AIRMAN CERTIFICATION STANDARDS: REMOTE PILOT SMALL: You will know and be able to explain in writing or oral form the below tasks regarding LOADING AND PERFORMANCE.

Task	Task A. Loading and Performance
References	AC 107-2; FAA-H-8083-25
Objective	To determine that the applicant is knowledgeable in the loading and performance of an sUAS.
Knowledge	The applicant demonstrates understanding of:
UA.IV.A.K1	1. General loading and performance: 1.
UA.IV.A.K1a	a. Effects of loading changes
UA.IV.A.K1b	b. Balance, stability, and center of gravity
UA.IV.A.K2	2 The importance and use of performance data to predict the effect on the aircraft's performance of an sUAS.

Aircraft Weight & Balance

A small mistake in CG can lead to much bigger problem. Picture courtesy of CASA

Why is it important?

WEIGHT

PERFORMANCE EFFECTS

The pilot should always be aware of the consequences of overloading. An overloaded aircraft may not be able to leave the ground, or if it does become airborne, it may exhibit unexpected and unusually poor flight characteristics. If not properly loaded, the initial indication of poor performance usually takes place during takeoff.

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 rate and angle of climb
- Lower maximum altitude
- Shorter range
- Reduced cruising speed
- Reduced maneuverability
- Higher stalling speed
- Higher approach and landing speed
- Longer landing roll
- Excessive weight on the nose wheel or tail wheel

WEIGHT CHANGES

The operating weight of an aircraft can be changed by simply altering the fuel load. Gasoline has considerable weight—6 pounds per gallon. Thirty gallons of fuel may weigh more than one passenger. If a pilot lowers airplane weight by reducing fuel, the resulting decrease in the range of the airplane must be taken into consideration during flight planning.

Other Causes for Weight Changes

- Reduction of Fuel of an aircraft in flight which will also change the center of gravity (Balance)
- Changes in fixed equipment added to, removed or replaced in the aircraft. W&B must be recalculated and updated in the aircraft maintenance log.

Balance, Stability, and Center of Gravity

Balance refers to the location of the ***center of gravity (CG)*** of an aircraft, and is important to stability and safety in flight. The CG is a point at which the aircraft would balance if it were suspended at that point.

The <u>primary concern in balancing an aircraft is the fore and aft location of the CG along the longitudinal axis in a fixed wing aircraft</u>. 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. The distance between the forward and back limits for the position of the center for gravity or CG range is certified for an aircraft by the manufacturer. The pilot should realize that if the CG is displaced too far forward on the longitudinal axis, a nose-heavy condition will result. Conversely, if the CG is displaced too far aft on the longitudinal axis, a tail heavy condition results. It is possible that the pilot could not control the aircraft if the CG location produced an unstable condition.

<u>**In a UAS we not only are concerned with the longitudinal but also the lateral access since the center of gravity is position at the center of the UAS frame and its counter rotating props.**</u>

Effects of Adverse Balance

Adverse balance conditions affect flight characteristics in much the same manner as those mentioned for an excess weight condition. *It is **vital** to comply with weight and balance limits established for all aircraft.* Operating above the maximum weight limitation compromises the structural integrity of the aircraft and can adversely affect performance. Stability and control are also affected by improper balance.

Stability

Loading in a nose-heavy condition causes problems in controlling and raising the nose, especially during takeoff and landing. Loading in a tail heavy condition has a serious effect upon longitudinal stability, and reduces the capability to recover from stalls and spins. Tail heavy loading also produces very light control forces, another undesirable characteristic. This makes it easy for the pilot to inadvertently overstress an aircraft.

Stability and Center of Gravity

Limits for the location of the CG are established by the manufacturer. These are the fore and aft limits beyond which the CG should not be located for flight. These limits are published for each aircraft in the Type Certificate Data Sheet (TCDS), or aircraft specification and the AFM or pilot's operating handbook (POH). If the CG is not within the allowable limits after loading, it will be necessary to relocate some items before flight is attempted.

The forward CG limit is often established at a location that is determined by the landing characteristics of an aircraft. During landing, one of the most critical phases of flight, exceeding the forward CG limit may result in excessive loads on the nosewheel, a tendency to nose over on tailwheel type airplanes, decreased performance, higher stalling speeds, and higher control forces.

Effects of Adverse Balance

Control

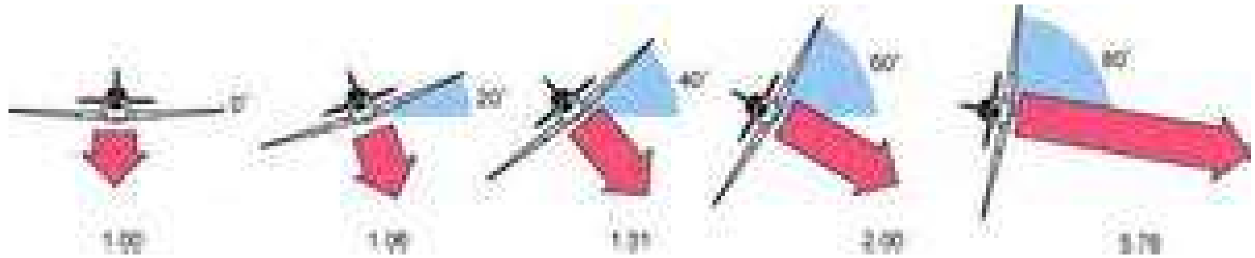
In extreme cases, a CG location that is beyond the forward limit may result in nose heaviness, making it difficult or impossible to flare for landing.

In addition to decreased static and dynamic longitudinal stability, other undesirable effects caused by a CG location aft of the allowable range may include extreme control difficulty, violent stall characteristics, and very light control forces which make it easy to overstress an aircraft inadvertently.

A restricted forward CG limit is also specified to assure that sufficient elevator/control deflection is available at minimum airspeed. When structural limitations do not limit the forward CG position, it is located at the position where full-up elevator/control deflection is required to obtain a high AOA for landing.

The aft CG limit is the most rearward position at which the CG can be located for the most critical maneuver or operation. As the CG moves aft, a less stable condition occurs, which decreases the ability of the aircraft to right itself after maneuvering or turbulence.

Be aware of load changes as a result of flight maneuvers. A 70 degree bank would make the load on your 10 lb drone 3 times as great or 30 lbs.



Fixed Wing Load Factor

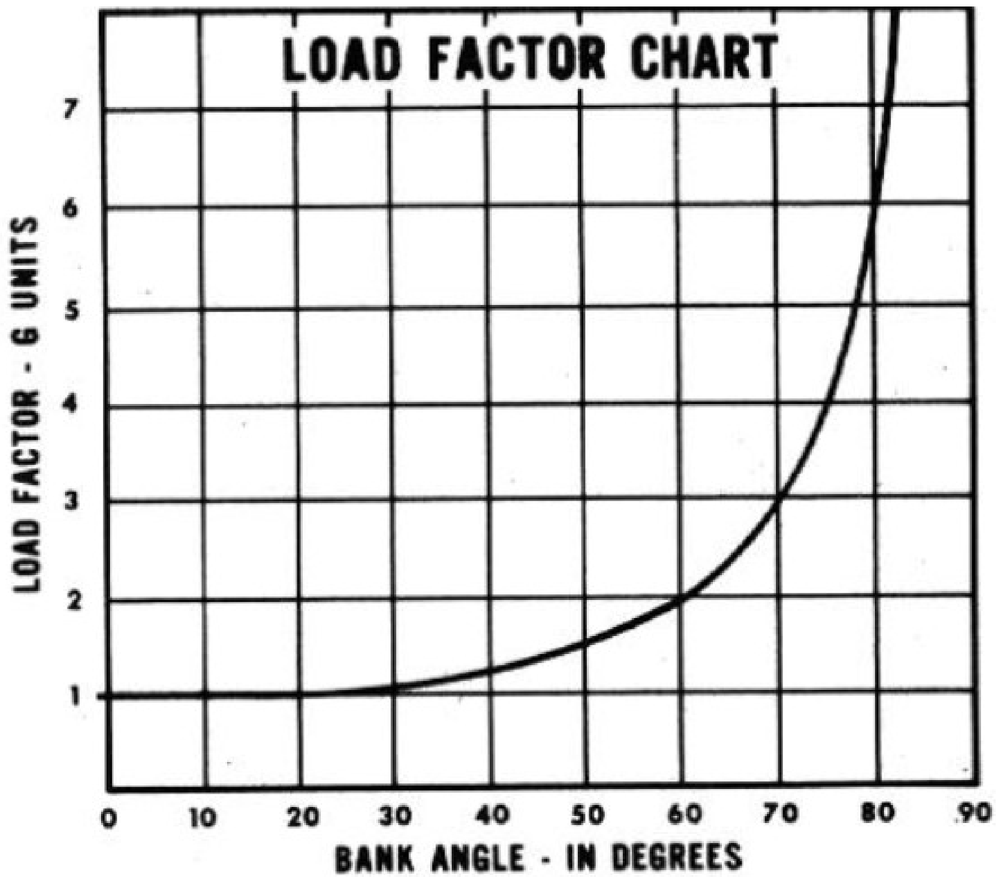


Figure 17–48 Angle of Bank Changes Load Factor

Management of Weight and Balance

Control

Weight and balance control should be a matter of concern to all pilots. The pilot controls loading and fuel management (the two variable factors that can change both total weight and CG location) of a particular aircraft.

Before any flight, the pilot should determine the weight and balance condition of the aircraft. Simple and orderly procedures based on sound principles have been devised by the manufacturer for the determination of loading conditions. The pilot uses these procedures and exercises good judgment when determining weight and balance. In many modern aircraft, it is not possible to fill all seats, baggage compartments, and fuel tanks, and still remain within the approved weight and balance limits. If the maximum passenger load is carried, the pilot must often reduce the fuel load or reduce the amount of baggage.

Terms and Definitions

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. Terms defined by the General Aviation Manufacturers Association (GAMA) as industry standard are marked in the titles with GAMA.

Terms and Definitions `

- **Arm** (moment arm)—the horizontal distance in inches from the reference datum line to the CG of an item. The algebraic sign is plus (+) if measured aft of the datum and minus (–) if measured forward of the datum.
- **Basic empty weight**—the standard empty weight plus the weight of optional and special equipment that have been installed.
- **Center of gravity** (CG)—the point about which an aircraft would balance if it were possible to suspend it at that point. It is the mass center of the aircraft or the theoretical point at which the entire weight of the aircraft is assumed to be concentrated. It may be expressed in inches from the reference datum or in percent of MAC. The CG is a three-dimensional point with longitudinal, lateral, and vertical positioning in the aircraft.
- **CG limits**—the specified forward and aft points within which the CG must be located during flight. These limits are indicated on pertinent aircraft specifications.
- **CG range**—the distance between the forward and aft CG limits indicated on pertinent aircraft specifications.
- **Datum** (reference datum)—an imaginary vertical plane or line from which all measurements of arm are taken. The datum is established by the manufacturer. Once the datum has been selected, all moment arms and the location of CG range are measured from this point.
- **Delta**—a Greek letter expressed by the symbol **r** to indicate a change of values. As an example, rCG indicates a change (or movement) of the CG.
- **Floor load limit**—the maximum weight the floor can sustain per square inch/foot as provided by the manufacturer.

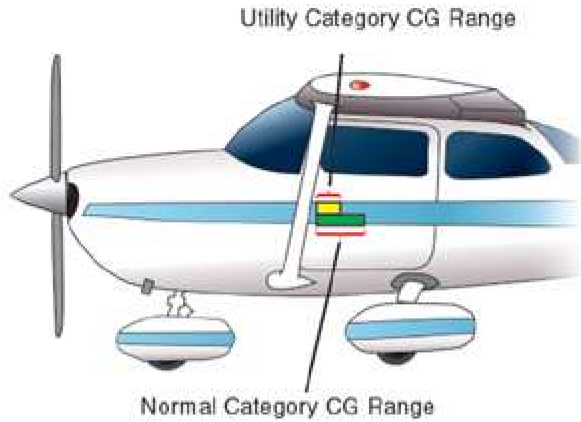
- **Fuel load** —the expendable part of the load of the aircraft. It includes only usable fuel, not fuel required to fill the lines or that which remains trapped in the tank sumps.
- **Licensed empty weight**—the empty weight that consists of the airframe, engine(s), unusable fuel, and undrainable oil plus standard and optional equipment as specified in the equipment list. Some manufacturers used this term prior to GAMA standardization.
- **Maximum landing weight**—the greatest weight that an aircraft is normally allowed to have at landing.
- **Maximum ramp weight**—the total weight of a loaded aircraft including all fuel. It is greater than the takeoff weight due to the fuel that will be burned during the taxi and run-up operations. Ramp weight may also be referred to as taxi weight.
- **Maximum takeoff weight**—the maximum allowable weight for takeoff.
- **Maximum weight**—the maximum authorized weight of the aircraft and all of its equipment as specified in the TCDS for the aircraft.
- **Maximum zero fuel weight** (GAMA)—the maximum weight, exclusive of usable fuel.
- **Mean aerodynamic chord** (MAC) —the average distance from the leading edge to the trailing edge of the wing.
- **Moment**—the product of the weight of an item multiplied by its arm. Moments are expressed in pound-inches (in-lb). Total moment is the weight of the airplane multiplied by the distance between the datum and the CG.
- **Moment index** (or index)—a moment divided by a constant such as 100, 1,000, or 10,000. The purpose of using a moment index is to simplify weight and balance computations of aircraft where heavy items and long arms result in large, unmanageable numbers.

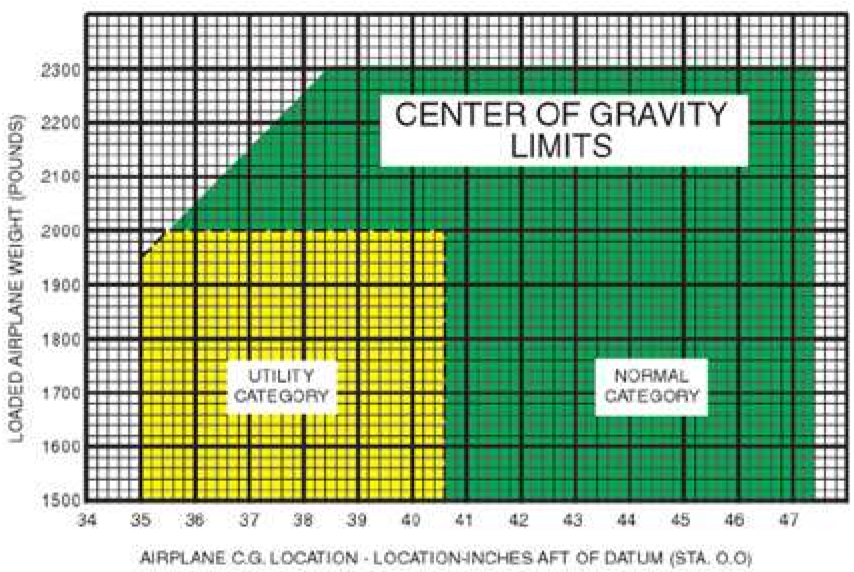
- **Payload** (GAMA)—the weight of occupants, cargo, and baggage.
- **Standard empty weight** (GAMA)—aircraft weight that consists of the airframe, engines, and all items of operating equipment that have fixed locations and are permanently installed in the aircraft, including fixed ballast, hydraulic fluid, unusable fuel, and full engine oil.

- **Standard weights**—established weights for numerous items involved in weight and balance computations. These weights should not be used if actual weights are available. Some of the standard weights are:

Gasoline.. 6.0 lbs/US gal
Jet A, Jet A-1...................................... 6.8 lbs/US gal
Jet B...6.5 lbs/US gal
Oil...7.5 lbs/US gal
Water..,, 8.35 lbs/US gal

- **Station**—a location in the aircraft that is identified by a number designating its distance in inches from the datum. The datum is, therefore, identified as station zero. An item located at station +50 would have an arm of 50 inches.
- **Useful load**—the weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil. It is the basic empty weight subtracted from the maximum allowable gross weight. This term applies to general aviation (GA) aircraft only.





MANEUVER LIMITS

NORMAL CATEGORY

This airplane is certificated in both the normal and utility category. The normal category is applicable to aircraft intended for non-aerobatic operations. These include any maneuvers incidental to normal flying, stalls (except whip stalls), lazy eights, chandelles, and turns in which the angle of bank is not more than 60°. Aerobatic maneuvers, including spins, are not approved.

UTILITY CATEGORY

This airplane is not designed for purely aerobatic flight. However, in the acquisition of various certificates such as commercial pilot, instrument pilot and flight instructor, certain maneuvers are required by the FAA. All of these maneuvers are permitted in this airplane when operated in the utility category.

Manufacturers Load Limit Categories

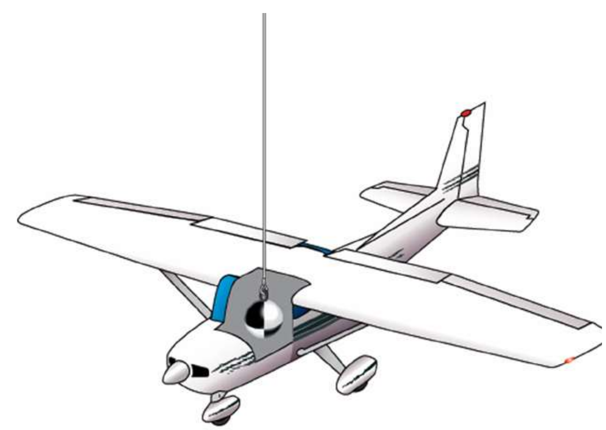
Normal +3.8G, -1.52G
Utility +4.4G, -1.76G
Acrobat +6.0G, -3.00G

Principles of Weight and Balance Computations

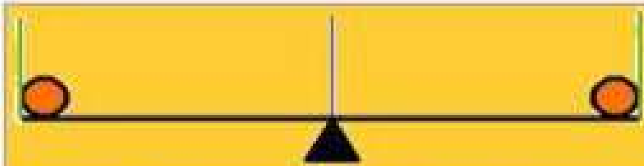
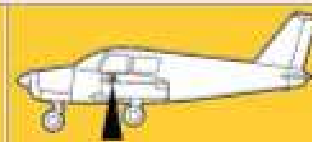
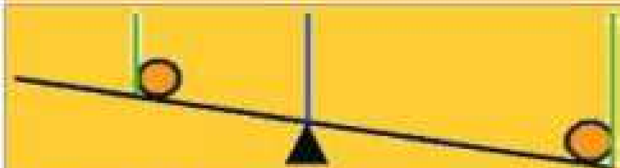
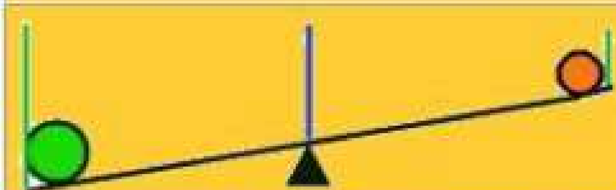
It is imperative that all pilots understand the basic principles of weight and balance determination. The following methods of computation can be applied to any object or vehicle for which weight and balance information is essential.

By determining the weight of the empty aircraft and adding the weight of everything loaded on the aircraft, a total weight can be determined—a simple concept. A greater problem, particularly if the basic principles of weight and balance are not understood, is distributing this weight in such a manner that the entire mass of the loaded aircraft is balanced around a point (CG) that must be located within specified limits. It is the imaginary point at which all the weight is concentrated. To provide the necessary balance between longitudinal stability and elevator control, the CG is usually located slightly forward of the center of lift. This loading condition causes a nose-down tendency in flight, which is desirable during flight at a high AOA and slow speeds.

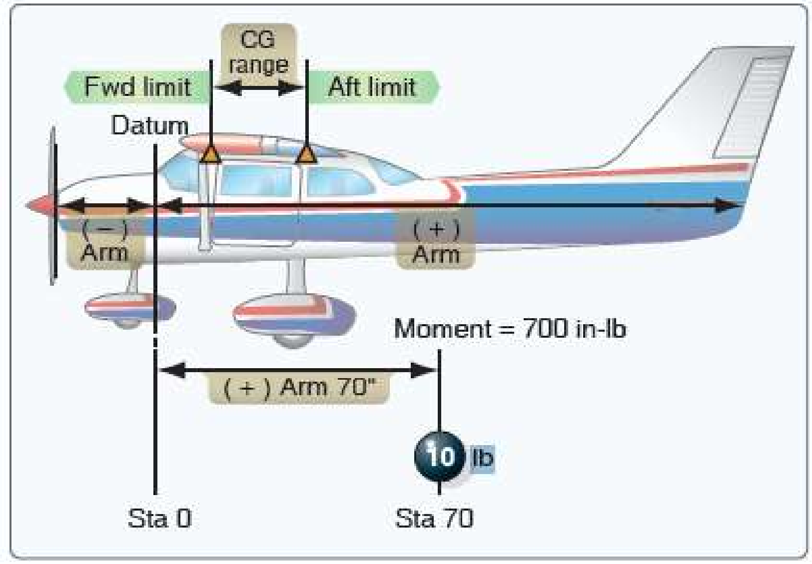
(CG) - IMAGINARY POINT OF BALANCE FOR THE AIRCRAFT



Balance

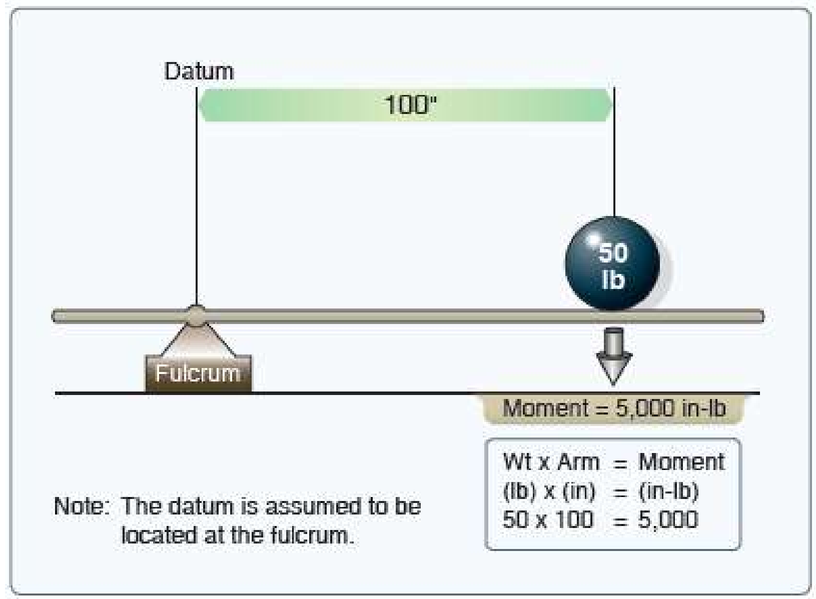
		
5 pounds X 10 inches = 50 inch/pounds	5 pounds X 10 inches = 50 inch/pounds	The airplane is balanced when weight and distance is equal from the center of gravity balance point.
		
5 pounds X 5 inches = 25 inch/pounds	5 pounds X 10 inches = 50 inch/pounds	If one of the weights is shifted, an imbalance will also exist.
		
10 pounds X 10 inches = 100 inch/pounds	5 pounds X 10 inches = 50 inch/pounds	If one of the weights is increased, an imbalance occurs.
		
10 pounds X 5 inches = 50 inch/pounds	5 pounds X 10 inches = 50 inch/pounds	Shifting the weight will return the plane to a balanced condition.

Principles of Weight and Balance Computations



The *safe zone* within which the balance point (CG) must fall is called the ***CG range***. The extremities of the range are called the forward CG limits and aft CG limits. These limits are usually specified in inches, along the longitudinal axis of the airplane, measured from a reference point called a datum reference. The datum is an arbitrary point, established by aircraft designers that may vary in location between different aircraft.

The distance from the datum to any component part or any object loaded on the aircraft is called the arm. When the object or component is located aft of the datum, it is measured in positive inches; if located forward of the datum, it is measured as negative inches or minus inches. The location of the object or part is often referred to as the station. If the weight of any object or component is multiplied by the distance from the datum (arm), the product is the moment. The moment is the measurement of the gravitational force that causes a tendency of the weight to rotate about a point or axis and is expressed in inch-pounds (in-lb).

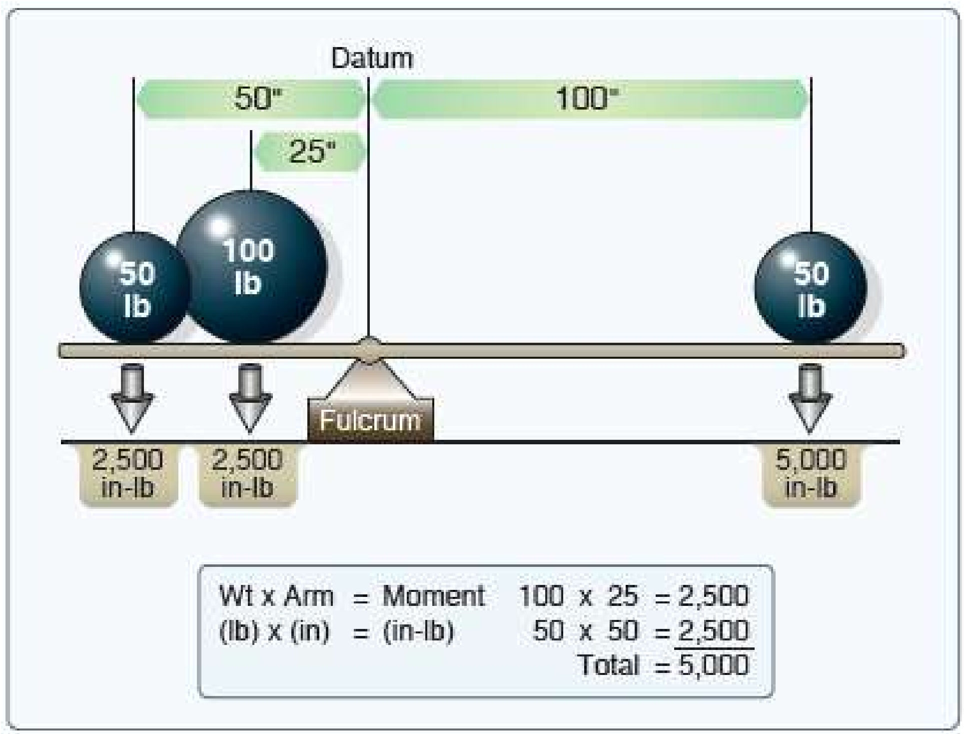


To illustrate, assume a weight of 50 pounds is placed on the board at a station or point 100 inches from the datum. The downward force of the weight can be determined by multiplying 50 pounds by 100 inches, which produces a moment of 5,000 in-lb.

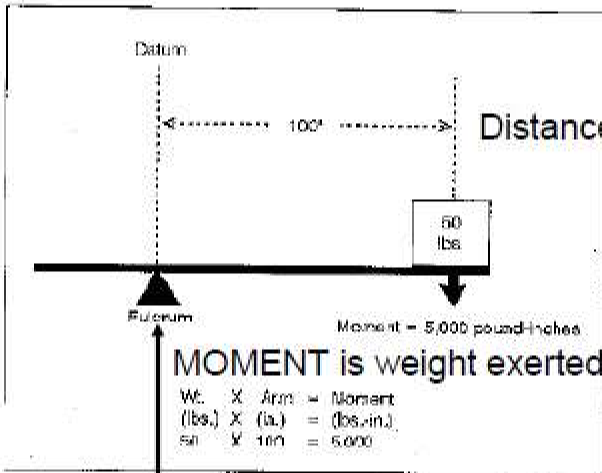
Principles of Weight and Balance Computations

To establish a balance, a total of 5,000 in-lb must be applied to the other end of the board. Any combination of weight and distance which, when multiplied, produces a 5,000 in-lb moment will balance the board.

For example, if a 100-pound weight is placed at a point (station) 25 inches from the datum, and another 50-pound weight is placed at a point (station) 50 inches from the datum, the sum of the product of the two weights and their distances total a moment of 5,000 in-lb, which will balance the board. 50 lb 100" Moment = 5,000 in-lb Fulcrum Datum Wt x Arm = Moment (lb) x (in) = (in-lb) 50 x 100 = 5,000 Note: The datum is assumed to be located at the fulcrum.



Distance weight is from datum is called ARM

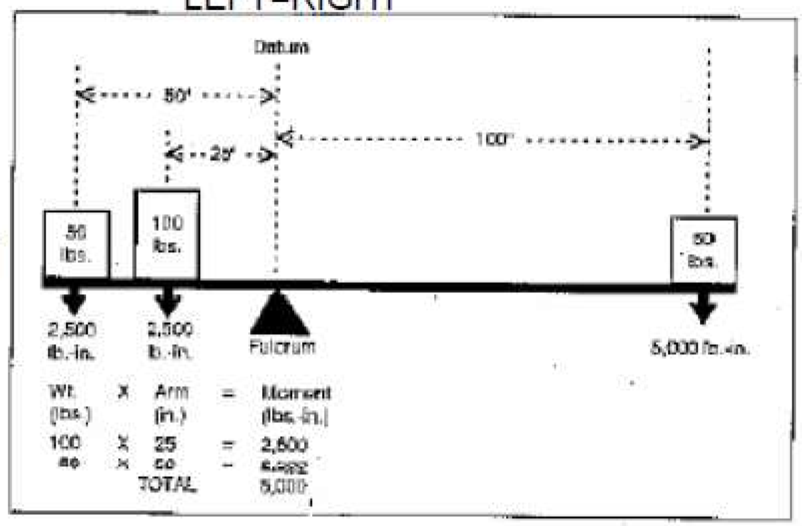


MOMENT is weight exerted at end of the arm

Reference Datum is our fulcrum

LEFT=RIGHT

BALANCING ACT

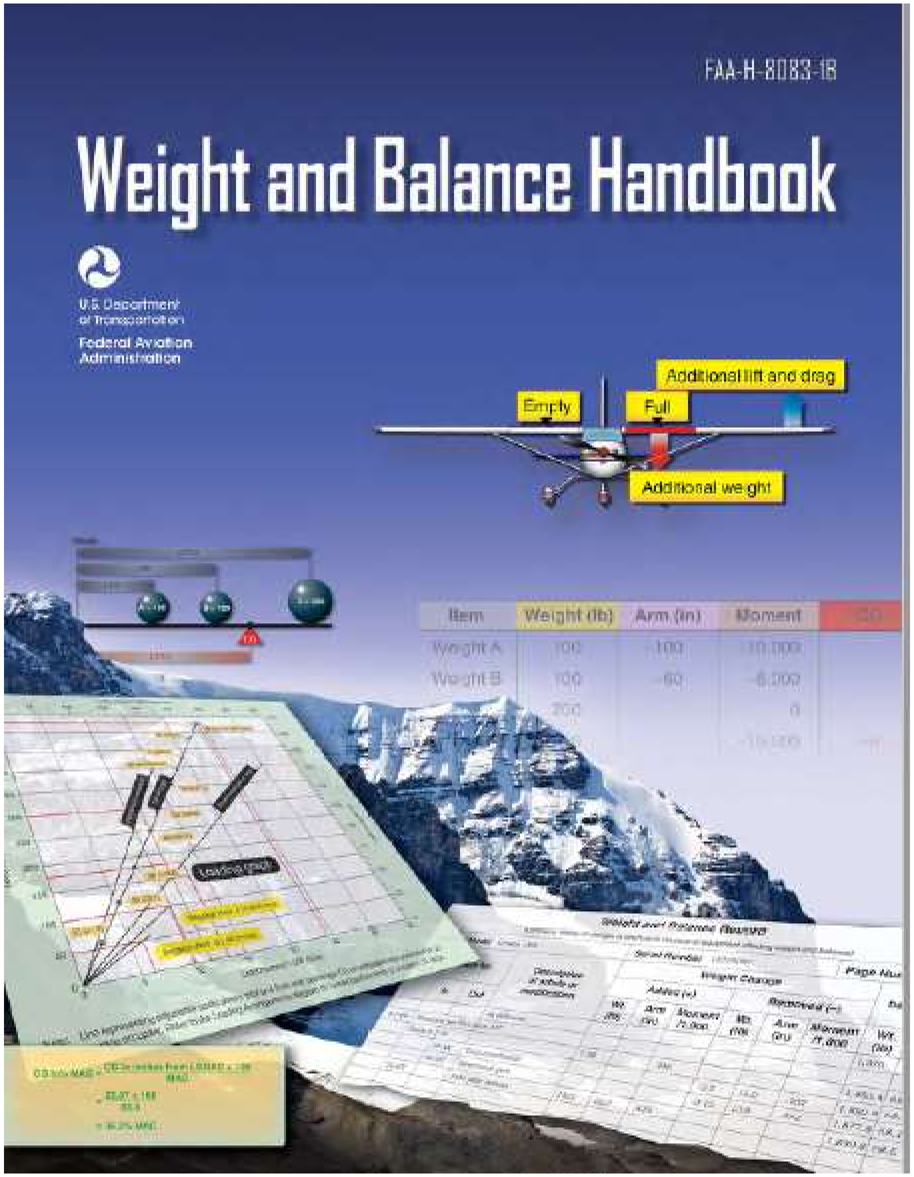


MEASURING YOUR UAS WEIGHT AND BALANCE

If greater than 55 lbs, it is best to have the vehicle evaluated for proper weight an balance by an aviation maintenance shop that has equipment to calibrate fixed wing aircraft.

Otherwise weight and balance can be evaluated manually by the operator with simple tools. Fully load the UAS with battery and sensors as it would be flying the mission, then

1. use a scale to weigh the UAS to insure it does not exceed the manufacturer's gross weight
2. suspend the UAS by wire or strong string from the center of the frame and visually observe than it does not exhibit forward or reward CG



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Created by Steve Reisser

[REMAINING SLIDES ARE FOR COMMERCIAL STUDENTS ONLY]

PERFORMANCE

You as Remote Pilot are responsible to prepare and fly your sUAS in accordance to FAA 91 and 107 regulations. That means that you must plan and execute each flight understanding every aspect of your mission prior to launch, and you must be prepared to execute emergency procedures should that be required.

Performance

- You must know your UAS. You should have a "owners handbook" (User's Manual) which will identify the flight parameters of your UAS.
- You must know and be able to monitor SPEEDS in any given flight mode, ALTITUDES, and FLIGHT DURATION in any configuration.
- You must know when it is time to make a safe return of the UAS to its launch point.
- You should plan alternate recovery locations should your UAS be unable to return to its launch point.
- <u>*PREFLIGHT ALL FLIGHT SEGMENTS, OPERATIONS, AND CONTINGENCIES PRIOR TO LAUNCH*</u>.

FAA 107 5.10 covers several performance considerations.

5.10 Operating Limitations for Small UA.

The small UA must be operated in accordance with the following limitations:

- Cannot be flown faster than a groundspeed of 87 knots (100 miles per hour);
- Cannot be flown higher than 400 feet above ground level (AGL), unless flown within a 400-foot radius of a structure and does not fly higher than 400 feet above the structure's immediate uppermost limit;
- Minimum visibility, as observed from the location of the CS, may not be less than 3 statute miles (sm); and
- Minimum distance from clouds being no less than 500 feet below a cloud and no less than 2000 feet horizontally from the cloud.

Note: These operating limitations are intended, among other things, to support the remote pilot's ability to identify hazardous conditions relating to encroaching aircraft or persons on the ground, and to take the appropriate actions to maintain safety.

5.10.1 Determining Groundspeed.

There are many different types of sUAS and different ways to determine groundspeed. Therefore, this guidance will only touch on some of the possible ways for the remote PIC to ensure that the small UA does not exceed a groundspeed of 87 knots during flight operations. Some of the possible ways to ensure that 87 knots is not exceeded are as follows:

- Installing a Global Positioning System (GPS) device on the small UA that reports groundspeed information to the remote pilot, wherein the remote pilot takes into account the wind direction and speed and calculates the small UA airspeed for a given direction of flight, or

- Timing the groundspeed of the small UA when it is flown between two or more fixed points, taking into account wind speed and direction between each point, then noting the power settings of the small UA to operate at or less than 87 knots groundspeed, or

- Using the small UA’s manufacturer design limitations (e.g., installed groundspeed limiters).

5.10.2 Determining Altitude.

In order to comply with the maximum altitude requirements of part 107, as with determining groundspeed, there are multiple ways to determine a small UA's altitude above the ground or structure. Some possible ways for a remote pilot to determine altitude are as follows:

- Installing a calibrated altitude reporting device on the small UA that reports the small UA altitude above mean sea level (MSL) to the remote pilot, wherein the remote pilot subtracts the MSL elevation of the CS from the small UA reported MSL altitude to determine the small UA AGL altitude above the terrain or structure;

- Installing a GPS device on the small UA that also has the capability of reporting MSL altitude to the remote pilot;

- With the small UA on the ground, have the remote pilot and VO pace off 400 feet from the small UA to get a visual perspective of the small UA at that distance, wherein the remote pilot and VO maintain that visual perspective or closer while the small UA is in flight; or

- Using the known height of local rising terrain and/or structures as a reference.

5.10.3 Visibility and Distance from Clouds.

Once the remote PIC and VO have been able to reliably establish the small UA AGL altitude, it is incumbent on the remote PIC to determine that visibility from the CS is at least 3 sm and that the small UA is kept at least 500 feet below a cloud and at least 2,000 feet horizontally from a cloud. One of the ways to ensure adherence to the minimum visibility and cloud clearance requirements is to obtain local aviation weather reports that include current and forecast weather conditions. If there is more than one local aviation reporting station near the operating area, the remote PIC should choose the closest one that is also the most representative of the terrain surrounding the operating area. If local aviation weather reports are not available, then the remote PIC may not operate the small UA if he or she is not able to determine the required visibility and cloud clearances by other reliable means. It is imperative that the UA not be operated above any cloud, and that there are no obstructions to visibility, such as smoke or a cloud, between the UA and the remote PIC.

FARs prohibits operation of an sUAS at night, which is defined in part 1 as the time between the end of evening civil twilight and the beginning of morning civil twilight, as published in The Air Almanac, converted to local time. In the continental United States (CONUS), evening civil twilight is the period of sunset until 30 minutes after sunset and morning civil twilight is the period of 30 minutes prior to sunrise until sunrise. In Alaska, the definition of civil twilight differs and is described in The Air Almanac. The Air Almanac provides tables which are used to determine sunrise and sunset at various latitudes. These tables can also be downloaded from the Naval Observatory and customized for your location. The link for the Naval Observatory is http://aa.usno.navy.mil/publications/docs/aira.php.

Civil Twilight Operations. When sUAS operations are conducted during civil twilight, the small UA must be equipped with anticollision lights that are capable of being visible for at least 3 sm. However, the remote PIC may reduce the visible distance of the lighting less than 3 sm during a given flight if he or she has determined that it would be in the interest of safety to do so, for example if it impacts his or her night vision. sUAS not operated during civil twilight are not required to be equipped with anti-collision lighting.

In-Flight Emergency.

An in-flight emergency is an unexpected and unforeseen serious occurrence or situation that requires urgent, prompt action. In case of an in-flight emergency, the remote PIC is permitted to deviate from any rule of part 107 to the extent necessary to respond to that emergency. A remote PIC who exercises this emergency power to deviate from the rules of part 107 is required, upon FAA request, to send a written report to the FAA explaining the deviation. Emergency action should be taken in such a way as to minimize injury or damage to property.