AIRPLANE WEIGHT AND BALANCE

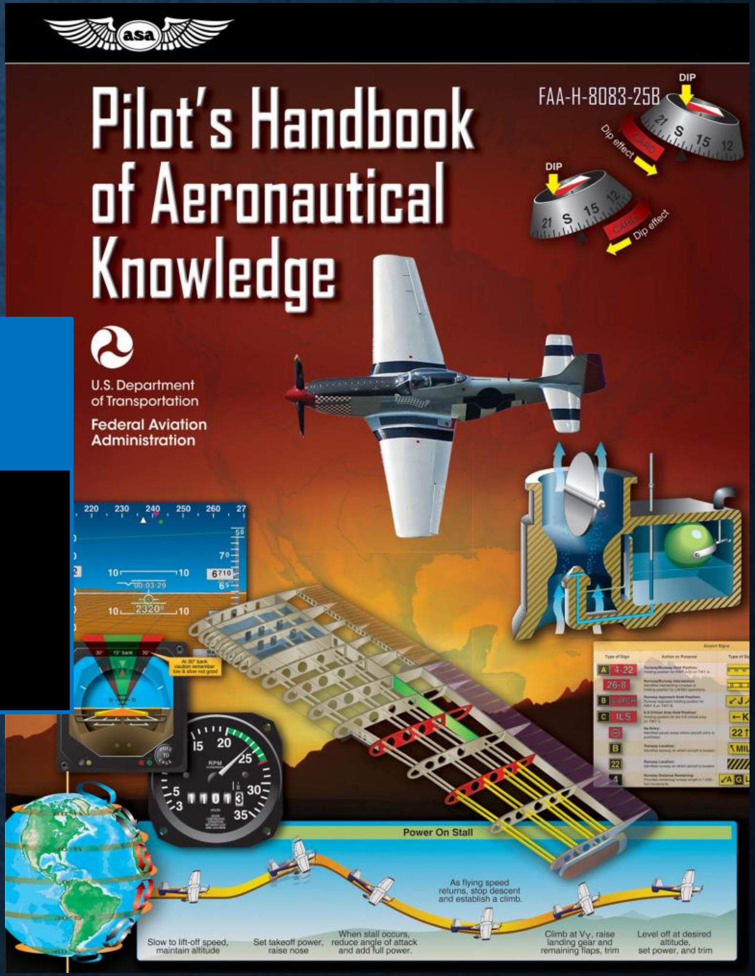
LESSON OUTLINE

LESSON OBJECTIVE

To determine that the student exhibits proficient knowledge of the elements related to airplane weight and balance by describing the elements on the following slide.

LESSON SOURCE(S)

Pilot's Handbook of Aeronautical Knowledge
FAA-H-8083-25



LESSON OUTLINE

LESSON ELEMENTS

Weight and Balance Terms
Effect of Weight and Balance on Performance
Methods of Weight and Balance Control
Determination of Total Weight and Balance and Center of Gravity

TIMEFRAME

35 Minutes
approximately

Discuss Objectives
Present and Review Material
Student Questions
Conclusion and Quiz

EQUIPMENT/TOOLS

Lesson Presentation
Whiteboard and Markers
FAA Sources and References

LESSON OUTLINE

INSTRUCTOR ACTIONS	STUDENT ACTIONS	COMPLETION STANDARDS
Present Objectives and Standards Teach Lesson from Presentation Ask and Answer Student Questions Assign Homework Check Student's Post Lesson Quiz	Participate in Lesson Take Notes Ask and Respond to Questions Pass the Post Lesson Quiz	Student is able to understand and differentiate between the different lesson elements. Student is further able to apply this acquired knowledge in flight training/flight operation scenarios effectively and appropriately.

WEIGHT AND BALANCE TERMS

The pilot should be familiar with the appropriate terms regarding weight and balance. The following list of terms and their definitions is standardized, and knowledge of these terms aids the pilot to better understand weight and balance calculations of any aircraft.

Arm

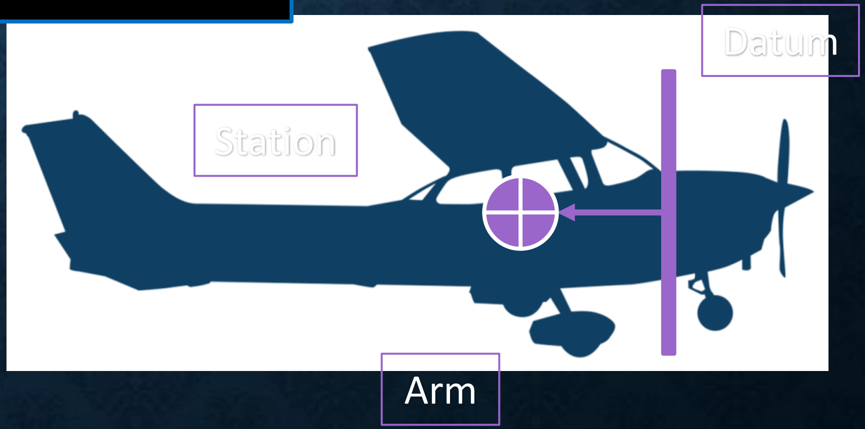
The horizontal distance in inches from the reference datum line to the CG of an item.

Station

A location in the aircraft that is identified by a number designating its distance from the datum.

Datum

An imaginary vertical plane from which all measurements of arm are taken. Established by the manufacturer.



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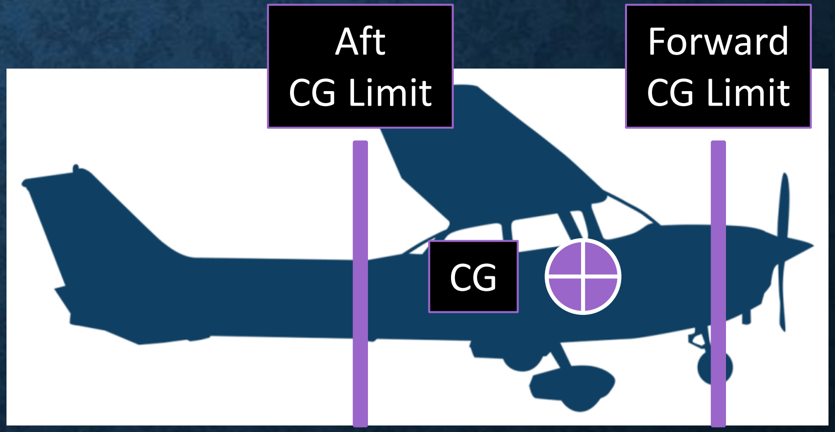
Center of Gravity (CG)

The point about which an aircraft would balance if it were possible to suspend it at that point.

CG Limits

The specified forward and aft points within which the CG must be located during flight.



WEIGHT AND BALANCE TERMS

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Basic Empty Weight

The standard empty weight plus the weight of optional and special equipment that has been installed.

Maximum Zero Fuel Weight

The maximum weight, exclusive of usable fuel. All weight added above this weight must be in fuel only.

Maximum Takeoff Weight

The maximum allowable weight for takeoff.

Maximum Weight

The maximum authorized weight of the aircraft and all of its equipment.

Maximum Ramp Weight

The maximum weight an aircraft can weigh on the ramp prior to takeoff. This may be a higher number than max takeoff weight.

Maximum Landing Weight

The greatest weight that an aircraft is normally allowed to have at landing.

WEIGHT AND BALANCE TERMS

The pilot should be familiar with the appropriate terms regarding weight and balance. The following list of terms and their definitions is standardized, and knowledge of these terms aids the pilot to better understand weight and balance calculations of any aircraft.

Standard Empty Weight

Aircraft weight that consists of the airframe, engines, and all items of operating equipment that are permanently installed.

Payload

The weight of occupants, cargo, and baggage.

Usable Fuel

The amount of fuel available for flight planning purposes. Established by the POH.

Standard Weights

Established weights for numerous items. Gas = 6 lbs/gallon. Oil = 7.5 lbs/gallon.

Useful Load

The weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil.

Fuel Load

Includes only usable fuel, not fuel required to fill the lines or that remains trapped in the tank sumps.

WEIGHT AND BALANCE TERMS

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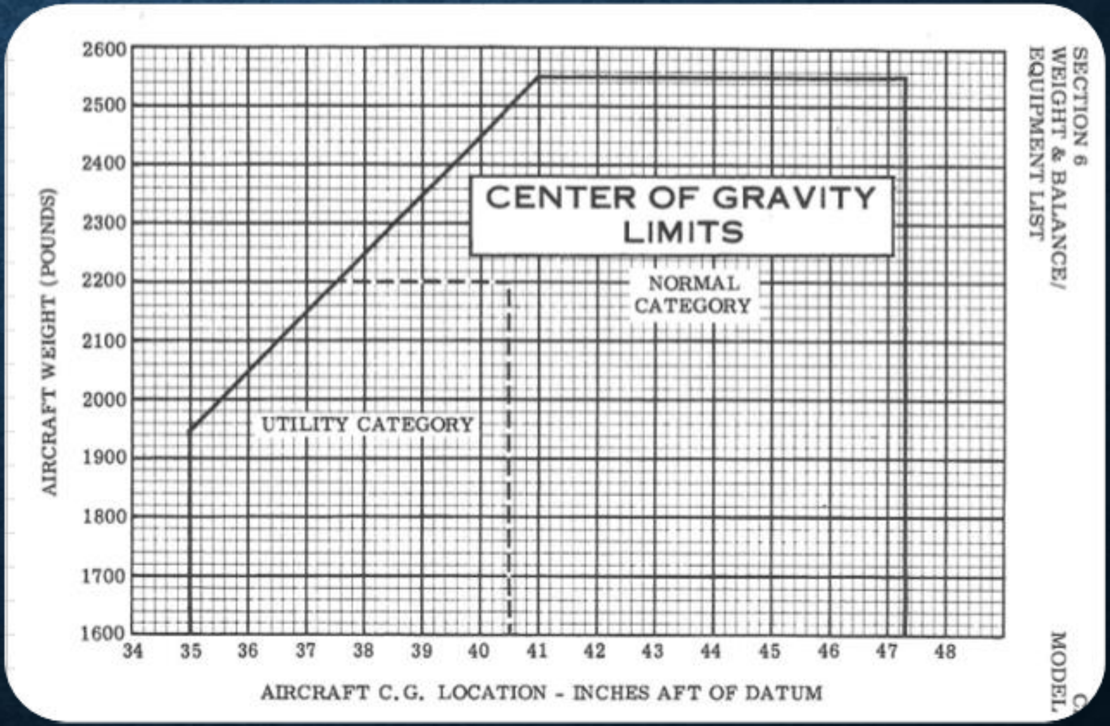
Moment

The product of the weight of an item multiplied by its arm. Weight X Arm = Moment.

Moment Index

A moment divided by a constant such as 100, 1,000, or 10,000. This is used to simplify weight and balance computations.



EFFECTS ON PERFORMANCE

Overweight

Excessive weight reduces the flight performance in almost every respect. For example, the most important performance deficiencies of an overloaded aircraft are:

- Higher Takeoff Speed
- Longer Takeoff Run
- Reduced Climb Rate
- Lower Max Altitude
- Shorter Max Range
- Slower Cruise Speed
- Reduced Maneuverability
- Higher Stall Speed
- Higher Landing Speed
- Longer Landing Roll

EFFECTS ON PERFORMANCE

Balance Control

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Forward CG Effects

- Longer takeoff roll
- Longer landing roll
- Higher stall speed
- Easier stall recovery
- Decreased cruising speed

Aft CG Effects

- Lower stall speed
- Reduced elevator authority
- Difficult stall recovery
- Faster cruising speed

EFFECTS ON PERFORMANCE

Balance Control

Forward CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Longer Takeoff Roll

Because the weight is concentrated forward in the aircraft, it will need to gain more airspeed before it is able to achieve liftoff and climb.

EFFECTS ON PERFORMANCE

Balance Control

Forward CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Longer Landing Roll

The forward weight will create momentum in pulling the aircraft down the runway. Also, there won't be as much weight over the main wheels decreasing braking effectiveness.

EFFECTS ON PERFORMANCE

Balance Control

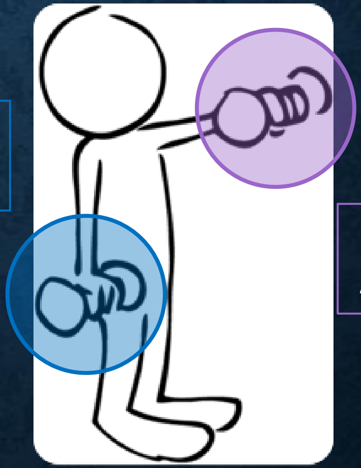
Forward CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Higher Stall Speed

The aircraft will stall at a higher airspeed due to "wing loading." The wings will seem to be carrying more weight and will need to fly at a higher airspeed to produce enough lift to carry the additional feel of weight.

Actual Weight = 10lbs
Apparent Weight = 10lbs



Actual Weight = 10lbs
Apparent Weight = 20lbs

EFFECTS ON PERFORMANCE

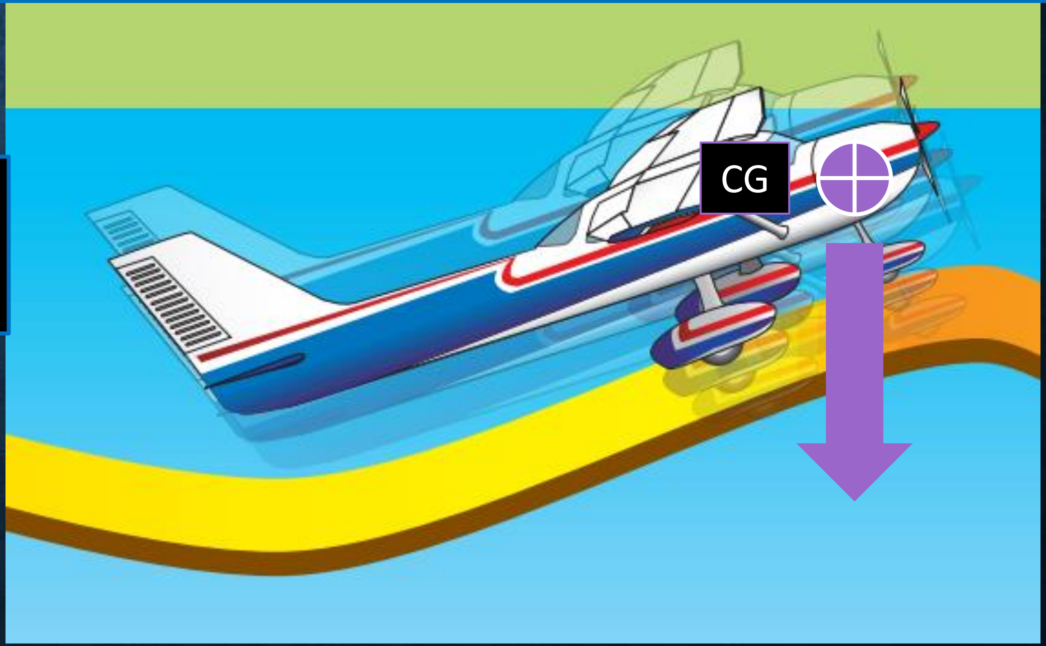
Balance Control

Forward CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Easier Stall Recovery

The forward CG will assist the aircraft in reducing its angle of attack to recover from a stall.



EFFECTS ON PERFORMANCE

Balance Control

Forward CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Slower Cruise Speed

Because the CG is forward, the pilot will need to trim the aircraft nose-up to maintain altitude at cruise. The deflected trim tab will cause drag with the relative airflow.

EFFECTS ON PERFORMANCE

Balance Control

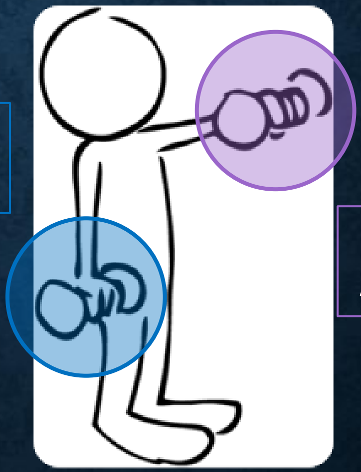
Aft CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Lower Stall Speed

With the CG aft, the aircraft will have a lower stalling airspeed due to decreased wing loading.

Actual Weight = 10lbs
Apparent Weight = 10lbs



Actual Weight = 10lbs
Apparent Weight = 20lbs

EFFECTS ON PERFORMANCE

Balance Control

Aft CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Less Elevator Authority

The aft CG will cause the elevator and rudder to be less effective. This is because the arm from the CG to the elevator and rudder is shorter. This will make stall recovery more difficult.

EFFECTS ON PERFORMANCE

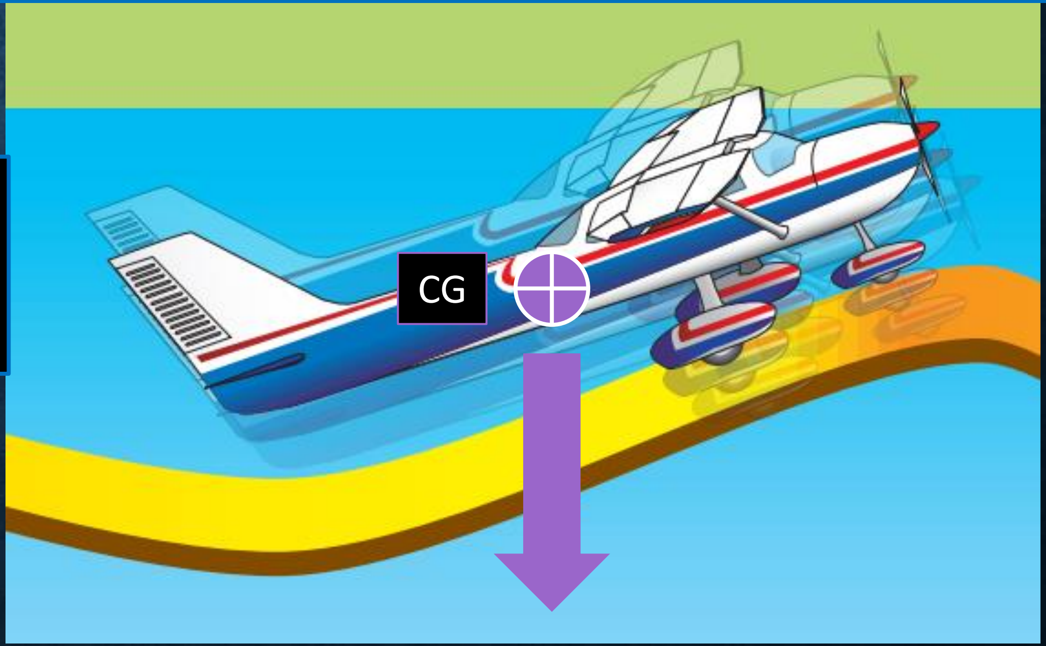
Balance Control

Aft CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Difficult Stall Recovery

Because the weight is concentrated aft in the aircraft, it will be more difficult to lower the angle of attack in order to recover from a stalled condition.



EFFECTS ON PERFORMANCE

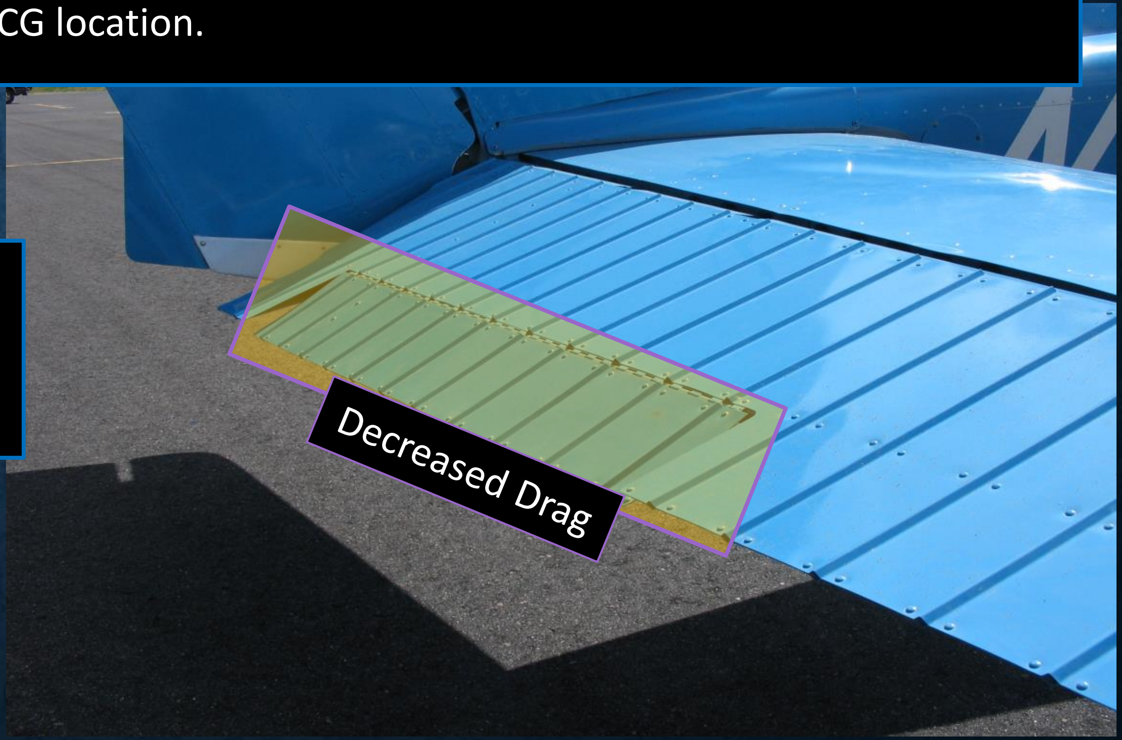
Balance Control

Aft CG Effects

The primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis. The CG is not necessarily a fixed point; its location depends on the distribution of weight in the aircraft. As variable load items are shifted or expended, there is a resultant shift in CG location.

Faster Cruise Speed

The aft CG will not cause the trim tab on the elevator to be deflected as far or at all. This creates less drag at cruise.



WEIGHT AND BALANCE CONTROL

Weight Shift Formula

When weight is shifted from one location to another, the total weight of the aircraft is unchanged. The total moments, however, do change in relation and proportion to the direction and distance the weight is moved. When weight is moved forward, the total moments decrease; when weight is moved aft, total moments increase.

$$\frac{\text{Weight shifted}}{\text{Total weight}} = \frac{\Delta\text{CG (change of CG)}}{\text{Distance weight is shifted}}$$

$$\frac{100}{8{,}000} = \frac{\Delta\text{CG}}{120}$$

$$\Delta\text{CG} = 1.5 \text{ in}$$

The change of CG is added to (or subtracted from when appropriate) the original CG to determine the new CG:
77 + 1.5 = 78.5 inches aft of datum

The shifting weight proportion formula can also be used to determine how much weight must be shifted to achieve a particular shift of the CG. The following problem illustrates a solution of this type.

The mathematical equation for shifting weight in an aircraft.

WEIGHT AND BALANCE CONTROL

Weight and Balance Example

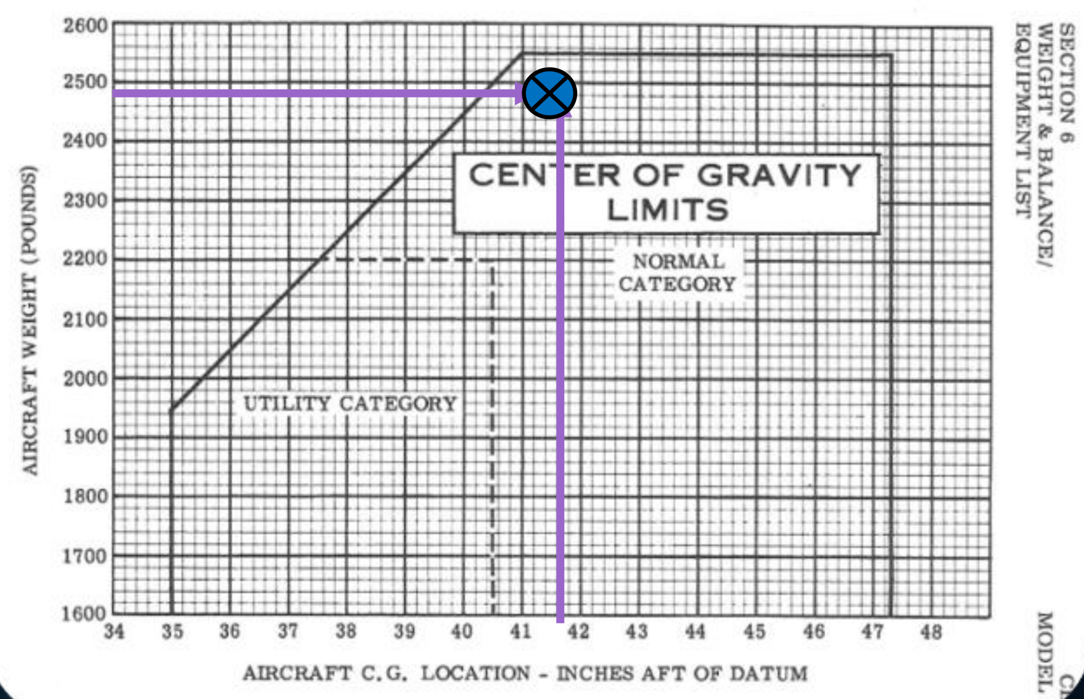
There are various methods for determining the loaded weight and CG of an aircraft. There is the computational method as well as methods that utilize graphs and tables provided by the aircraft manufacturer.

Example Numbers

Front Pilots = 320lbs
Rear Passengers = 150lbs
Baggage Area = 50lbs
Fuel on Board = 50 gallons (6lbs/gal for 300lbs)

The numbers already filled in are from chapter 6 of the POH.

	WEIGHT	ARM	MOMENT
Empty Aircraft	1662.65	36.94	61423.2
Front Passengers	320 X	37	= 11,840
Rear Passengers	150 X	73	= 10,950
Baggage Area	50 X	95	= 4,750
Fuel	300 X	48	= 14,400
6 lbs per gallon			
Totals	2,482.65	41.63	103,363.2



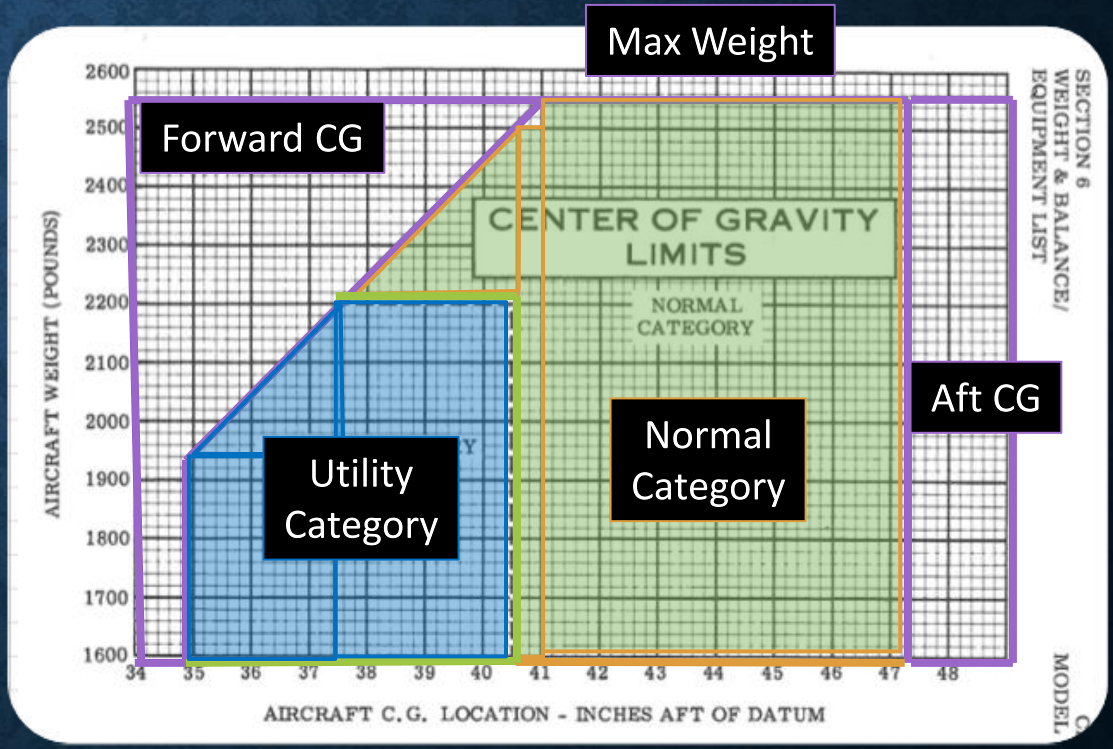
WEIGHT AND BALANCE CONTROL

Normal Category

An aircraft must fall into this category to safely perform normal flight maneuvers. Such as takeoffs, landings, steep turns, slow flight, stalls, etc.

Utility Category

An aircraft must fall into this category to perform special flight maneuvers such as spins or other maneuvers specified in that aircraft's POH.



LESSON SUMMARY

In this lesson we discussed weight and balance terminology and definitions, effects of being overweight and forward and aft CG locations, the weight-shift formula, and an example weight and balance with graph explanations.