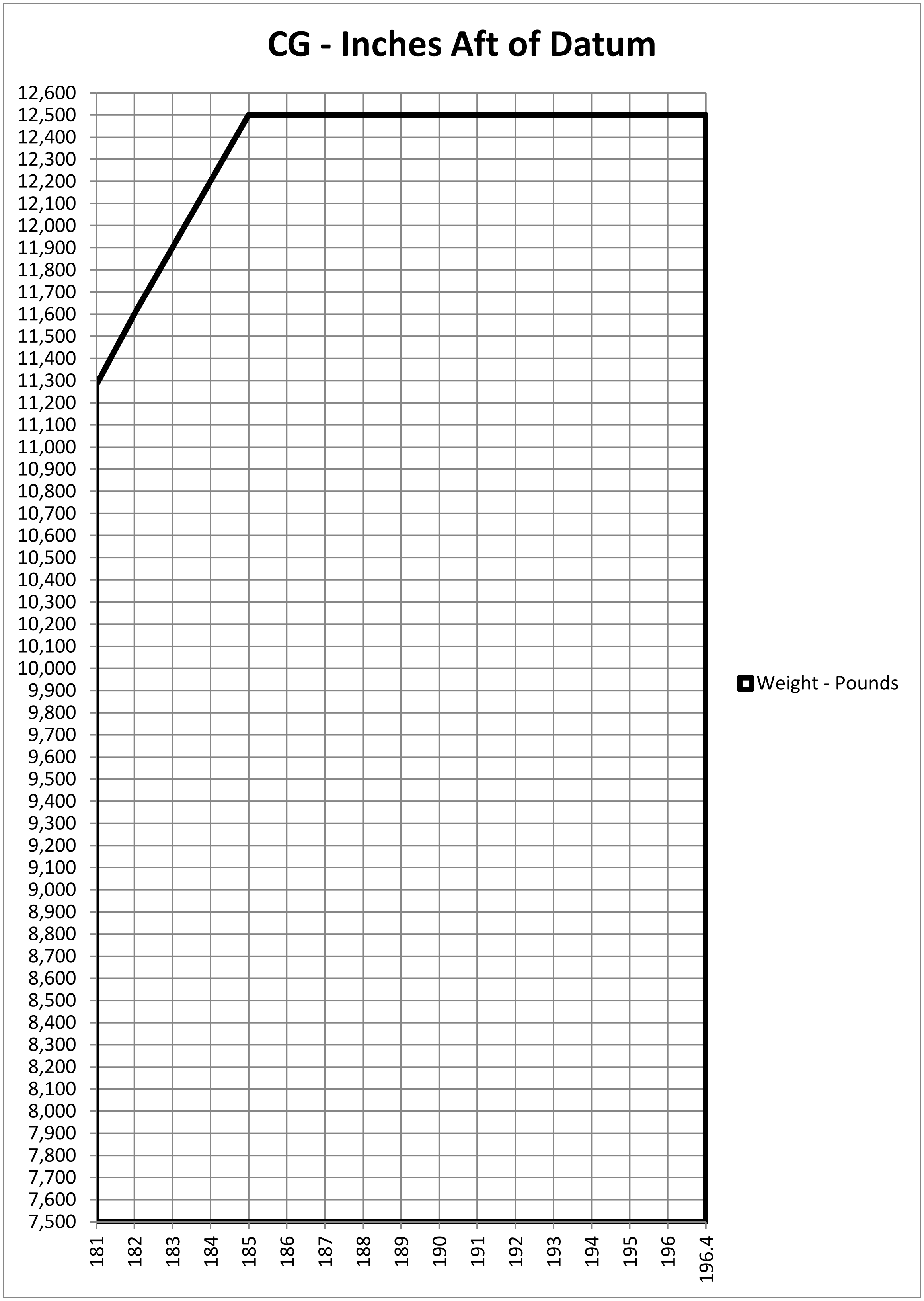
Step 5: Determine the Takeoff Condition. Our King Air can reasonably be expected to use about 90 pounds of fuel during the startup, taxi, and takeoff phase of a flight. Yes, it might use more at a large busy airport, or less if you're parked near the departure end of a small airfield, but 90 pounds is a good average, so that's what we use for our standard in calculating Takeoff Condition. Subtract 90 pounds from the Ramp Condition weight you calculated in Step 4, and enter it into the Takeoff Condition weight column. Subtract 138 from the Ramp Condition moment/100 you calculated in Step 4, and enter the value in the Takeoff Condition moment/100 column.

Step 6: Determine the Landing Condition. Enter the amount of fuel you expect to burn enroute to your destination. You should have calculated this as part of your flight planning. (You did plan your flight, didn't you?) Subtract the weight and moment/100 of the enroute fuel from the Takeoff Condition weight and moment/100, and enter the values on the Landing Condition line.

Step 7: Calculate the Takeoff CG and Landing CG. Divide the Takeoff Condition Moment/100 by the Takeoff Condition Weight. The result is the location of the CG expressed in inches aft of Datum. Enter the value in the Takeoff blank on the "CG in inches" line. Divide the Landing Condition Moment/100 by the Landing Condition Weight and enter the result on the Landing blank.

Locate each CG at the point where the appropriate aircraft weight (Takeoff or Landing) crosses a line drawn upwards from the "CG - Inches Aft of Datum" scale at the bottom of the Weight and Balance Diagram on Page 10. Both the Takeoff CG and Landing CG must be within the boundaries shown by the heavy black lines.

WEIGHT AND BALANCE DIAGRAM



EXAMPLE

By now, it's entirely possible that your head hurts. That's okay. There's a lot of math. Let's look at an example that might help clear things up.

Example 1: The Flight1 Default

Here, we have four souls on board: pilot, co-pilot, and two passengers. There is no baggage. We'll start with full tanks, and plan a flight that will burn 804 pounds of fuel.

<u>Step 1: Calculate the Zero-Fuel Weight.</u>

All four people aboard weigh 170 pounds.

Add the weight of the passengers to the airplane's Basic Empty Weight:

7538 + (170 *4) = 7538 + 680 = 8218

We'd also add the weight of any baggage aboard, if there were any.

<u>Step 2: Determine the Zero Fuel Moment/100.</u>

The Captain and FO each weigh 170 pounds, and are seated at F.S. 129, so the math looks like this:

(170 * 129)/100 = 219

Our two passengers are in the third row of seats, F.S. 253:

(170 * 253)/100 = 430

Add the moments/100 of the four passengers to the airplane's Basic Empty Moment/100:

14545 + (219 * 2) + (430 * 2) = 14545 + 438 + 860 = 15843

<u>Step 3: Enter the fuel weight and moment/100.</u>

Full fuel tanks gives us 3645 pounds of fuel, which is shown on the Fuel Weights and Moments table to have a moment/100 of 6936.

Step 4. Calculate the Ramp Condition.

Add the Zero Fuel Weight and the Fuel Weight:

8218 + 3645 = 11863

Add the Zero Fuel Moment/100 and the Fuel Moment/100:

15843 + 6936 = 22779

Step 5: Determine the Takeoff Condition.

Subtract 90 pounds from the Ramp Weight to account for startup and taxi fuel:

11863 - 90 = 11773

Subtract 138 (90 pounds fuel moment/100) from the Ramp Condition Moment/100:

22779 - 138 = 22641

Step 6: Determine the Landing Condition.

Subtract 804 pounds from the Takeoff Condition weight to account for enroute fuel burn:

11773 - 800 = 10969

Subtract the moment/100 for 803 pounds fuel (obtained from the Fuel Weights and Moments table) from the Takeoff Condition Moment/100:

22641 - 1443 = 21198

Step 7: Calculate the Takeoff CG and Landing CG.

Divide the Takeoff Condition Moment/100 by the Takeoff Condition Weight:

22641 / 11773 = 192.3

Divide the Landing Condition Moment/100 by the Landing Condition Weight:

21198 / 10969 = 193.3

WEIGHT AND BALANCE WORKSHEET

	Weight	Arm	Moment/100
BEW	7538		14545
Captain	170	129	219
First Officer	170	129	219
Aft Facing - L	______	176	______
Aft Facing - R	______	176	______
Aft Facing - L	______	214	______
Aft Facing - R	______	214	______
Fwd Facing - L	170	253	430
Fwd Facing - R	170	253	430
Baggage/Jump	______	326	______
Baggage/Jump	______	326	______
ZFW	8218		15843
Fuel	3645		6936
Ramp Condition	11863		22779
Less Taxi Fuel	90		138
Takeoff Condition	11773		22641
Less Fuel to Destination	804		1443
Landing Condition	10969		21198
CG in inches	192.3 Takeoff		193.3 Landing

WHAT IF THE CALCULATED CG IS OUTSIDE THE LIMITS?

Quite simply, you don't fly until you've rearranged the load or reduced the weight enough to produce a result that is within the published limits. If your CG is too far aft (the calculated value is greater than 196.4), try moving some weight forward. Move a heavier passenger toward the front of the aircraft, which may mean swapping seats with a lighter passenger. Leave some baggage behind. If the CG is too far forward, move a passenger or two toward the rear of the airplane. Then, redo your calculations with the new weight distribution.

WHAT IF THE CALCULATED WEIGHT IS OUTSIDE THE LIMITS?

Again, you don't fly until you lighten the airplane. It sounds like the obvious solution, but all too often, pilots kill themselves and their passengers by failing to observe this rule. What's most important for the mission: payload or range? If you need range, offload some baggage or a passenger or two. If you need payload, drain some fuel from the King Air's tanks. Then redo your calculations.

JUST HOW DID I COME UP WITH THAT BASIC EMPTY MOMENT?

I started by determining the centroid fuselage station (a physical position relative to the datum, expressed in inches) for the Flight1 B200's reference_datum_position. I used a known fuselage station, that of the pilot's seat, which in the real airplane is FS 129, and in the Flight1 B200 is located 3.68 feet (44.16 inches) forward of the reference_datum_position. By adding these two figures together, I was able to determine that the reference_datum_position equates to a point 173.16 inches aft of Datum.

I next needed to know the location of the airplane's CG at empty weight. The longitudinal value set in the aircraft.cfg for empty_weight_CG_position is "-1.650", or 1.65 feet (19.8 inches) aft of the reference_datum_position, or at 192.96 inches aft of Datum. Multiplying this value by the Basic Empty Weight of 7,538 pounds gives us a Basic Empty Moment /100 of 14545.

Time for a sanity check. I compared these numbers with for the Flight1 King Air B200 with what I knew from the Aeroworx B200. In that airplane, the Basic Empty Weight is 8432 pounds, and the empty moment/100 is 15670. Dividing the empty moment by the basic empty weight, I determined the empty weight CG for that aircraft to be 185.84. Knowing that our King Air's Garmin G1000 gives us about 250 to 300 pounds less weight in the nose, it stands to reason that the Flight1 King Air's empty CG would be further aft than that of the Aeroworx.

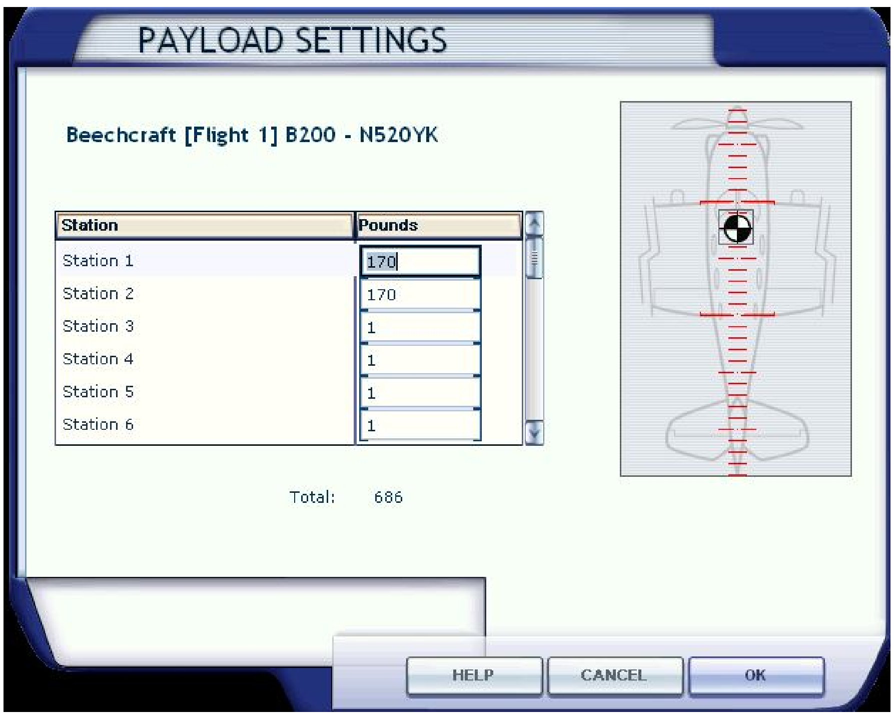
AS PROMISED: HOW TO GET THE DEFAULT PAYLOAD BACK

If, after changing your payload settings, you find that the airplane has become difficult to fly, you'll need to return the payload to the default settings **and test fly the King Air again** before asking Flight1 for support. Here's how:

In the Aircraft > Fuel and Payload user interface, click "OK" on the pop-up warning and then enter the following:

In stations 1, 2, 7, and 8: 170
In all other stations: 1

It should look like this when you're done:



THE WRAP UP

That's it! We've covered weight and balance terminology, the important weights you need to know before changing the payload in your Flight1 Super King Air B200, how to properly calculate the weight distribution so that you keep your airplane within flyable limits, and how to correct weight and balance issues that put the airplane's CG outside safe operating limits. For the geeks among you, we unraveled the mystery of how to determine a workable Basic Empty Moment. Happy flying!

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