Small UAS Loading

Session Time: Two, 50-minute sessions

DESIRED RESULTS

ESSENTIAL UNDERSTANDINGS

A deep understanding of how loading affects UAS operations, which enables a remote pilot to fly the vehicle to its maximum capabilities in both normal and abnormal situations. (EU1)

Safe and efficient aviation operations require that pilots use math, science, and technology. (EU2)

ESSENTIAL QUESTIONS

1. What effects will an UAV experience if it is overloaded, or loaded in a manner that makes it unbalanced? How can these situations be avoided?
2. How can a remote pilot determine the center of gravity (CG) of their aircraft? How can weight and balance be calculated?

LEARNING GOALS

Students Will Know

- Why it is important not to overload a UAV, or to fly one that is unbalanced.
- How to compute weight and balance for a UAV.
- The impact that maneuvers other than straight and level flight can have on the load factor a UAV experiences.

Students Will Be Able To

- *Identify* different characteristics that a UAV might exhibit if it is overloaded or unbalanced in flight. [DOK-L1]
- *Make observations* about a UAV's CG, using experiments to determine a vehicle's balance. [DOK-L2]
- *Draw conclusions* about how a UAV's CG can shift in flight, using manufacturer data, experimentation, and weight and balance formulas. [DOK-L3]

ASSESSMENT EVIDENCE

Warm-up
Students will recall concepts of aircraft weight and balance and relate this information to emerging payload drone technologies.

Formative Assessment

Students will answer questions to demonstrate their knowledge of topics from the lesson, including how UAVs with additional payloads operate and how to determine the center of gravity (CG) of an sUAV with an additional payload.

Summative Assessment
Students will apply their knowledge of topics from the lesson, including how to load a UAV and how to analyze load factor.

LESSON PREPARATION

MATERIALS/RESOURCES

- Small UAS Loading Presentation
- Small UAS Loading Student Activity 1
- Small UAS Loading Student Activity 2
- Small UAS Loading Student Activity 3
- Small UAS Loading Teacher Notes 1
- Small UAS Loading Teacher Notes 2
- Small UAS Loading Teacher Notes 3

Drone Center of Gravity Experimentation: Student Activity 1 (per group)

- 2 metal wire coat hangers
- 5 feet of string
- 20 rubber bands
- Needle nose pliers
- 5 pencils, markers, or pens
- Masking tape or duct tape
- Several thumbtacks

LESSON SUMMARY

Lesson 1: Practical Weather for UAS Pilots
Lesson 2: Small UAS Loading
Lesson 3: UAS Aerodynamics and Performance

This lesson begins with a warm-up that asks students to recall what they learned about aircraft weight and balance in grade 10. Students reflect on why these principles are important and how they might be applied to unmanned aerial vehicles (UAVs). Two short videos will introduce students to new uses and applications for fixed-wing and multirotor drones that involve the use of payloads.

During the next part of the lesson students will focus on important weight and balance concepts, including center of gravity, and how they apply to UAVs. Weight and balance limitations and center of gravity will vary depending on the drone model or type (fixed-wing or multirotor), and on various conditions such as weather or additional payloads. Students will learn how to compute weight and balance for a UAV as well as how to determine its center of gravity if no such information is provided by the manufacturer.

Finally, students will consider the concept of load factor, and how turns, climbs, and descents can add centrifugal stress to a UAV. Students will learn how to calculate a UAVs load factor using a load factor chart, which can help remote pilots determine the limits for safe maneuvering of their drones.

BACKGROUND

As UAV technology continues to advance, many new uses and applications are being considered. When most people think of drones, they might imagine small toy drones used for personal entertainment, UAVs primarily used for aerial video and photography, or racing drones used by sports enthusiasts. In recent years, however, an ever-increasing number of industries have begun to use UAVs in new and exciting ways. Building inspections, law enforcement, and terrain mapping are just a few examples of how drones are being used today.

Many new drone applications involve attaching a payload. Examples of such payloads include medical supplies, flotation devices, and fire hoses. Retail and delivery companies such as Amazon and UPS are working to develop advanced UAVs capable of carrying hundreds of pounds. Drones that carry payloads need to meet certain weight and balance specifications in order to ensure safe operation when they are loaded and unloaded. Environmental factors that can impact a UAVs performance, such as weather, altitude, and heat, must be taken into account as well.

MISCONCEPTIONS

It is sometimes thought that considerations of weight and balance for unmanned aerial systems (UAS) are not important, and that such considerations are necessary only for manned aircraft flight. While remote pilots will typically not find it necessary to calculate weight and balance or center of gravity (CG) for each flight, these are still important considerations, especially if aftermarket payloads are added to a UAV (e.g., a camera).

In the world of manned flight, weight and balance are very important and are calculated prior to flight. This helps to ensure that an aircraft's CG remains within acceptable limits for safe flight. Because of this, manned aircraft manufacturers provide precise data detailing the empty weight of an aircraft and the location of its empty-weight center of gravity (EWCG). An aircraft's operating envelope, including its maximum weight and balance limitations, is shown as well.

Many people may assume that similar weight and balance information is also available for UAVs. However, beyond basic UAV takeoff weight and center of gravity, additional information is often not provided by manufacturers. For this reason, if additional modifications or payloads are added to a UAV, the pilot must also act as a test pilot to determine the vehicle's CG and weight limitations. This can be accomplished with the use of math or experimentation, as this lesson will demonstrate.

DIFFERENTIATION

To support student understanding of center of gravity (CG), vehicle weight, and balance, locate images or videos on the Internet of drones carrying a payload. Have students form groups to discuss their observations and make inferences about UAV loading.

LEARNING PLAN

ENGAGE

Teacher Material: Small UAS Loading Presentation

Session 1

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

Slides 4-8: Conduct the **Warm-Up**.

Teaching Tips

Remind students of the differences between these commonly used terms: UAS, UAV, sUAS, sUAV, and drone. UAS = unmanned aerial system, which includes the ground communication systemUAV = unmanned aerial vehicle (i.e., the “drone” itself)sUAS = small unmanned aerial system, which includes the ground communication systemsUAV = small unmanned aerial vehicle (i.e., a small “drone”)drone = a commonly used slang term, typically referring to any unmanned aerial vehicle. Additionally, before watching the video, ask students to recall and define the terms forward and aft: forward = located at the front of an aircraftaft = located at the tail or rear of an aircraft

Warm-Up

Ask students to recall what they learned about aircraft weight and balance in grade 10. As needed, review the four forces of flight: lift, weight, thrust, and drag. Remind students that maintaining proper weight and balance is critical to an aircraft’s ability to maintain a center of gravity (CG) required for safe flight. Students should recall that weight is the gravitational force that pulls down toward the center of the Earth. It is the opposing force to lift. If weight exceeds lift, an aircraft can’t maintain altitude.

Ask students: How might these principles apply to unmanned vehicles?

Students may mention that excess or unbalanced weight may impede a UAVs ability to take off or maneuver properly. Excess weight may also require the UAV to use more power and spin its propellers more rapidly, stressing the UAV’s components and making it less responsive to remote pilot control inputs and potentially unsafe to fly.

Slide 5 shows an illustrated example of different payload weights on a UAV. Overloading a UAV can put stress on its ability to maintain lift. Overloaded UAVs can be stressed beyond their operational limits, causing structural damage, less maneuverability, and reduction of power.

Ask: What does the cartoon suggest about how to properly load a UAV with different payload weights?

Students may answer that excess weight may cause a UAV to struggle beyond its structural and power limitations.

Then, watch the following videos, which show two types of drones (fixed-wing and multicopters) performing different operations that involve payloads.

Remind students that a multirotor UAV uses propellers for lift and maneuvering; a fixed-wing sUAV might take off and land vertically with propellers, but it flies like a traditional airplane, using fixed wings to provide lift.

- “Giant delivery drones are coming, but at what cost?” (Length 6:43)
  https://video.link/w/ekqz

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/WRY0NQmYIS8

- “Drone Could Help Firefighters by Putting Out Fires” (Length 3:13)
  https://video.link/w/blqz

For teachers unable to access Safe YouTube links, the video is also available here: https://youtu.be/Bm2BVTTir4c

Ask students the following question to stimulate discussion: What kinds of weight and balance considerations would be necessary when flying either cargo drones or the firefighting drone depicted in the video?

Students may mention the necessity of keeping the payload within weight and balance limits, and talk about how the UAV's center of gravity (CG) could shift from flight to flight (or even during a flight), depending upon the weight of the payload and where it is placed.

Teaching Tips

Keep in mind that cargo drones are being designed to carry heavy payloads, often over great distances. Such drones must be larger and more powerful than the commercial products that students may have access to. The firefighting drone in the video is still in development; it is supplied with water from a connected hose. This connection to the ground would reduce power, control, stability, and range.

EXPLORE

Teacher Material: Small UAS Loading Presentation

Slides 9-10: Remind students that the CG of any aircraft is the point at which the aircraft would balance if it were suspended. Ask students to recall how a forward CG and aft CG affect the flight characteristics of manned aircraft. (An aircraft with forward CG will pitch down, and an aircraft with aft CG will pitch up.) Then, have students watch the following video, which uses a model airplane with aft CG to demonstrate how controllability is affected.

- "Flite Test - Tail Heavy Plane - FLITE TIP" (Length 5:51)
  https://video.link/w/XvB0

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/00CGAPOp7A0?start=19&end=352

Teaching Tips

The FAA defines center of gravity (CG) as "the point at which all of the weight of the aircraft is considered to be concentrated." Remind students that pilots must maintain their aircraft's CG within the allowable range for its operational weight. Adding a payload to an aircraft or UAV can change the CG and make the aircraft unstable by causing it to pitch too far forward or aft. Unevenly distributed or unsecured payloads can result in instability or, as depicted in the preceding video, catastrophic loss of control.

Briefly discuss the video, asking students how the stability of the aircraft was affected by the aft CG weights, and how this was counteracted by the remote pilot. Student answers should reference the extreme instability of the aircraft, and note the extra control inputs that the pilot was required to make.

Questions

How might a forward-weighted CG imbalance affect the aerodynamics of the UAV?
How might the UAV's pilot need to compensate to maintain control?

It is not important to correct student answers at this point, as these concepts will be explored during the lesson.

EXPLAIN

Teacher Materials: Small UAS Loading Presentation, Small UAS Loading Teacher Notes 1
Student Material: Small UAS Loading Student Activity 1

Slide 11: The motorized propellers on a multirotor UAV produce the thrust that provides the lift; typically, a battery provides the power to operate the motors. Fixed-wing UAVs operate with wings to provide lift; again, a battery typically provides the power necessary for thrust. Students may believe that simply adding a larger high-capacity battery could provide a UAV with a longer flight time or greater lift. Like an aircraft, however, a UAV has lift and balance limitations that must be considered before adding extra components, such as a camera or a larger battery. Adding extra weight can make the drone too heavy to lift off; it may also cause the drone to become imbalanced by shifting its center of gravity (CG).

Teaching Tips

Ask students to consider how many books they could comfortably carry in a knapsack before they became loaded down and unable to move comfortably. Relate this to different UAS models, and remind students that there are payload limitations for what different drones can conceivably carry.

Slide 12: Companies that manufacture UAS provide specifications of the maximum gross weight for their products. These weights vary depending upon the model. They also depend on factors such as the strength of the structure of a UAV (including its wings or propellers), as well as its battery power and wing-loading capacity (the weight per square foot that a wing or propeller can support).

Slide 13: It is important not to overload a UAV with excess weight beyond what is specified by the manufacturer. Doing so may limit the capabilities of the UAV and create dangerous or unsafe flying conditions. Although extra weight may be tolerated by a UAV, it can put extra stress on the parts, which could reduce the lifespan of the vehicle. A UAV may also not perform as well with added weight because its motors must work harder to maneuver (e.g., battery life is shorter, endurance is reduced, climbing time is increased, and maneuverability is reduced).

Slide 14: Adding extra weight to a UAV will also increase the amount of lift required to compensate for it. Have students recall the lift equation: L=1/2CLV2S. In this equation, CL represents the coefficient of lift (or angle of attack), represents pressure, V is velocity and S is surface area. Pressure and the surface area of a UAV's airfoils are fixed, which means that the angle of attack and velocity are the two variables that can be changed to increase lift.

If one is flying a fixed-wing drone, the angle of attack can be increased to increase lift, or the airspeed can be increased. In the case of a multicopter, more thrust will be required from the propellers to increase their velocity and, as a result, lift. If a UAV is too severely overloaded, it may not be possible to increase either the angle of attack or velocity enough to compensate, and the vehicle could stall.

Teaching Tips

Remind students that an aircraft's angle of attack is the wing's (or propellers') chord relative to the direction of the wind. The greater the angle of attack, the greater the lift. However, increased angle of attack also creates more drag, which requires greater thrust to overcome.

Slide 15: Remote pilots should familiarize themselves with the manufacturer's maximum launch weight for a UAV. Many UAS companies provide specifications of the maximum gross weight (takeoff weight) for their products. Even if a remote pilot is flying a UAV within its specified weight limits, it is important to remember that less-than-optimal conditions can cause the vehicle to exhibit decreased flight performance characteristics. When this is the case, weight might need to be reduced before flying.

Less-than-optimal conditions that could contribute to a UAV's decreased flight performance include:

- high wind
- high elevations
- high air temperatures
- high humidity

Other factors that may require a pilot to reduce a drone's weight prior to flight include:

- sloping or uneven terrain
- launch area size or length
- obstacles such as trees or power lines

Slide 16: Remind students that UAVs, like all aircraft, maneuver around three dimensions, or axes of rotation: roll, pitch, and yaw. This rotation occurs along the UAV's longitudinal, lateral, and vertical axes, respectively, which are perpendicular to one another and pass through the vehicle's CG.

A UAV's CG is the average location of the weight of the aircraft. This is also the point from which an aircraft would balance if it were suspended in the air from that point. The principles behind a UAV's CG (including its relationship to axes, weight, and balance) are the same for fixed-wing and multirotor UAVs.

Teaching Tips

Remind students that the three axes of rotation (pitch, yaw, and roll) are the same for a UAV as they are for an airplane.

- Roll or bank occurs when an aircraft tilts to the right or left along its longitudinal axis (the axis running parallel to the fuselage, from nose to tail).
- Pitch occurs when an aircraft tilts upward or downward along its lateral or transverse axis, which runs parallel from wingtip to wingtip.
- Yaw occurs when the nose of an aircraft turns clockwise or counterclockwise along its vertical axis, which runs perpendicular to the wings and fuselage of the aircraft.

Slide 17: Lift keeps an aircraft aloft. Lift forces are concentrated at the center of pressure on a UAV's airfoil or propeller. On a multirotor UAV, the spinning propellers act as the wings and generate lift forces as they push down against the air. The center of pressure moves depending on the UAV's angle of attack, or angle of movement relative to the air. Because the angle of attack is variable as a UAV moves, there is a range of acceptable limits, or flight envelope, within which the CG must remain for the UAV to remain stable and under control. If a UAV moves outside of acceptable operational limits, its roll, pitch, and yaw stability will be adversely affected. Thus, a UAV that flies outside its flight envelope may not operate correctly and could suffer structural damage or stall.

Questions

These questions refer to the picture on the slide.

- How might lift be adversely affected by the human payload this UAV is carrying?
  Students may answer that the payload being carried by the UAV could slow or hinder its ability to move. The UAS remote pilot may also need to adjust control inputs to maintain a safe flight.

- Is this UAV operating within its flight envelope?
  Students may answer that the UAV is operating within an acceptable flight envelope because it is able to maintain lift with the payload of the human it is carrying.

Teaching Tips

Remind students that center of gravity (CG) is not a fixed point on the aircraft. CG can shift based on changes to payload weight and distribution.

Slide 18: Because the CG on a fixed-wing or multirotor UAV can change due to payload or external conditions, so can stability.

- If CG is too far forward on a fixed-wing aircraft, a nose-heavy condition will result. This will pitch the aircraft down, and the aircraft may struggle to pull up from a dive. This will also result in a nose-heavy condition when flying a fixed-wing UAV; in contrast, a multirotor UAV will drift forward when its CG is too far forward.
- If CG is too far aft, the aircraft will be tail-heavy and pitch backward. Aft CG will cause a fixed-wing aircraft or UAV to struggle to pitch down and a multirotor UAV to drift backward.

A UAV with its CG outside its operational limits may still be able to fly. However, this would likely require the remote pilot to apply additional controls to maintain a stable flight. This could also reduce the endurance of the UAS.

Teaching Tips

Point out to students that the drone in the picture on the slide is leaning to one side because its CG has shifted due to the equipment attached below. Similarly, a UAV with additional weight added to the left or right side will result in left or right drift that the remote pilot would need to compensate for.

Slide 19: If additional payload weight is more than a UAV is specified to carry, an extremely unstable flight or catastrophic loss of control could result. Because additional weight can cause the CG to shift, the UAV could become difficult to control. Loss of sUAV control can create unsafe flying conditions for the remote pilot, nearby people, wildlife, and structures.

Slide 20: If additional payload weight is to be added to a UAV, the remote pilot should conduct a test flight to determine if there are any unforeseen performance issues. Test flights should be limited in height and range and conducted away from people and obstacles.

Slide 21: While manned aircraft manufacturers provide important information on weight and balance, unmanned aircraft manufacturers provide much less information, if they include it at all. Some unmanned aircraft manufacturers create UAS that are intended to carry different payload attachments. When this is the case, the maximum takeoff weight for these UAVs will be included. Some UAVs will be marked on the aircraft to show where the CG is located. This can help a pilot to know where best to attach a payload or other additional weight to the vehicle.

Some third-party manufacturers create attachment devices for UAVs that were never intended to carry a payload by the original manufacturer. Third-party companies may include weight limitations and instructions for their devices, but the remote pilot should still conduct test flights and never assume an aftermarket addition to a UAV (e.g., adding a payload attachment, video camera, or lights) is safe just because it was manufactured to be attached to a specific drone.

Slides 22-23:

Questions

Many remote pilots modify or build their sUAS from scratch using many parts from different manufacturers. As a result, they will have to act as test pilots to determine the weight and balance limitations of their UAV, as well as its center of gravity (CG). When this is the case, how can a remote pilot determine CG?

Students may answer that calculations can be used or estimations can be made by experimentation through flight or trial-and-error tests.

Clarify that experimentation may involve hanging a modified or custom-built UAV from a line or string to determine its CG. If the UAV dips and does not hang level, as it would in flight, then the estimated CG is off.

Custom-built model aircraft or UAVs will not come with data for weight and balance. A good method to determine the CG of an aircraft is to experiment by suspending, or balancing, it until the CG has been located. When the aircraft or UAV properly balances from a specific point, as it would during level flight, the CG has been located.

The aircraft on display in the picture on the slide is level because it has been supported from a line attached to its CG.

Slide 24: To end the first session, distribute **Small UAS Loading Student Activity 1**.

Explain that if a remote pilot creates an UAS from scratch or attaches aftermarket attachments to a UAV, the pilot will not know the weight and balance limitations of the modified UAS. To find this information and determine CG, the pilot will generally need to become a test pilot and experiment. Through trial and error, the pilot can ensure that their custom-built or modified UAV will fly properly and predictably.

In this activity, students will conduct this kind of experimentation and explore how different loading configurations can adversely affect a UAV's flight characteristics. Students will use wire coat hangers and other materials to construct and suspend a mock quadcopter frame. By adding a weighted bundle, or payload, students will observe how the balance, and consequently the CG, of a UAV can shift. Sample responses and other notes for the instructor are available in **Small UAS Loading Teacher Notes 1**.

> **Teaching Tips**
>
> If a UAV is available, the experiment can be demonstrated using the UAV; students will see how it behaves when weight is added to different sections. Be sure the rubber bands and string used can properly support the UAV.

EXTEND

Teacher Materials: Small UAS Loading Presentation, Small UAS Loading Teacher Notes 2
Student Material: Small UAS Loading Student Activity 2

Session 2

Slide 25: Point out to students the red lines superimposed on the image of the UAV in the slide; explain that the center of the "X" indicates the CG of the UAV. While simple experimentation might be sufficient to determine CG and weight and balance limitations for a small UAV, a larger UAV might require mathematical calculations to determine this data.

Remind students that arm is the distance from the weight to the CG, and that a moment is the force that is applied to a vehicle as the result of both weight and distance from CG. To find the different CG values for a UAS in different configurations, students can divide the total moment by the total weight.

- Weight Arm = Moment
- CG = Total Moment Total Weight

The initial CG can be determined either by reading manufacturer documentation or through experimentation. Emphasize to students that they may need to calculate the center of gravity of an sUAV because manufacturers may not provide this information.

> **Teaching Tips**
>
> Ask students to recall what they know about weight and balance computations for manned aircraft. Refer students who need extra help to the content in Grade 10 (particularly slide 21 of Unit 4, Section C, Lesson 1).
>
> - Reference datum (or simply datum): an arbitrarily chosen point from which all other locations are measured in inches fore (forward) or aft (behind); considered "station zero"
> - Arm: the distance between the reference datum and a given station, measured in inches
> - Load moment (or simply moment): the product of weight (measured in pounds) and arm (measured in inches); a measure of the tendency of a mass to create a rotating force around a fixed point

Slide 26: Complete the **Formative Assessment.**

Formative Assessment

Distribute **Small UAS Loading Student Activity 2**. Students will work individually to answer the questions in order to demonstrate their understanding of the information and concepts covered in the lesson so far. Sample answers are provided in **Small UAS Loading Teacher Notes 2**.

[DOK-L1; *identify*]

Slide 27: Weight is not the only factor that affects the performance of a UAV. The way a UAV is maneuvered also has an impact on the load experienced by the UAV. Wing loading is a measurement that relates an aircraft's mass to its total wing area. Wing loading is calculated by taking the total weight of an aircraft and dividing it by the total surface area of its wings. In straight and level flight, a UAV's wings or rotors must support a load equal to the sum of the weight of the UAV and its contents. This specific weight for a UAV has a load factor of one G-unit (gravity unit).

However, whenever an sUAV is flying along a curved path (turns, climbs, or descents), centrifugal force is created that acts to the outside of the curve and increases the weight (additional G-units) that the sUAV structure must support. The weight supported by an airplane's wings or an sUAV's propellers in a steep turn is greater than the aircraft's total weight.

Aircraft and UAVs also have what is called load factor. The maximum load is the total weight that an aircraft can support. Load factor is the relationship between an aircraft's maximum load and its total weight. Because different flight maneuvers create additional centrifugal force G-units, aircraft and UAVs are constructed to withstand load factors greater than are required for straight and level flight.

Slides 28-29: To calculate the weight that a UAV's propellers would need to support at a specific bank angle, students can use a load factor chart such as the one on slide 28. To make the calculation, take the weight of a UAV and multiply it by the load factor, represented as (n) in the load factor chart, that corresponds to the bank angle. For example, a 25-pound UAV that enters a 60º bank angle has a load factor (represented in G-units) that is two times greater than normal, so the propellers on the UAV would need to support 50 pounds of weight.

- 25 2 = 50 lbs

Slide 30: Have students use the load factor chart to perform the following calculation. Remind them that load factor increases as the bank angle increases.

Questions

How much weight would the propellers of a 30-pound UAV need to support if it entered a 45º bank angle?

To find the answer, multiply the weight of the UAV (30 lbs) by the load factor (n) for a 45º bank angle; according to the load factor chart, a 45º bank angle has a load factor of 1.414.30 x 1.414 = 42.42 lbs

Slide 31: When a UAS is turned too sharply or pitched up too steeply or rapidly, the critical angle of attack may be exceeded, and the aircraft may stall. Remote pilots should work to avoid these scenarios; given the proximity of UAS to the ground, there is rarely much time to recover from such a scenario.

While a single overload may not cause problems, doing so repeatedly can cause components to fail—sometimes many hours later while performing normal maneuvers.

EVALUATE

Teacher Materials: Small UAS Loading Presentation, Small UAS Loading Teacher Notes 3
Student Material: Small UAS Loading Student Activity 3

Slides 32-51: Quiz students on the FAA Remote Pilot Knowledge Test questions on slides.

Slide 52: Conduct the **Summative Assessment**.

Summative Assessment

Students will answer written questions. Provide students with **Small UAS Loading Activity 3**. Correct answers and guideline responses are provided in **Small UAS Loading Activity 3 Teacher Notes 3**.

[DOK-L3; *draw conclusions*]

Summative Assessment Scoring Rubric

- Follows assignment instructions
- Postings show evidence of one or more of the following:
  - Knowledge of UAV weight and balance, and center of gravity (CG)
  - Knowledge of how to compute or estimate UAV weight and balance
  - Provides explanation of the impact UAV maneuvers have on load factor
- 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	Consistently demonstrates criteria
7-8	Usually demonstrates criteria
5-6	Sometimes demonstrates criteria
0-4	Rarely to never demonstrates criteria

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
        - 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

FAA AIRMAN CERTIFICATION STANDARDS

REMOTE PILOT

I. Regulations, Task B. Operating Rules

- Knowledge The applicant demonstrates understanding of
    - **UA.I.B.K2** Requirement for the sUAS to be in a condition for safe operation.
    - **UA.I.B.K20** Preflight familiarization, inspection, and actions for aircraft operations.

III. Weather, Task B. Effects of Weather on Performance

- Knowledge The applicant demonstrates understanding of:
    - **UA.III.B.K1** Weather factors and their effects of performance:
        - **UA.III.B.K1a** a. Density altitude
        - **UA.III.B.K1b** b. Wind and currents
        - **UA.III.B.K1c** c. Atmospheric stability, pressure, and temperature

IV. Loading and Performance, Task A. Loading and Performance

- Knowledge The applicant demonstrates understanding of:
    - **UA.IV.A.K1** General loading and performance:
        - **UA.IV.A.K1a** a. Effects of loading changes
        - **UA.IV.A.K1b** b. Balance, stability, and center of gravity
    - **UA.IV.A.K2** Importance and use of performance data to calculate the effect on the aircraft's performance of an sUAS.

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