Weight and Balance

Session Time: Three, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

Comprehensive preflight planning is an integral (and regulatory) component of safety for all flights.

Safe and efficient aviation operations require that pilots use math, science, and technology.

Pilots rely upon a wide range of printed and electronic resources for flight planning.

A thorough understanding of how an aircraft operates enables a pilot to fly an aircraft safely within its design parameters.

ESSENTIAL QUESTIONS

1. How does a pilot use aircraft documentation to determine whether an aircraft is loaded appropriately for flight?

LEARNING GOALS

Students Will Know

- How to determine if an aircraft is within safe weight and balance limits.
- How to adjust weight on an aircraft in order to operate it within safe limits.

Students Will Be Able To

- *Recall* key terms relevant to aircraft weight and balance. [DOK-L1]
- *Calculate* the weight and balance of an aircraft using industry standard tables and graphs. [DOK-L2]
- *Explain* how an aircraft's operation is affected by weight and balance. [DOK-L2]

ASSESSMENT EVIDENCE

Warm-up
In pairs, students will review key terms about weight and balance using a matching exercise. They will then discuss any difficult or confusing terms as a class.

Formative Assessment
In pairs, students will recall key weight and balance concepts and synthesize those concepts in a weight-shifting scenario.

Summative Assessment

In pairs, students will analyze a scenario for aircraft weight and balance, determine changes in a dynamic situation, and make decisions as the pilot-in-command regarding safety of flight.

LESSON PREPARATION

MATERIALS/RESOURCES

- Weight and Balance Presentation
- Weight and Balance Student Activity 1
- Weight and Balance Student Activity 2
- Weight and Balance Student Activity 3
- Weight and Balance Student Activity 4
- Weight and Balance Teacher Notes 1
- Weight and Balance Teacher Notes 2
- Weight and Balance Teacher Notes 3
- Weight and Balance Teacher Notes 4
- **Calculator**

Student Activity 2

- **5 whiteboards or pieces of chart paper**
- **Markers**

LESSON SUMMARY

Lesson 1: Weight and Balance
Lesson 2: Density Altitude
Lesson 3: Takeoff and Landing Distances
Lesson 4: Aircraft Power Settings

The lesson will begin with a warm-up reviewing fundamental terms and concepts of aircraft weight and balance. This will be followed by group discussions about the impact of weight and balance and opportunities to calculate weight and balance in unique scenarios.

In the next part of the lesson, students will be introduced to the table method of computing weight and balance. Students will have multiple opportunities to discuss and apply weight and balance concepts, compute the center of gravity for an aircraft, and determine the impact weight and balance changes have on an aircraft.

Finally, students will work in pairs and act as pilot-in-command to apply the fundamental concepts of weight and balance to scenarios impacting safety of flight.

BACKGROUND

Teaching Tips
Consider reviewing Grade 10, Unit 4, Section C, Lesson 1, as this lesson reviews and builds on that material.

As discussed in previous lessons, it is important to operate an aircraft within its approved weight and balance limitations. An aircraft's performance and handling characteristics depend on its weight and balance condition. Nearly every aspect of aircraft performance is influenced by how much weight is carried and where it is placed in the aircraft.

Too much weight can increase takeoff distance, reduce climb performance, and increase fuel consumption. Structural damage is even a possibility in turbulence, during maneuvering, or while landing.

The location of passengers, baggage, cargo, and fuel within an aircraft affects the performance characteristics as well. An improperly balanced aircraft is said to be “out of limits,” and aircraft control and performance suffer. In extreme cases, a pilot may find it impossible to make the aircraft climb or descend.

Proper weight and balance calculations are critical to the safety of every flight. For all aircraft, there are acceptable values for total weight (gross weight) and the location of that weight within the aircraft (center of gravity or CG).

Aircraft that are over their approved weight limits must have weight removed to fly safely. If a pilot finds that the aircraft is within weight limits but out of CG limits, they may redistribute the weight within the aircraft in an attempt to move the CG into the approved range which is called “the envelope.”

As part of preflight planning, pilots use the data found in the aircraft’s pilot operating handbook (POH) to calculate the weight and balance for their aircraft and determine that it is safe to fly. This determination can be done using computations, graphical methods or the use of tables. The weight and balance information for an aircraft must be carried aboard the aircraft and is usually found within the POH. Federal Aviation Regulations (FARs) 91.9, 91.103, and 21.1589 effectively require that current weight and balance information for the aircraft being flown is in the aircraft. It should be part of the airplane flight manual (AFM) which is considered a part of the POH. FAR 91.103 stipulates that during preflight planning, a pilot must be aware of “all available information” about that particular flight. This includes performing a weight and balance calculation.

MISCONCEPTIONS

Students might assume a four-seat aircraft can always take off with four people, but this is not necessarily the case. An aircraft can take off with all of its seats occupied only if the combined weight of all people onboard (plus all other baggage, fuel, and equipment) is less than the maximum allowable weight of the aircraft. In actuality, few general aviation aircraft can carry average adults in every single seat, the maximum amount of cargo, and full fuel without being over the maximum allowable weight. Even if there is an empty seat, room for more baggage, and less than full fuel in the tanks, it is possible to be overweight for a particular flight (density altitude could be a limiting factor for example). Equally important is the placement of any weight in the aircraft. An aircraft may be under its maximum allowable weight, yet outside its CG limits.

Regardless of how many seats there are, how much room is available in the baggage area, or how much fuel the tanks can hold, it is critical that pilots compute the weight and balance prior to taking off.

Students may think that if the aircraft CG is calculated to be outside the acceptable aircraft limitations that it is an automatic “do not fly.” While pilots should not fly in that particular configuration, they can choose to adjust the distribution of the weight on the aircraft or reduce the weight to bring the weight and balance within CG limits.

DIFFERENTIATION

To promote learner confidence and motivation during the EXPLORE section of the lesson plan, circulate among students to assist with calculations. Working quickly and with a group may be a challenge for some students. Having their instructor provide some guidance can help them work in the right direction.

To encourage learner motivation and engagement during the EXPLAIN and EXTEND sections of the lesson plan, have students perform a think-pair-share when asking the discussion questions. This will encourage participation from all students, not just those who are eager to share their answers.

LEARNING PLAN

ENGAGE

Teacher Materials: Weight and Balance Presentation, Weight and Balance Teacher Notes 1
Student Material: Weight and Balance Student Activity 1

Session 1

Slides 1-3: Introduce the topic and learning objectives of the lesson.

Slide 4: Conduct the **Warm-Up**.

> **Warm-Up**
>
> Divide the class into pairs and distribute **Weight and Balance Student Activity 1**. Students will work together to match terms associated with weight and balance with their meanings. Potential responses are available in **Weight and Balance Teacher Notes 1**.
> [DOK-L1; *recall*]

Once the students have completed the warm-up, come together as a class and identify any terms that were difficult to discern or potentially confusing. Allow students to share techniques for distinguishing difficult terms.

EXPLORE

Teacher Materials: Weight and Balance Presentation, Weight and Balance Teacher Notes 2
Student Materials: Weight and Balance Student Activity 2, **Whiteboards or Chart Paper, Markers**

Slide 5: Divide the class into five groups and distribute **Weight and Balance Student Activity 2**. Students will work in teams to brainstorm and record key aspects of the impact of weight and balance on an aircraft. Potential responses are available in **Weight and Balance Teacher Notes 2**.

Once students have completed the activity, discuss the results. Ask students if they saw any inaccurate information, or if any information is missing from each station. Confirm that students understand these key concepts before proceeding.

EXPLAIN

Teacher Materials: Weight and Balance Presentation, Weight and Balance Teacher Notes 3
Student Material: Weight and Balance Student Activity 3

Slide 6: There are certain key terms for weight and balance that must be well understood.

- **Basic Empty Weight:** The weight of the airframe, engines, installed equipment, unusable fuel, and all required fluids (like oil, unusable fuel, and hydraulic fluid). It does not include items such as usable fuel, cargo, baggage, or occupants.
- **Maximum Gross Weight:** The maximum authorized weight of the aircraft.
- **Useful Load:** The maximum gross weight minus the basic empty weight. It is the amount of weight that can be loaded onto the aircraft, including the pilot, copilot, passengers, baggage, usable fuel and drainable oil. (Because of some variation in certification, pilots should confirm whether oil is included in the empty weight for their particular airplane.)
- **Arm:** The distance from the reference datum to an applied force. The datum is simply a designated reference point. In some airplanes, it is the nose; in others, it is the firewall separating the engine compartment from the passenger compartment.

Slide 7: Because pilots so frequently perform weight and balance calculations, they should be familiar with the weights of common fluids:

- Fuel: 6.0 lbs/gal
- Water: 8.35 lbs/gal

- Oil: 7.5 lbs/gal

Note: Oil is weighed in pounds per *gallon*, but for most general aviation aircraft, oil quantity is measured in quarts.

Finally, it is worth noting that the FAA has a weight for a "standard person" of 190 lbs (see AC 120-27e). While this is commonly used for larger airplanes with many passengers, pilots of aircraft with just a few seats (and small margins in aircraft weight) should use actual passenger weights unless a passenger is uncomfortable sharing that information. In that case, using the FAA standard is a good starting point.

Slide 8: Pilots consider weight and balance important because of the significant impact it can have on the aircraft. Have students recall Weight and Balance Student Activity 2, which they just completed, and discuss:

Questions

What problems are caused by overloading an aircraft?

Potential responses include:

- *Higher weights require higher takeoff speeds, which then require longer takeoff distances and longer runways.*
- *Higher weights also require longer landing distances because approach and landing speeds are higher.*
- *The climb rate and angle of climb are lower, meaning it takes longer to get to cruise altitude.*
- *The cruise speed is lower and the drag due to lift is higher, resulting in higher fuel consumption and shorter range.*
- *Stall speed is also higher, potentially decreasing the margin between the normal airspeed range and stall speed.*

Slide 9: Weight and balance can affect the safety of a flight, so pilots must address any out-of-limit conditions before takeoff. Common problems are too much weight onboard which may put the aircraft over its maximum gross weight, and an out-of-limit CG which may make the aircraft uncontrollable in pitch.

Managing weight and balance may require compromises. For example, in order for a family to travel together, the pilot may only be able to carry enough fuel to fly part of the distance to the destination. This means that the pilot will have to plan a fuel stop along their route.

Questions

What can a pilot do if a fully loaded aircraft is overweight?

If the aircraft is overweight, weight must be removed. This could be done by removing baggage, reducing the number of people on the flight, or, in some cases, removing fuel from the fuel tanks on the airplane. Reducing fuel will have other effects like reducing the range the aircraft can fly.

How might pilots address issues if an aircraft is within its required weight but its CG is out of the approved envelope?

If the center of gravity is beyond the approved limits, it must be moved back inside the envelope prior to flight. This may be done by redistributing weight within the aircraft. For example, if the CG is too far aft, a heavy item from the rear of the plane (a large suitcase, for example) can be moved forward onto a seat.

How can you use the graphical method to know if the CG is too far forward or aft?

The weight and balance result will plot outside of the drawn envelope on the chart.

Slides 10–11: Besides the computational and graphical methods of determining weight and balance learned in previous lessons, a third technique is the table method.

Teaching Tips

When multiplying a weight by an arm, the units are typically pounds and inches. Some charts use the units lbs-in (pounds inches) and some charts use the units in-lbs (inch pounds). Note that these units are interchangeable.

The table method of calculating weight and balance is simply a tabular format of the same calculations done in previous lessons. If the manufacturer provides them, the tables will be present in the POH.

To use the table method of calculation, pilots typically follow the steps below. Use Figure 10-9 from Student Activity 2 as an example of a tabular weight and balance sheet.

1. Determine the weight of the front seat and rear seat occupants.

2. Find these weights and their associated moments on the “Occupants” table, and enter them on the “Sample Loading Problem” table.

3. Perform the same procedure for the usable fuel and baggage.

4. Add the weights and moments, and enter those values on the “Sample Loading Problem” table.

5. Locate the total weight on the weight and moment tables.

6. Compare the total moment figure from the “Sample Loading Problem” table to the two moments that correspond to the weight.

7. If the total moment is between these two values, then the aircraft is within CG limits.

Questions

Is the example aircraft in weight and balance limits?

Yes, the weights should add to 2,799 pounds with a moment total of 2,278 /100 lb-in. At 2,800 lbs on the table, the range of allowable moments is 2,254 to 2,381 lb-in. The CG is within the allowable range at that weight.

Slide 12: Complete the **Formative Assessment**.

Formative Assessment

Divide the class into pairs and distribute **Weight and Balance Student Activity 3**. Students will work together to demonstrate an understanding of basic weight and balance definitions and apply their knowledge in a notional changing weight and balance scenario. Potential responses are available in **Weight and Balance Teacher Notes 3**.

[DOK-L2; *calculate, explain*]

EXTEND

Teacher Material: Weight and Balance Presentation

Session 2

Slide 13: Recall that "balance" is not strictly an aviation concept, but rather a concept of physics applied to aviation. Consider the example of a simple fulcrum and lever. On one side of the fulcrum, a 50-pound weight located 100 inches from the fulcrum exerts a moment of 5,000 in-lbs (50 100 = 5,000).

Questions

Where does a 100-pound weight need to be placed on the other side of the fulcrum to achieve balance?

The question is asking the students to find the arm. The 100-pound weight needs to exert the same moment, or 5,000 in-lbs.

Since weight arm = moment, then arm = moment weight.

5,000 in-lbs 100 lbs = 50 inches

Slide 14: The next fulcrum comes from the FAA Private Pilot Knowledge Test Supplement. A key difference from the last fulcrum is that this one accounts for the weight of the plank (while the weight of the plank was previously ignored). The weight is still considered to be acting at a point (at the CG of the plank), so the equations remain the same, except there are two loads on one side of the equation.

Questions

How should the 500-lb weight be moved to balance the fulcrum?

Conceptually, students should recognize that the larger weight needs a shorter arm to balance the smaller weight / longer arm on the other side. Also, the weight of the plank is acting on the right side of the fulcrum. Mathematically, the moments should be equal on each side:

500 lbs (X in) = (250 lbs 20 in) + (200 lbs 15 in)

500X in-lbs = 5000 in-lbs + 3000 in-lbs = 8000 in-lbs

500X in-lbs = 8000 in-lbs

X = 16 inches

Since the weight is currently at 15 inches, it needs to move 1 inch to the left, away from the balance point.

Slide 15: The details of weight and balance are mathematical, but the concepts should become relatively intuitive to a pilot.

Consider:

Questions

If the arm for a basic empty weight Cessna C-172 is 47 inches from the datum, and the pilot seat station is 37 inches from the datum, how will the aircraft CG change when a single pilot flies a solo flight?

Since the front seats are in front of the empty aircraft CG, the CG will move forward when the pilot sits in the front seat.

The pilot of the C-172 then loads two passengers in the back seat, with a station arm of 73 inches, leaving the other front seat empty. How will the CG change?

Since the rear seats are behind the empty aircraft CG, the CG will move aft with the addition of the passengers. Without doing computations we don't know how far aft, but we do know it moves aft.

Slides 16–17: Often the problem a pilot faces isn't calculating weight and balance, but calculating the changes to weight and balance. Aircraft weight and balance is not a static problem. Fuel is used, passengers get on and off the aircraft, and baggage is loaded and unloaded at various points. Every time the loading changes, the pilot needs to confirm the impact to the aircraft weight and balance.

Questions

The pilot of the same C-172 (one pilot, two rear seat passengers) performs the weight and balance calculations and determines the aircraft is within the CG envelope, and will be at the maximum weight when the fuel tanks are full. Wanting to maximize the aircraft's range, the pilot fills the fuel tanks. Then, one of the passengers remembers they wanted to bring their golf clubs, which weigh 60 pounds and will go in the baggage compartment behind the rear seats.

How will the addition of the golf clubs change the current weight and balance?

Since the pilot maximized the weight by adding full fuel, adding more weight will put the aircraft over its weight limit. The equipment will also move the CG further aft.

How can the pilot reduce the weight back below the maximum allowable weight (without leaving a passenger or baggage behind)? What are the repercussions for this change?

Without removing a passenger or the golf clubs, the only other option is to remove fuel. Students should recognize the aircraft is now 60 pounds overweight. To reduce the weight by offloading fuel, which is 6 lbs per gallon, the pilot will need to remove 10 gallons of fuel. Generally, this will need to be drained. In some cases, the fuel could be "burned off" on the ground; however, in a

Cessna, it would take an hour at high throttle settings to burn that much fuel, and it will be faster and easier to simply drain it.

The first repercussion for this late change will be a delay in the flight. Despite the delay, the pilot should not be tempted to begin the flight overweight.

The second repercussion will be range. Removing fuel will shorten the range of the aircraft. If the flight was already planned at maximum range, the addition of the golf clubs and subsequent reduction in fuel carried will require a fuel stop, which will make the total trip time longer.

After removing fuel, the pilot recalculates the weight and balance to account for the golf clubs and finds that the CG is too far aft. What can the pilot do to adjust the CG so that it falls within the acceptable range?

The pilot needs to move weight forward. This could mean moving a passenger to the front seat and /or moving the golf clubs forward to a seat. The pilot will need to perform a weight and balance calculation to ensure the new CG is within limits.

Slides 18–20: Not every weight and balance change requires a complete recalculation of all numbers. In some cases, the pilot can recompute just the change and see how it impacts the overall weight and balance.

For the following example, reference the tables and charts on the slides:

Questions

For the example aircraft chart provided, what is the change in weight and balance caused by consuming 30 gallons of fuel?

According to the fuel table, 30 gallons is 180 pounds and a moment of 135 in-lbs / 100. Thus, removing that fuel would result in a reduction of 180 pounds and a –135 in-lbs /100 change in moment.

If the aircraft took off with a weight of 2,784 pounds and a moment of 2,222 in-lbs / 100 (plotted on the chart), where would the new CG location be after burning 30 gallons of fuel?

Students should be able to plot 2,604 lbs (2,784 – 180) and a moment of 2,087 (2,222 – 135).

How do you think fuel consumption affects the weight and balance of most aircraft?

The consumption of fuel causes an airplane to get lighter. With regard to balance, aircraft designers normally design the airplane's fuel systems so that an aircraft's CG stays within the CG range as it burns fuel. This makes sense; otherwise, a pilot could take off in a safe airplane and fly it into an unsafe condition purely by using fuel. This tends to be why fuel is stored in the wings and fuselage tanks near the wings, which is where the center of gravity is located on most aircraft. The end result is that the CG change is relatively small.

There are exceptions: Some large and complex aircraft have to monitor where the fuel is stored on the aircraft and may even have to pump the fuel between tanks while flying in order to maintain a proper CG. However, most general aviation aircraft have simple fuel systems that permit a pilot to fly a long flight without concern for the CG location as a result of burning fuel.

Slide 21: The next several slides present a realistic travel scenario. Refer to the tables and charts on the slides for the calculations.

Using the charts on the slide: A family goes on a cross country flight. An adult (180 lbs) and a teenager (140 lbs) are in the front seats. Another passenger (170 lbs) is in one of the rear seats (forward position). There is a 50 lb suitcase in the baggage area, and the aircraft has 49 gallons of fuel.

What is the total weight and moment?

Weight: 180 + 140 + 170 + 50 + 294 = 839 lbs

Moment: 153 + 119 + 189 + 75 + 221 = 757 in-lbs

(Students may choose to round the fuel quantity or use the 49-gallon numbers.)

Aircraft total:

Weight: 2,110 + 839 = 2,949 lbs

Moment: 1,652 + 757 = 2,409 in-lbs

Slide 22: Is the aircraft within its weight and balance envelope?

Yes, the aircraft is within its envelope.

Slide 23: After landing, the aircraft has consumed 20 gallons of fuel. The adult in the front seat gets out and takes the suitcase. The rear seat passenger moves to the front seat. How has the weight and balance changed?

New Weight: 2950 – 180 – 120 – 50 = 2,600 lbs

New Moment: 2409 – 153 + 145 – 189 – 90 – 75 = 2,047 in-lbs

Slide 24: Plot the new CG location on the chart.

If the aircraft returns to the starting airport without refueling, burning another 20 gallons of fuel, how do you think the CG will change? Estimate the location of the new CG on the chart.

Students should be able to estimate that the weight and moment will both decrease. Because the fuel has an arm of 75 inches and the CG diagram is centered at about 82 inches, less fuel at 75 inches will cause the CG to move aft slightly. Therefore, the change in CG on the chart should be indicated by a short line slightly down and to the right of the last calculation. This can be demonstrated graphically with the following math:

Weight: 2600 – 120 = 2,480 lbs

Moment : 2047 – 90 = 1,957 in-lbs / 100

Slide 25: The center of gravity computation can provide more information than just “in the envelope,” as demonstrated by this example. Students may recall that there are many categories of aircraft. The word category appears in weight and balance charts, but it means something different here.

On a weight and balance chart, the term normal category refers to operations where maneuvers for normal flying are safe as are practice stalls, and bank angles of 60° or less. Some additional commercial pilot maneuvers are also permitted when aircraft loading falls in the normal category envelope.

The area on the weight and balance chart identified as the utility category allows pilots to perform additional maneuvers that involve high load factors such as intentional spins and steep turns with bank angles between 60° and 90°. In order to ensure structural integrity and aircraft controllability in this range, the CG envelope is limited and maximum weight is limited.

Questions

At a weight of 1,900 lbs and a moment of 70 lb-in /1,000, what category is the aircraft in?

According to the chart, the aircraft is in the utility category when these conditions are plotted.

What do you think this means to the pilot?

The responses will vary based on the students' understanding of aircraft category.

Depending on the aircraft, the normal and utility categories have different operating capabilities or limitations. For example, the envelope for the utility category in this example is smaller than the normal category. To be in the utility category, this aircraft has to have a CG that is further forward and a maximum weight that is lower than most of the normal category. These limits give an increased safety margin against the limits of the aircraft, which often allows the aircraft to be used in different ways.

For example, many Cessna 172 aircraft, if loaded so as to be in the utility category, can be used for flight training in which the aircraft is intentionally spun, while they are not allowed to be intentionally spun if they are in the normal category.

EVALUATE

Teacher Materials: Weight and Balance Presentation, Weight and Balance Teacher Notes 4
Student Material: Weight and Balance Student Activity 4

Session 3

Slide 26: Have students watch the following video of a crash caused by a shift in cargo that resulted in an excessively aft CG. (This is the same video from the grade 10 weight and balance lesson. As it is a film of an actual aircraft crash with fatalities, consider previewing the video to determine its suitability for the class.)

- "National Air Cargo's Boeing 747 freighter crash in Afghanistan" https://video.link/w/kObe

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/7sUWC2jfjqI?start=0&end=43

The accident was caused when cargo shifted to the rear on takeoff, causing the CG to move well aft of the limit and forcing the 747 to pitch up; the pilots did not have enough elevator authority to hold the nose down. The aircraft climbed until it stalled, despite the efforts of the pilots to lower the nose.

Slide 27: The 747 crash was caused by cargo that shifted. There are many notable pictures of aircraft with their tails on the ground due to improper loading. The long tails of most cargo airplanes, which sit well aft of the pivot point of the main landing gear, make them susceptible to tilting backwards if not loaded properly or in the right sequence while on the ground. This is a known issue, which is why many aircraft use tail stands to prevent tipping while cargo is being loaded.

Slides 28–29: Consider: If professional pilots, trained cargo loadmasters, and experienced corporations can have problems properly loading an aircraft, what are the chances the same might occur in the general aviation community? Can a small Cessna or Piper aircraft be improperly loaded?

Divide the students into two groups. Assign each group one of the following two questions. Allow each group to discuss and list some responses, and then have the groups share their thoughts with the whole class. Alternatively, present each question to the entire class for discussion.

Questions

What are some potential reasons why a general aviation pilot might fly an aircraft that is overweight or out of CG (either intentionally or unintentionally)? For example, a pilot who is rushed may not want to take the time to drain fuel to get the aircraft below its weight limit, and might give in to the pressure to fly anyway.

A passenger may not honestly say what they weigh, or may bring baggage on board that is heavier than expected. (There is no requirement for the passenger or baggage to be weighed, unless the pilot requires it.) A pilot who does an improper preflight may not realize there is cargo in the back or how much fuel is onboard.

The pilot may be pressured to get somewhere on time. For example, the pilot may have planned to have half-full fuel tanks, but the refueling truck accidentally filled them to the top. Now, the aircraft will be overweight, but if the pilot waits to drain fuel, they may be late to their destination. Similarly, a business pilot may be pressured by the company to make the flight happen to create revenue. In both cases, external pressure may influence a pilot to take off in an aircraft that is not within its limits.

When the overage is small, the pilot may be tempted to think that just being over the limit "a little bit" is okay.

What are some potential outcomes if a GA pilot flies an aircraft out of CG or weight limits?

An overweight aircraft could be structurally damaged on landing, it may not have enough runway to take off, or it could stall easily. Cruise performance and fuel consumption may suffer. If an aircraft is out of CG limits, it could be difficult to raise the nose either on takeoff or landing, causing an accident, or it could be difficult to lower the nose and prevent a stall.

However, another possibility is that nothing would happen. A pilot may give in to the temptation to fly an aircraft that is just a "little bit" out of limits. It is possible the aircraft will still be flyable (even if outside the published limits), and the flight may be uneventful. It would not be uncommon to find a general aviation pilot who will admit to flying an aircraft outside of its limits with "no problem," but that does not mean it is either acceptable or safe. It could just mean the pilot was lucky in that particular instance. Pilots need to be cautious about the potential for normalization of deviance; that is, a desensitization to the limits and rules that comes if they see them violated without repercussions. The aircraft limits have been created to ensure flight safety and should be adhered to.

Slide 30: Pilots must remember that no matter how many people, organizations, or authorities are involved in preparing, loading, and assessing an aircraft and its passengers and cargo, there is only one person who is held ultimately responsible for the safe operation of the aircraft.

Questions

Who is ultimately responsible for the proper loading of an aircraft?

The pilot-in-command. This is true even if cargo handlers put the baggage on board or a company policy dictates how a pilot is supposed to fly. The PIC is ultimately held responsible, and has ultimate authority to ensure the safe operation of the aircraft.

Slide 31: Conduct the **Summative Assessment.**

Summative Assessment

Divide the class into pairs and distribute Weight and Balance Student Activity 4. Students will work together to evaluate a realistic, changing weight and balance scenario. Potential responses are available in Weight and Balance Teacher Notes 4.

[DOK-L2; *explain*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Postings show evidence of one or more of the following:
    - Correct recall of weight and balance concepts, calculations, and the impact of weight and balance on aircraft flying characteristics.
    - Reasonable application of weight and balance concepts to realistic scenarios
    - Evidence and explanation of the above that demonstrate understanding of the material
- Contributions show understanding of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

Points	Performance Levels
9-10	Demonstrates a clear understanding of all weight and balance concepts, calculations, and the impact of weight and balance on flying characteristics, and reasonably applies that understanding to realistic scenarios, with appropriate explanations.
7-8	Correctly understands most weight and balance concepts, calculations, and the impact of weight and balance on flying characteristics, with some errors, and generally reasonably applies that understanding to realistic scenarios, with some incomplete analysis or errors.
5-6	Understands some weight and balance concepts, calculations, and the impact of weight and balance on flying characteristics, or generally reasonably applies that understanding to realistic scenarios but lacks adequate explanation.
0-4	Provides few, if any, correct ideas about weight and balance concepts, calculations, and the impact of weight and balance on flying characteristics, and/or poorly applies them to scenarios with inadequate explanation.

STANDARDS ALIGNMENT

NGSS STANDARDS

Three-Dimensional Learning

- **HS-ETS1-2** - Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
    - Science and Engineering Practices
        - Asking Questions and Defining Problems
        - Constructing Explanations and Designing Solutions
    - Disciplinary Core Ideas
        - ETS1.A: Defining and Delimiting Engineering Problems
    - Crosscutting Concepts
        - None

COMMON CORE STATE STANDARDS

- **RST.11-12.2** - Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- **RST.11-12.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
- **WHST.11-12.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
- **WHST.11-12.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- **WHST.11-12.9** - Draw evidence from informational texts to support analysis, reflection, and research

REFERENCES

FAA Advisory Circular 120-27e
FAA Weight and Balance Handbook FAA-H-8083-1B
FAA Pilot Handbook of Aeronautical Knowledge
"National Air Cargo's Boeing 747 freighter crash in Afghanistan"
https://youtu.be/7sUWC2jfjqI
Unit 4 Section C Lesson 1 Student Notes 1
Piper Aztec Excel Weight and Balance Spreadsheet
Airman Knowledge Testing Supplement for Sport Pilot, Recreational Pilot, Remote Pilot, and Private Pilot 2018