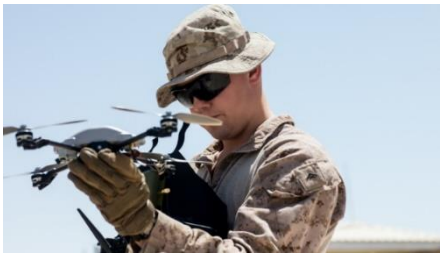
STEM IN THE AIR

Challenge 3: Up, Up, but not Away!

Radio-controlled drones have grown in popularity as both a hobby and as useful tools. They have become so widespread that the Federal Aviation Administration (FAA) has implemented new rules to regulate their use and continues to work with industries to find solutions for newly discovered problems. The most common type of radio-controlled drone is commonly referred to as a quad-copter, because it uses four helicopter-like propellers attached to four independent motors. These four motors work together to create the lift needed to get the drone off the ground and control its flight.

Your mission in this challenge is to research different propeller styles and design a single-motor-drone to complete a variety of mission achievements. You will begin with a basic drone body to test how different styles of propellers impact the lift of the drone. Your team will then design your own drone by selecting propellers and body styles to achieve specific outcomes.



RESEARCH AND PLAN:

Your team will be provided a basic drone body and a variety of propellers. Discuss the similarities and differences of the propellers and record these in your Team Engineering Notebook. For each propeller you test, record a picture of the propeller attached to the drone and draw the lift and weight vectors acting on the drone. After testing, record the time it takes for the drone to reach to top of the testing apparatus. If a particular configuration does not reach the top, record its maximum height (which may be zero). Adjust your vector diagram as necessary to show which vector is larger at lift-off.

CREATE A PROTOTYPE:

When given the appropriate instructions, design a drone of your own using one of the propellers you tested and an available body style. Consider one (or more) of the Mission Achievements when designing your drone. You will be able to adjust your design to test for different achievements. Your prototype design should be recorded in your TEN before materials will be provided.

Design Constraints:

- The testing apparatus (including tethering device) cannot be modified.
- Only the body style and propeller can be changed on your prototype.

EVALUATE:

Mission Achievements:

- Reach the top of the testing apparatus **(minimum criteria for success)**
- Take at least 4 seconds to reach the top of the apparatus
- Reach, but do not pass, a mark halfway to the top of the testing apparatus
- Create two different drones (different bodies and propeller styles) that perform the same

STEM in the Air Challenge 3: Up, Up, but not Away

WEDNESDAY (8:00-10:00AM YBO PLATOONS & 3:30-5:30 RGP PLATOONS)

Overview

This STEM Challenge, *Up, Up, but not Away*, will use small, one-propeller drones to reinforce cadets' prior learning about the effects of lift and weight on flying objects. Teams will gather data about the lift generated by varying styles of propellers as they attach the propellers to a tethered drone. The magnitude of the generated lift will be measured by the time needed to reach the top of a testing apparatus. After gathering data, teams will be challenged to design their own drone using different propellers and body styles to attempt various mission achievements.

Important Vocabulary

Clockwise (CW)
Counterclockwise (CCW)
Lift
Weight

Learning Outcomes

- Represent the relationship between lift and drag vectors graphically.
- Make design decisions based on gathered data.

Materials

Instructional Materials

- 1 Instructor Tablet (1 per instructional team)
- Laptop with LCD projector on media cart with speakers or sound system
- Mission Achievements Central Record sheet (electronic version is on tablet)
- General Achievements Record sheet (electronic version is on tablet)
- Chart Paper & Markers
- 4 Testing apparatus per platoon
  - Stand (1)
  - Fishing line or string (2)
  - Connector (2)
- Extra cups for drone body (3 styles)
- Drone batteries (2 per apparatus plus extras)
- Battery Charger (1 per platoon)
- 2 Triple Beam Balances per platoon

Per Team of 3 Cadets

- Team Engineering Notebook (located in OneNote app on tablet)
- 3 Mission Briefs (1per cadet)
- 1 team tablet and stylus
- Drone motors (1)
- Various cups for drone body (3 styles per team)
- Various propellers (both CW and CCW) (5 styles per team)
- Safety goggles (1 per cadet)

Set up

- Each testing apparatus should serve two teams. Fishing line or light string should be attached to the bottom of the stand and run over the top of the stand. Cadets will pull down on the tether line to pull the line taut. (See diagram 1)
- Use a marker or tape to make a level halfway to the top of the apparatus. This will be used during testing for mission achievements.
- To connect the drone to the testing apparatus, you need to assemble the connector. Attach two pieces of drinking straw at a right angle to make a T-shape. The tether-line of the testing apparatus will be threaded through the open piece of straw while the other piece is attached to the drone body or motor body. (See diagram 2).
- For the Research phase, the testing apparatus will be attached directly to the motor. The drone bodies (various size cups) will not be used until the Plan and Create Phase.

Diagram 1:

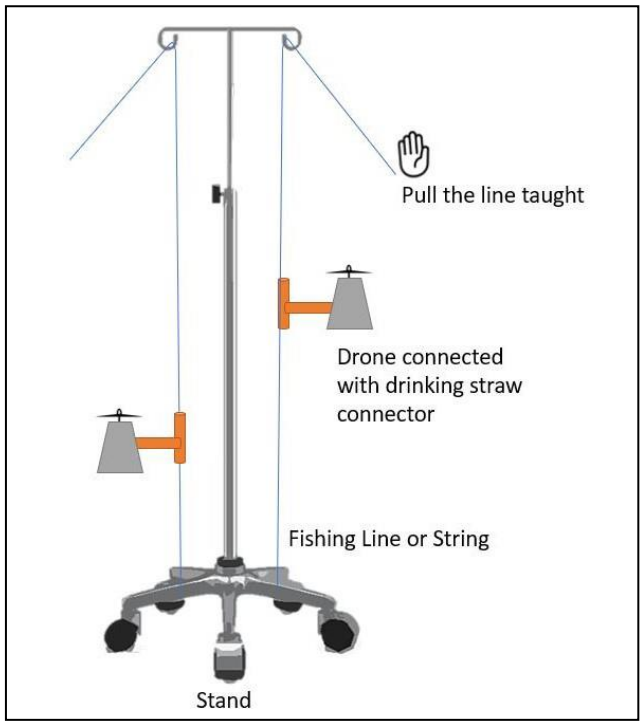
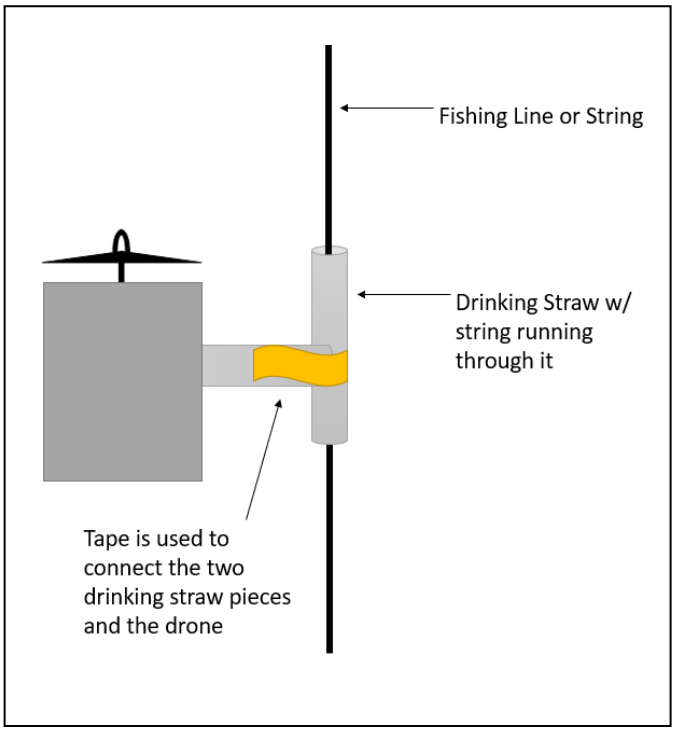


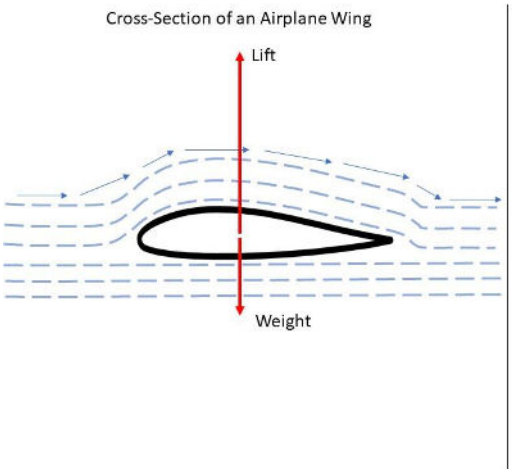
Diagram 2:

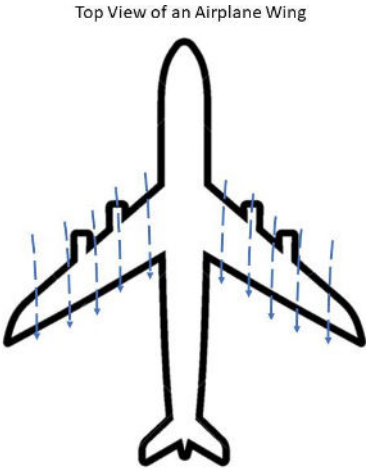


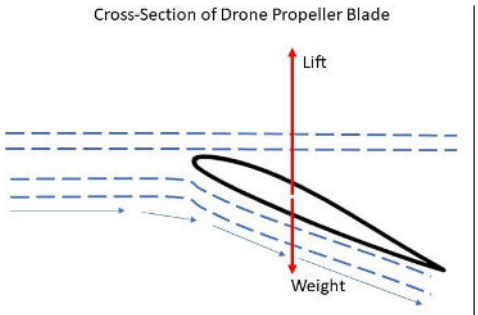
Instructional Plan: (120 minutes)

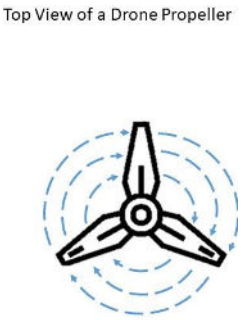
Research & Launch Challenge (45 min)

Inform cadets that they will be exploring a different kind of flying apparatus for this challenge. Briefly discuss the basic difference between how airplanes and gliders generate lift and how helicopters and drones generate lift. **Fixed-wing vehicles produce lift by getting air to pass around a wing, while rotary vehicles spin angled blades rapidly to push air in a certain direction.** With chart paper and markers, create two posters comparing an airplane wing to the blade of a propeller on a drone. Sketch the basic airflow around the wing and propeller blade. Also use this time to review drawing a vector diagram. Draw vectors for weight and lift.









Note: Cadets will not be assessed on how each type of aircraft achieves flight. This *brief* discussion is to introduce the concept only. Through Research, cadets will observe the phenomenon of flight using a drone propeller. Later they will observe airplane flight in the final challenge.

Ask cadets to share different styles of propellers they may have seen or used before (e.g., different length blades, different number of blades, different blade angles).

Pass out the **Mission Brief** and direct cadets to open **page 1** of their **TEN.** Allow a few minutes for cadets to read over the brief. As a group, read over the Mission Achievements. Highlight the minimum criteria for success. Explain that teams should attempt to complete as many mission achievements as possible, but that this criteria must be met for their robot to be considered minimally successful. Explain that they do not have to build one drone that will complete every achievement; they will be able to make adjustments to their build as they try for different goals.

Using the Mission Achievements central record:

- Go to the Content Library and open the Mission Achievements tab.
- Click on the Excel sheet icon (located just above the displayed table). This will open the fillable achievements worksheet.
- Record each team's name at the top of each column (one column will be used to track achievements for each team).
- Keep the Excel sheet open and be ready to record achievements in this file.
- Place an X in the cells as teams make achievements.
- Save the file. When you save the changes, updates to the file will be displayed in the Notebook.

Remind cadets of the General Achievements that are being tracked through every design challenge.

Show cadets the motor connected to the testing apparatus they will be using and the stand to which it will be tethered. Demonstrate how to remove and reattach the drone to the tether-line. Also explain how to carefully attach and remove propellers.

Explain that each motor will be attached directly to a battery. Once the connection is made, the propeller will start to spin rapidly. Stress the importance of making sure the area immediately around the propeller is clear before attaching the battery. Demonstrate the testing process to cadets using an example set-up and displayed diagram.

1. Mass the drone body including motor and propeller
2. Connect the drone body to the tethering attachment using tape
3. Run the tethering line through the attachment and pull tight over the top of the testing apparatus (one cadet will hold the line tight during the drone's flight)
4. After being cleared for flight, connect the battery to the motor and allow drone to travel up the tethering line

Safety glasses should always be worn while near the testing apparatus. Before connecting the battery and motor, the area immediately around the propeller and along the flight path should be clear of cadets, especially their fingers, and other possible obstructions.

NOTE: Each completed achievement should be marked in the team's TEN by the Instructor observing the testing, and this instructor will also record it in the central Mission Achievements tracking document. This "central record" is in the Content Library of the OneNote Notebook. Allow time for questions after the discussion.

Safety Notice: The propellers will spin fast enough to cause injury/damage to anything they contact. They may also detach from the motor while spinning, creating a flying hazard. Stress to cadets the importance of following safety procedures, and model working safely while assisting teams.

After giving preliminary instructions, ensure that each team knows where they will be testing. Each testing apparatus will accommodate two teams. Provide each team with a basic drone body and set of propellers. Offer an opportunity for teams to ask any last clarifying questions before allowing teams to begin gathering data. Instruct teams to open their **TEN** to **page #2** and complete numbers 1-2. Teams should start by organizing their propellers by how much lift they think each propeller will generate (from most lift to least lift). They should also write a short statement justifying their predictions. Reasonable answers should refer to structural aspects of the propeller and drone body. For example, number and angle of blades and mass of drone. Use guiding questions to redirect any teams that provide unreasonable answers such as color of the propeller.

Note: Each propeller is designed to produce lift by rotating either clockwise (CW) or counter-clockwise (CCW). Ensure that each team receives the appropriate type of propeller for their motor. The rotation of the motor is signaled by the color of the wires that attach the motor to a power source.

Once teams have made their predictions, allow teams to move to **pages #3-4** of their **TEN.** Teams should start testing each propeller and, using the table provided in number 3, record the time it took for their drone to reach the top of the stand and draw a vector diagram showing the direction and relative magnitudes of the lift and weight vectors acting on the drone.

While teams are gathering data, ensure that teams are recording data in the TEN and are observing safety guidelines.

When testing is complete, direct teams to complete numbers 4-5 on **page #5** of their **TEN.** Encourage teams to be prepared to discuss their hypotheses and results later in the lesson. A discussion of differing hypotheses and outcomes will be held during the wrap-up for this lesson. Instructors should replace and recharge batteries as necessary throughout this challenge.

Plan and Create (15 min)

After teams have gathered data on each propeller, lead a whole group discussion about their findings. Have teams share which propeller they feel worked the best and which performed the worst. Was the ranking consistent across all or most teams? If there were differences in how different teams ranked the propellers, have teams share ideas about some possible causes. Address any differences caused by procedural problems teams may have encountered but allow for differences that are justified using the structure of the propeller or drone body.

Note: For testing provide each team with a CW and CCW propeller in the style they requested. Ask teams to try both and record any differences in performance.

Teams will now design their own drone to attempt mission achievements. Review the mission brief and safety guidelines with teams. Collect all testing propellers from teams and display the propellers and body-styles (cups) available to teams. Have teams open **page #6** in their **TEN** and complete number 6. **Teams must record a prototype design to receive materials for testing**. Once a team presents their design, provide them the appropriate materials and allow them to begin testing for mission achievements. All achievements should be recorded in their **TEN** and the **Mission Achievement central record.** Remind teams to re-mass their drone after any changes in design. **When cadets want to change their designs, they should show you or another instructor a sketch of the new prototype before receiving additional materials.**

Evaluate (45 min)

Teams should evaluate their design on the same testing apparatus they used while completing their research. Instructors should move around the room to record any mission achievements completed by a team in their **TEN** and in the **Mission Achievements central record**. Display the Mission Achievements central record using instructor version of the Notebook. Teams may redesign their drone to test for different achievements. Any redesign, however, should be accompanied by a design sketch in their TEN. If their plan requires different propellers, allow the team to keep any pairs of propellers they used in previous designs.

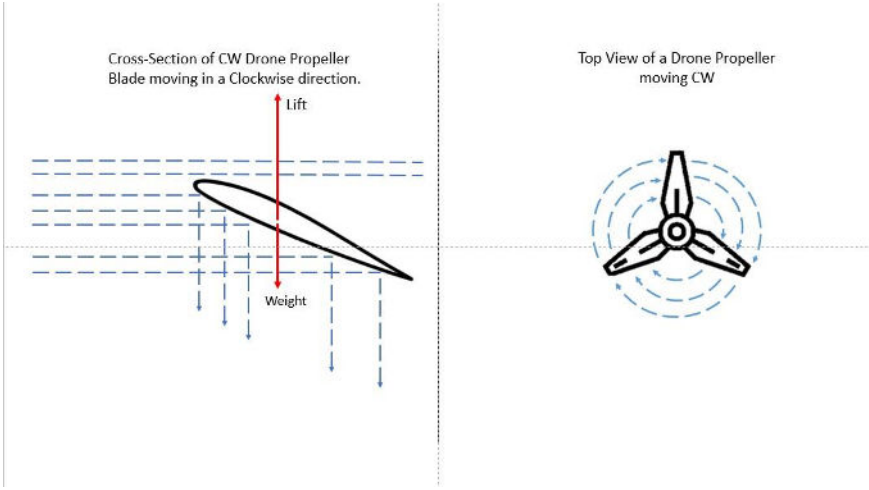
Once teams have been able to test for several mission achievements, encourage them to complete numbers 7-9 on **page #7** of their **TEN.** This will give them time to prepare for the wrap up discussion.

Communicate and Wrap Up (15 min)

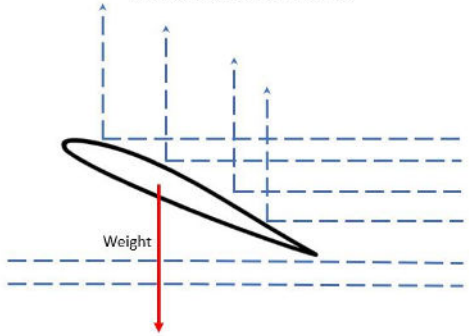
With about 15 minutes left in this challenge, have teams return to their workstations and clean their area. The testing apparatuses, including batteries,will be collected after the wrap-up session. Teams may keep their propellers and current drone design until the wrap-up session is completed. Begin the wrap up session by celebrating the achievements of all teams.

Give teams an opportunity to share about any successes and failures they feel are significant (referring to the answers to numbers 7-8 of their **TEN**).

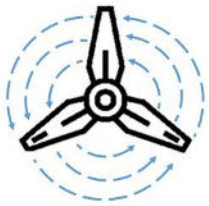
Ask teams to share about what they learned from the two different styles of propellers (answer to number 9 of their **TEN**). Use a flipchart or computer display to draw the lift and weight vectors acting on the drones and discuss how the propeller blade pushing down on the air means that the air is pushing up on the blade creating lift. Then, use a picture of angled propeller blades to discuss how the direction of spin affects how the air is pushed by the propeller. If the air is deflected up, the blade is pushed down, and the drone gets no lift. If that same propeller spins in the opposite direction, the air will be deflected down, and the blade pushed up. This will generate the lift needed to overcome the weight of the drone.



Cross-Section of CW Drone Propeller Blade moving in a Counterclockwise direction.



Top View of a Drone Propeller Moving CCW



Give teams time to complete number 9 on **page #7** of the **TEN** with the correct answer. Have teams share what direction they believe their motor spins, clockwise or counter-clockwise. They may then check against other teams with the same type of motor. (The motor type can be checked by looking at the color of wires connecting the motor to the battery.) After all teams confirm the direction of their motor, collect all materials from each team. Instructors should select 1 team per Platoon as the "winner." This drone will be displayed during the showcase on the final day of the Academy. Inform the winning team that visitors will ask questions about their drone's performance and they should be prepared with answers. All other drones can be disassembled, and materials stored appropriately.

Teamwork Check In and Reflections (5:30-6:00 pm All Platoons)

Teamwork Check In (12 minutes)

Lead teams in an activity to reflect on their experiences today. Let cadets know that each evening of the Academy they will spend time capturing their reflections and what they want to remember from each day's activities and experiences. Some days they will also complete a "team skills check in" to see how well their team is working together and how well they are contributing as a team member.

Start by passing out the "My Team's Teamwork Check In" handout, one per cadet. Cadets should record their team name at the top of the form and then follow the instructions to complete the worksheet. Ask cadets to try to remain quiet for about 5 minutes while they are quickly responding to each question on the handout.

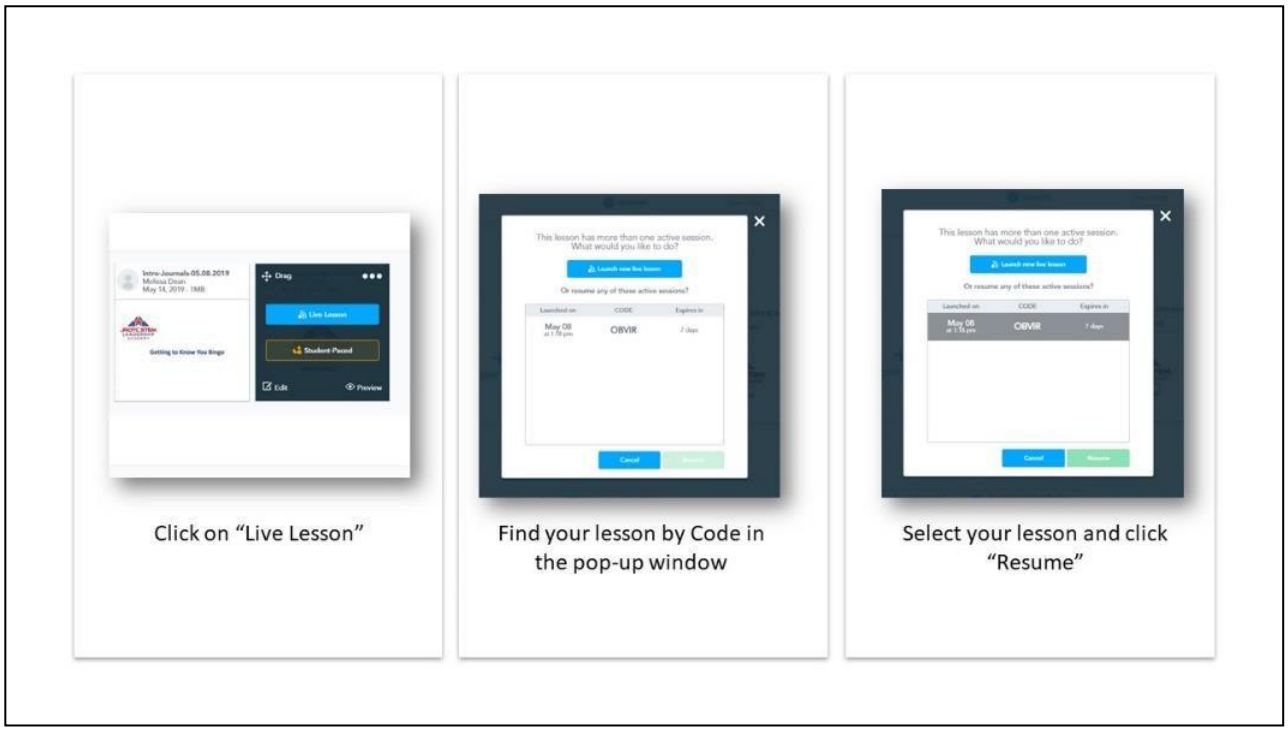
Then give teams 5 minutes to read aloud and discuss their responses with each other. Encourage teams to identify new strategies to better reach consensus. Walk around the room to listen to the discussion.

Use the remaining 2 minutes to highlight any exemplary discussions you heard while walking around the room. Take up the completed handouts and give them to the Materials Manager who will deliver them to the Research Team.

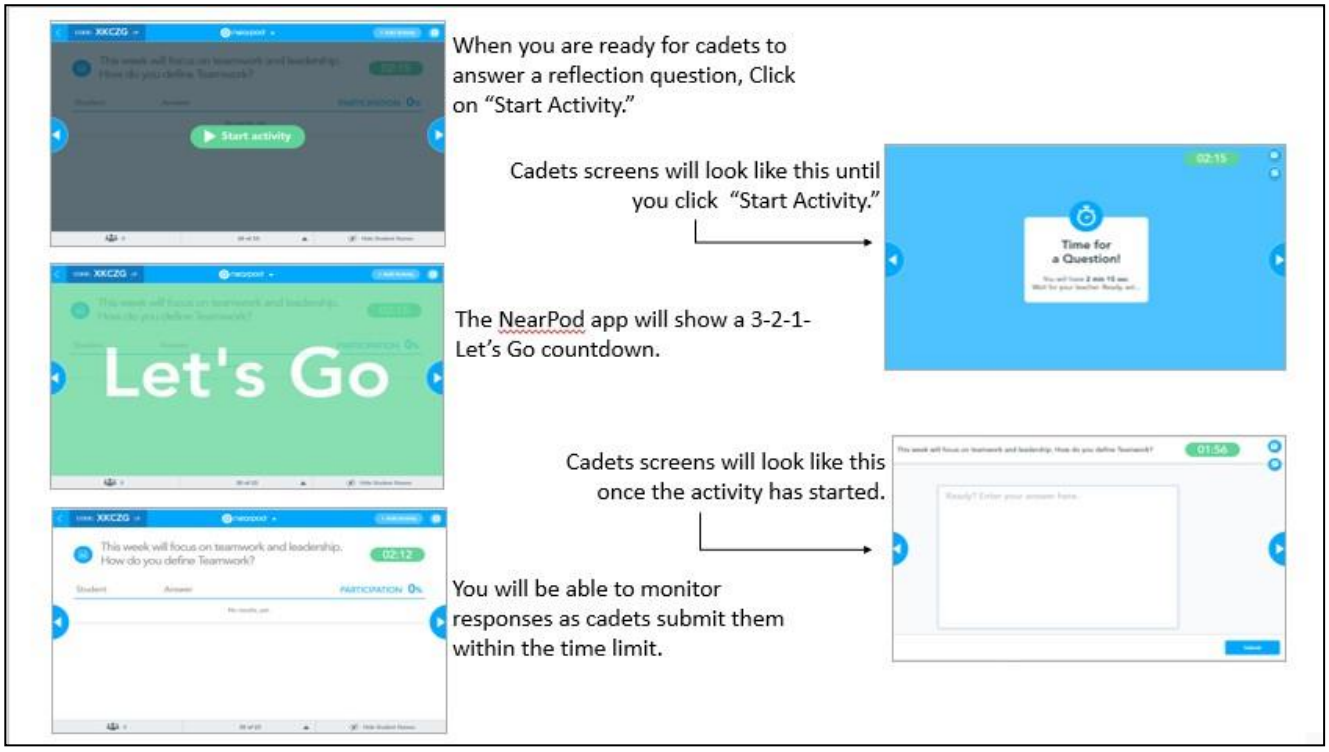
Electronic Journal Reflections (18 min)

Tell cadets the final activity is to reflect on what they've learned today using their electronic journals. Have cadets retrieve their individual tablets from the storage shelf while you pull up Nearpod lesson.

To re-open a lesson, you hover over the lesson thumbnail and select the "Live Lesson" option. A smaller window will pop-up which gives you the option to "Resume" a lesson. To retrieve your saved lesson follow the instructions below. The lesson should open to the last slide you displayed (Slide #36).



Display **Slide #37** and direct cadets to login to the Nearpod lesson by opening the application on their tablets and entering the lesson code. Have cadets respond to the first question, explaining that each question should be answered within 3 minutes time. Each of the reflection slides has a 3-minute timer. When time is up, move to the next slide. Repeat this process until **Slides #38-42** are complete. Use the instructor view of Nearpod to monitor cadet answers. You may decide to stay on a slide for longer than the allotted time if you see that cadets need more time to record their answer. Below is a brief description of how to launch each of the reflection prompts so cadets can answer the questions:



When all reflection prompts have been answered, exit the lesson, but remember to keep the lesson OPEN so you can return to it the next day for additional reflections.

STEM in the Air Challenge 3

Up, Up, but Not Away

Team Engineering Notebook

Team Name:_____

Platoon Color: _____ **Squad #**_____

Team Cadets:_____

_____

_____

_____

_____

STEM in the Air

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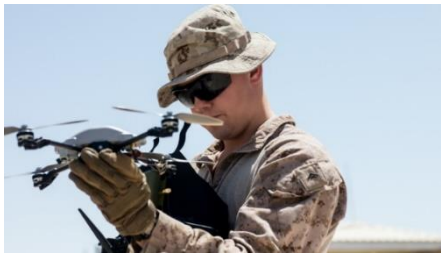

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Create a Prototype:

When given the appropriate instructions, design a drone of your own using one of the propellers you tested and an available body style. Consider one (or more) of the Mission Achievements when designing your drone. You will be able to adjust your design to test for different achievements. Your prototype design should be recorded in your TEN before materials will be provided.

Design Constraints:

- The testing apparatus (including tethering device) cannot be modified.
- Only the body style and propeller can be changed on your prototype.

Evaluate:

Mission Achievements:

- Reach the top of the testing apparatus (minimum criteria for success)
- Take at least 4 seconds to reach the top of the apparatus
- Reach, but do not pass, a mark halfway to the top of the testing apparatus
- Create two different drones (different bodies and propeller styles) that perform the same

RESEARCH:

1. Organize your propellers by number of blades and blade angle (high and low).

2. Make a list of your propellers based on your estimate of how much lift each propeller will generate. Start with the propeller you feel will generate the most lift and end with the propeller you feel will generate the least lift. Provide a brief (at least one sentence per propeller) explanation of the criteria you used for your ranking. You may also take a picture and insert the image here.

RESEARCH (CONTINUED):

3. Use the table to record data on your propellers. Complete 3 independent trials with each propeller recording the time it takes for each to reach the top of the testing apparatus. Find the average time for each propeller. After finding the average time, draw a vector diagram showing the relationship between the lifting force and the weight of the drone. Be sure to scale the length of your vector arrows appropriately.

Number of Blades	**Angle of Blade (circle one)**	**Trial 1 (time)**	**Trial 2 (time)**	**Trial 3 (time)**	**Avg. time**	**Vector Diagram**
	High **Low**					
Notes:						
Number of Blades	**Angle of Blade (circle one)**	**Trial 1 (time)**	**Trial 2 (time)**	**Trial 3 (time)**	**Avg. time**	**Vector Diagram**
	High **Low**					
Notes:						
Number of Blades	**Angle of Blade (circle one)**	**Trial 1 (time)**	**Trial 2 (time)**	**Trial 3 (time)**	**Avg. time**	**Vector Diagram**
	High **Low**					
Notes:						

RESEARCH (CONTINUED):

Number of Blades	**Angle of Blade (circle one)**	**Trial 1 (time)**	**Trial 2 (time)**	**Trial 3 (time)**	**Avg. time**	**Vector Diagram**
	High **Low**					
Notes:						
Number of Blades	**Angle of Blade (circle one)**	**Trial 1 (time)**	**Trial 2 (time)**	**Trial 3 (time)**	**Avg. time**	**Vector Diagram**
	High **Low**					
Notes:						
Number of Blades	**Angle of Blade (circle one)**	**Trial 1 (time)**	**Trial 2 (time)**	**Trial 3 (time)**	**Avg. time**	**Vector Diagram**
	High **Low**					
Notes:						

4. Use your data to list the propellers in order from greatest amount of lift to least amount of lift. You may also take a picture of the propellers sorted by amount of lift and insert here.

5. Compare the order of the list you estimated in number 2 to your data-based list in number 4. What similarities and differences do you see?

   If the first and last entries in the two lists are different, what do you think caused this difference?

Plan, Create, and Evaluate:

After sharing your findings with your Instructor and Platoon, you will design your own drone to attempt the achievements for this mission. Your design will consist of a propeller and body style. After testing for a mission achievement, you may change your design to test for additional achievements. **You are required to provide a prototype diagram to receive your materials.** You will receive two propellers per submission.

6. In the space below sketch both the propeller you will be using and your complete drone design. Be sure to record the mass of your complete drone design. Test your prototype using **both** propellers provided. After testing, list any mission achievements you were able to complete next to your sketch.

Drone mass:

Mission Achievements:

Use the remaining space to sketch additional drone designs as your team redesigns your prototype to meet different achievements. You will only be given the materials described in your sketch. Remember to record the mass of your complete drove design and mission achievements completed.

Communicate:

7. Place a check mark in the box next to all mission achievements completed by your team.

   ☐ Reach the top of the testing apparatus (minimum criteria for success).

   ☐ Take at least 4 seconds to reach the top of the apparatus

   ☐ Reach, but do not pass, a mark halfway to the top of the testing apparatus

   ☐ Create two different drones (different bodies and propeller styles) that perform the same

8. Describe any significant failures your team had to overcome to complete a mission achievement. If there were none, explain why you think your team was so successful.

9. For each prototype your team was given two propellers. Examine each pair and record what they have in common and what is different about them.

   Did both propellers in a pair perform the same?

   If they performed differently, what might have caused the difference?

