SAFEDRONE®

OPERATION & TRAINING UNIT

S.A.F.E.™ FIRST.

A SAFE FLIGHT PROTOCOL

FOR THE MIDDLE SCHOOL &
HIGH SCHOOL CLASSROOM

BY STEMPILOT®

Table of Contents

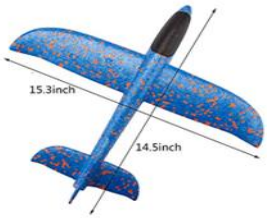
Remember

This is a living document. Please check with STEMPilot for any updates that may have been released since the arrival of your simulators.

Email: sales@stempilot.com or Call: (203) 527-5747 between 8 am & 4 pm (EST)

Included In Drone Package

SAFEDrone ES 5: Elementary School Classroom Kit

	***The STEMPilot Drone Course & Curriculum*** ***QTY: 1*** . "SAFEDrone" Operations & Training Unit (*This Document) (if you purchased the drone course with a flight simulator, there are Tutorial lessons for you to use that tie into this curriculum (SAFEDrone Operations & Training Unit) as well)*
	***Drone Simulation Software*** ***QTY: 5*** . The most current Drone flight simulation software is being used with our program, compatible controller, and installation package. *(if purchased with a simulator, the installation disk will not be included as it will be installed and set up for you in the shop)*
	***Foam Glider*** ***QTY: 1*** . The glider can be utilized to demonstrate and explain the 6 Degrees of Freedom *(Pitch, Roll, Yaw, Longitude, Vertical, and Lateral)*

SAFEDrone 1 Classroom Kit

	***The STEMPilot Drone Course & Curriculum*** ***QTY: 1*** . "SAFEDrone" Operations & Training Unit *(This Document) (if you purchased the drone course with a flight simulator, there are Tutorial lessons for you to use that tie into this curriculum (SAFEDrone Operations & Training Unit) as well)*
	***Drone Simulation Software*** ***QTY: 1*** . The most current Drone flight simulation software is being used with our program, compatible controller, and installation package. *(if purchased with a simulator, the installation disk will not be included as it will be installed and set up for you in the shop)*

Guarded Prop Quadcopter

QTY: 1

.

4 drones for your 4 active flight groups as well as 1 spare.

Each drone is small and lightweight to allow for safe indoor operation. They also will include options for altitude hold to use in more intermediate lessons, and a headless mode for additional control perspective.

Drone Landing Pads/Targets

QTY: 4

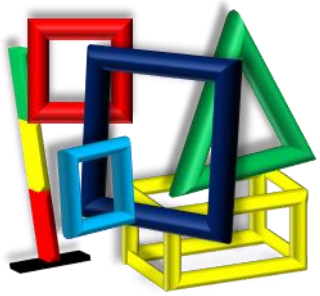
.

12" x 12", lightweight, sturdy landing platform for you to use in your classroom for any of your drone flying activities. Equipped with a point scale, vibrantly colored rings and a clear center marked by intersecting lines, this platform makes it easy for the user to judge their accuracy in landing while keeping course setup/layout consistent.

Spare Drone Batteries with Charger

.

An easy to install, spare battery for each active drone



Drone Flight Obstacles

QTY: 6

.

Light weight, stand-alone, foam padded shapes for you to place around your classroom and use as drone flight obstacles for your students.

Includes:

.

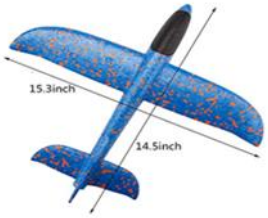
1 Large (Beginner) Square Hoop	1 Vertical Hold Altitude Post
1 Medium (Intermediate) Square Hoop	
1 Small (Advanced) Square Hoop	

Safety Glasses

QTY: 36 pairs

.

36 pairs of safety glasses. Enough for the instructor, an average class, a few onlookers and still have spares.



Foam Glider

QTY: 1

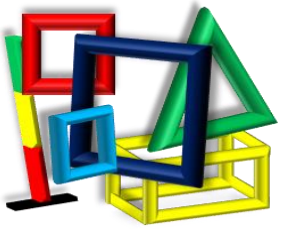
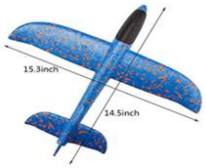
.

The glider can be utilized to demonstrate and explain the 6 Degrees of Freedom *(Pitch, Roll, Yaw, Longitude, Vertical, and Lateral)*

	***STEMPilot's Part 107 Study Guide*** ***QTY: 1*** Our STEMPilot's Part 107 Study Guide will assist students in preparing for their Part 107 certification.

SAFEDrone 5 Classroom Kit

	*The STEMPilot Drone Course & Curriculum* *QTY: 1* . "SAFEDrone" Operations & Training Unit (This Document) (if you purchased the drone course with a flight simulator, there are Tutorial lessons for you to use that tie into this curriculum (SAFEDrone Operations & Training Unit) as well)
	***Drone Simulation Software*** ***QTY: 5*** The most current Drone flight simulation software is being used with our program, compatible controller, and installation package. (if purchased with a simulator, the installation disk will not be included as it will be installed and set up for you in the shop)
	***Guarded Prop Quadcopter*** ***QTY: 5*** . 5 drones for groups of 3-4 students. Each drone is small and lightweight to allow for safe indoor operation. They also will include options for altitude hold to use in more intermediate lessons, and a headless mode for additional control perspective.
	***Drone Landing Pads/Targets*** ***QTY: 20*** . 12" x 12", lightweight, sturdy landing platform for you to use in your classroom for any of your drone flying activities. Equipped with a point scale, vibrantly colored rings and a clear center marked by intersecting lines, this platform makes it easy for the user to judge their accuracy in landing while keeping course setup/layout consistent.
	***Spare Drone Batteries with Charger*** .

	An easy to install, spare battery for each active drone
	***Drone Flight Obstacles*** ***QTY: 12*** . Light weight, stand-alone, foam padded shapes for you to place around your classroom and use as drone flight obstacles for your students. **Included:** . 2 Large (Beginner) Square Hoops 2 Medium (Intermediate) Square Hoops 2 Small (Advance) Square Hoops 2 Vertical Hold Altitude Posts
	***Safety Glasses*** ***QTY: 36 pairs*** . 36 pairs of safety glasses. Enough for the instructor, an average class, a few onlookers and still have spares.
	**Foam Glider** **QTY: 1** . The glider can be utilized to demonstrate and explain the 6 Degrees of Freedom *(Pitch, Roll, Yaw, Longitude, Vertical, and Lateral)*
	***STEMPilot's Part 107 Study Guide*** ***QTY: 1*** Our STEMPilot's Part 107 Study Guide will assist students in preparing for their Part 107 certification.

SAFEDrone 10 Classroom Kit

	**The STEMPilot Drone Course & Curriculum** **QTY: 1** . "SAFEDrone" Operations & Training Unit (This Document) (if you purchased the drone course with a flight simulator, there are Tutorial lessons for you to use that tie into this curriculum (SAFEDrone Operations & Training Unit) as well)

Drone Simulation Software

QTY: 10

.

The most current Drone flight simulation software is being used with our program, compatible controller, and installation package.

(If purchased with a simulator, the installation disk will not be included as it will be installed and set up for you in the shop)

Guarded Prop Quadcopter

QTY: 10

.

10 drones for groups of 3-4 students.

Each drone is small and lightweight to allow for safe indoor operation. They also will include options for altitude hold to use in more intermediate lessons, and a headless mode for additional control perspective.

Drone Landing Pads/Targets

QTY: 40

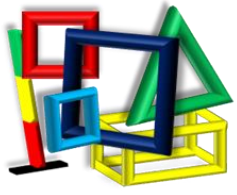
.

12" x 12", lightweight, sturdy landing platform for you to use in your classroom for any of your drone flying activities. Equipped with a point scale, vibrantly colored rings and a clear center marked by intersecting lines, this platform makes it easy for the user to judge their accuracy in landing while keeping course setup/layout consistent.

Spare Drone Batteries with Charger

.

An easy to install, spare battery for each active drone



Drone Flight Obstacles

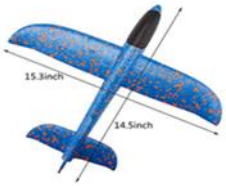
QTY: 18

Light weight, stand-alone, foam padded shapes for you to place around your classroom and use as drone flight obstacles for your students.

Included:

.

3 Large (Beginner) Square Hoops 3 Medium (Intermediate) Square Hoops 3 Small (Advance) Square Hoops	3 Vertical Hold Altitude Posts

	**Safety Glasses** **QTY: 36 pairs** . 36 pairs of safety glasses. Enough for the instructor, an average class, a few onlookers and still have spares.
	**Foam Glider** **QTY: 1** . The glider can be utilized to demonstrate and explain the 6 Degrees of Freedom *(Pitch, Roll, Yaw, Longitude, Vertical, and Lateral)*
	***STEMPilot's Part 107 Study Guide*** ***QTY: 1*** Our STEMPilot's Part 107 Study Guide will assist students in preparing for their Part 107 certification.

Unit 1

Pre-Flight Review

Course Overview

Welcome fellow aviators to the STEMPilot's Drone Course. Before we begin, students should form into flight crews. These crews of 3-4 students will be together throughout the duration of the course. By doing this, students will not only be learning about completing tasks on their own as the pilot in command, but also as a team and the importance of communication.

This operation and training unit for drone flight will walk you and your students through the basics of flight using a Quadcopter. You will learn the 6 degrees of freedom in flight, the different components/ "flight surfaces" of a Quadcopter, how each flight surface correlates to the degrees of freedom, how to execute standard flight operations safely and accurately (such as; takeoff, landing, yaw, hover, bank, etc.…), and so much more before even picking up an actual drone.

By utilizing the provided drone software in your classroom, you can learn everything you need to know about drones and their operation in a safe, controlled environment where only variables are simulated. Once students have completed the simulation section and shown their instructor they can safely operate and maintain control of a drone, they then earn their certificate and proceed to the actual flight section of this course.

Students will be able to test their skills in several Flight Task Courses with the use of scaled targets and obstacles. Each task has been given a worksheet with a step-by-step guide/checklist of the operation(s) to be completed. As the pilot in command executes each task, their crewmates will fill out the checklist as they go along. To pass, each student must complete the task at hand 5 times with no mistakes. The grade will be dependent on the scores placed at the landing pads during the 5 successful executions (Student's Score / Possible Score). If they wish to increase their grade they may continue flying, adding their new scores to their total and adjusting the possible score to match the number of times they have flown. This grading method means the more times they fly the smaller the difference in the score. This forces the students to take their time and fly more cautiously and precisely from the beginning. However, if they don't those students will end up with a lot more flight time/practice. It's a win-win.

At completion of both the Simulation and Real Drone Flight sections, you will find a Certificate of Achievement. Feel free to fill these out and present them to your students so they may take them home and show off their newly developed skills and past milestones.

Now, without further ado…

Let's Begin!

Vocabulary

WORD	DEFINITION
Accelerometer	An electronic device that is used to measure changes in velocity.
Airfoil	An object/shape with curved surfaces, designed and used for its favorable ratio of drag to lift when moved through the air. *This shape is commonly used in the design of wings and/or propellers*
Angle of Attack (A.O.A.)	The acute angle between the airfoil's chord line & direction of the relative wind *Depending on the aircraft, the airfoil will be applied differently (the fixed wings on an airplane vs the horizontal rotating propellers on a quadcopter).*
Autonomous Vehicles	Any non-manned vehicle that can navigate through the terrain without human input, usually due to the application of sensors
Battery	A container for one or more cells that convert chemical energy into electricity and are used as a source of power. *Batteries can be rechargeable as well as have only a 1 use lifespan.*
Bernoulli's Principle	The faster molecules within a fluid move, the less Pressure they exert on objects around them
Center of Gravity (C.G.)	The point from which the entire weight of an object (at rest) is evenly dispersed, and all sides are balanced.
Chord Line	The imaginary line through the airfoil from the leading edge to the trailing edge
Critical A.O.A.	*Each wing/airfoil has its own Critical A.O.A. Factors such as ice accumulation, physical damage, etc. disrupt the flow of air and in turn, change the critical angle of attack (usually by lowering it).*
Drone	An unmanned vehicle, equip to navigate a particular terrain/environment and can be piloted/controlled Autonomously or Remotely *Examples: UUV's (unmanned underwater vehicle), UGV's (unmanned ground/surface vehicle) and UAV's (unmanned aerial vehicle) are different types of drones you could use*
Electric Motor	An electrical machine that converts electrical energy into mechanical energy
Electronic Speed Control (ESC)	An electronic circuit that controls and regulates the speed of an electric motor (can also control the reversing of a motor and dynamic braking) *These devices are essential to modern quadcopters (and all multi-rotors) because of their dependency on variable motor speeds*
Gimbal	A mounting mechanism consisting of rings pivoted at right angles, for the purpose of keeping an instrument or device level on a moving vessel.

Gyroscope	A device consisting of a wheel or disk, mounted so that it can spin rapidly about an axis that is also free to move in any direction. It is designed this way, so the orientation of the axis is not affected by the tilting of the mount and therefore can be used to provide stability and/or maintain a reference direction for navigational systems.
Headless Mode (Drone)	Is when the drone's point of reference is from the controller instead of having a designated front, back, left and right side on the drone.
Inverter	A device that converts direct current and alternating current.
Lift	The name given to a force perpendicular to the airflow around an aircraft once it is great enough to oppose the force of gravity and move an object upwards. *In drone operation this is achieved by thrust and the displacement of air created by the horizontal propellers.* *- Airplanes are designed so the lift created by the wings oppose the weight force (gravity).*
LiPo (Lithium-Polymer) Battery	A lightweight, rechargeable Lithium-ion type battery that uses a polymer electrolyte *(formed from highly conductive gel polymers)* instead of a liquid electrolyte. *More correctly referred to as a Lithium-ion Polymer battery*
Pilot in Command	The person/pilot controlling the aircraft that is also responsible for its operation and safety during the current flight.
Pitch	A rotational motion of an aircraft around its lateral axis *Nose up = Tail down, Nose down = Tail up*
Propeller	A device consisting of 2 or more blades (shaped like airfoils) that spin around a central hub and displace the surrounding air (like a fan). When connected to an engine, the increased speed can displace the air with a large enough force to create thrust and "propel" it forwards. *Thrust can be controlled by the Propeller's speed and in cases of adjustable propellers, the angle of the propeller in relation to its mounting point.*
Quadcopter	Unmanned Helicopter/Drone with 4 rotors
Relative Wind	The direction of the atmosphere's movement relative to the aircraft or airfoil *If there's no wind and the aircraft is moving at 20 kn, the relative wind is 20 kn.*
Remote Control	A device able to control a machine from a distance by means of signals transmitted from a radio or electronic device.
Remotely Piloted Aircraft (R.P.A.)	A type of unmanned aerial vehicle that is piloted remotely.
Roll	A rotational motion of an aircraft around its longitudinal axis *Right side up = Left side down, Right side down = Left side up*

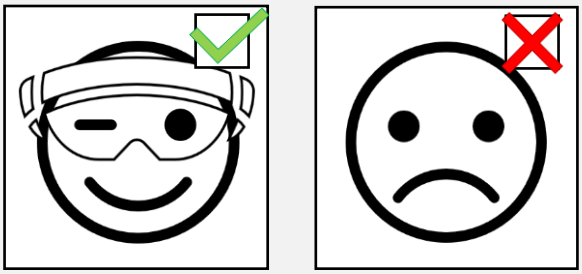
Situational Awareness (S.A.)	The perception of environmental elements and events in relation to time and/or space, the comprehension of their meaning, and the projection of their status after some variable (such as time or an event) has changed.
Thrust	To push something/someone suddenly or violently in the specified direction. *(The propulsive force of a jet or rocket engine.)*
Unmanned Autonomous Vehicle (U.A.V.)	Any machine or vehicle that can move/navigate through terrain without the need for human input.
Yaw	A rotational motion of an aircraft around its vertical axis *Nose right = Tail left, Nose left = Tail right (stay level and pivot)*

Safety

Safety is our first and foremost concern.

Please follow the steps below to keep a safe learning environment as you continue through this course.

- Maintaining your situational awareness is critical for all operations. Make sure you always know what obstacles you are around and how they may change.
- The Pilot in Command is responsible for safe pilotage. Make sure everyone on the crew knows who is in charge during each task.
- Drone operation should not be permitted until the student has completed the simulation lessons and fully understands how a drone is operated.
- For simplicity and learning purposes we will be working with Quadcopters (4 motors). Please do not move on to a larger or more advanced drone for these lessons until a solid comprehension of Quad-Copter flight is established.
- Please review all warning labels and documentation located in/on the Quadcopter and Flight Software packaging
- All individuals in the classroom must be wearing safety glasses at all times while Quadcopters are operational in your "Fly Zone".

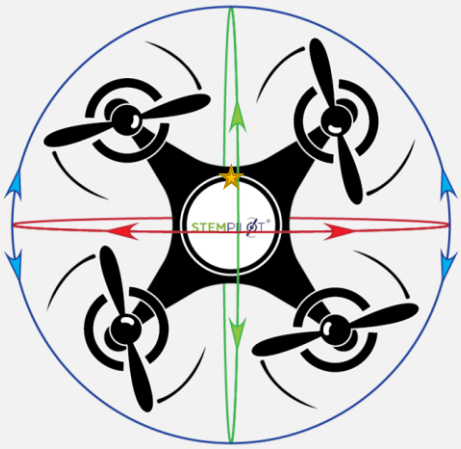


- Make sure the "Fly" and "No-Fly" zones are clearly marked.
- Loose hair should be fastened so it does not hang past your face.
- Exposed loose/dangling jewelry should be removed or fastened so it stays flush against skin.
- Loose clothing should be fastened, and sleeves should not cover/fall past your wrist so they cannot get caught in blades.
- Doors and windows should remain shut while drones are in flight to prevent loss of control due to drafts or lack of visibility (aka drone leaves the room)
    - Place a sign on the door to alert anyone who intends to enter that Quadcopters are in flight and to put on the safety glasses left by the door before entering.
- All liquid containers should be closed and removed from the "Fly" zone (if unable to remove, they should be secured against possibly being knocked over).
- All fans (preferably) should be turned off to avoid any drafts when flying. However, any unguarded fans must be turned off to avoid drones getting struck by the blades.
- Each operation, (simulated & not) should be done slowly, 1 step at a time (do not rush).

About the Quad-Copter

Quadcopters are an **unmanned aerial vehicle (UAV)** with 4 rotors:

- Each rotor has a motor and a propeller
- The drone's motor is what makes the propeller rotate
- Quadcopters generally use small batteries called Lithium-Polymer or Lithium-Ion batteries
  - They use these types of batteries because they are lightweight and allows your quadcopter to fly longer
- Each motor's speed can be controlled independently using an **electronic speed controller (ESC)** – tells your drone's motor how fast it can go
- Propellers can spin clockwise, as well as counterclockwise
- Drones have a **"Head"** or designated front to them. The head of your drone is what allows the drone to fly forward.
  - Headless mode is an option for some drones. This option allows the user to change the reference point to themselves instead of the drone's head.
- A drone has 4 degrees of freedom
  - **Pitch**
  - **Throttle**
  - **Yaw**
  - **Roll**
    - **STAR:** Drone's head
    - **BLUE:** Yaw axis: rotate the body of the drone to the right of left
    - **RED:** Roll axis: Fly to the left or right
    - **GREEN:** Pitch axis: Head of drone flies forward or backward



- Each movement is controlled with the simple action of one of the controller's two toggle switches.
  - **Yellow:** Straight forward and back
  - **BLUE: Yaw** axis, Left and Right pivot
  - **RED: Roll** axis, tilt/rotate Right and Left
  - **GREEN: Throttle**, increase or decrease speed to increase or decrease altitude.

Unit 2

Preparation

Simulation Set-up

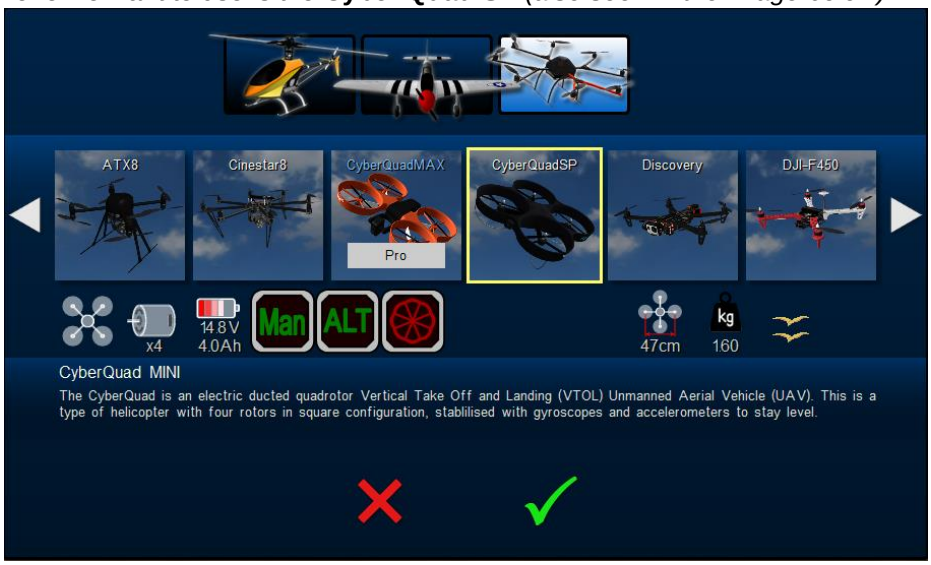
- Install Sim software with the supplied disk. (This step is not needed if the drone package was purchased with your simulator)
- Unplug any and all flight controls from the computer.
- Plug in the USB/Antenna for your wireless controller.
- Turn on the controller
    - Press the power button in the bottom left and right corners of your controller simultaneously and hold until the LED screen turns on
    - Verify the battery life *(displayed on the LED screen)* is adequate for the day's lesson.
- Open the Sim flight software on your computer. 
- The introduction video should begin to play
    - Press the "Space-Bar" to skip it
- You should begin in a "Free Flight" scenario *(like in the images below)*

Change your Drone:

- There is a tool bar in the bottom left of your window. *(as seen in the image below)*
    - If it is not already open/visible, select the **arrow** in the bottom corner to open it.

- Select the tool bar icon that resembles a Quad-Copter, to open the "Drone Selection Window"

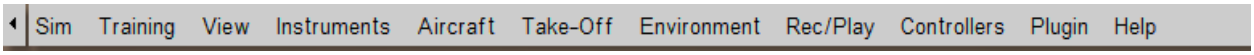
- Use the green arrows to scroll through the available aircraft options *(as seen in the image below)*
  - The drone we want to use is the **Cyber Quad SP** *(also seen in the image below)*



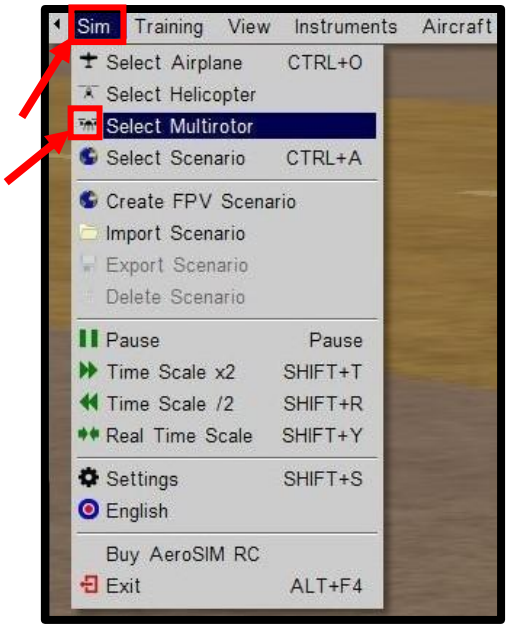
- Once you have found your drone, select the green checkmark at the bottom of the window. *(as seen in the image above)*

Open Training Activities

- There is a tool bar in the top left of your window *(as seen in the image below)*
  - If it is not already open/visible, select the **arrow** in the top corner to open it.

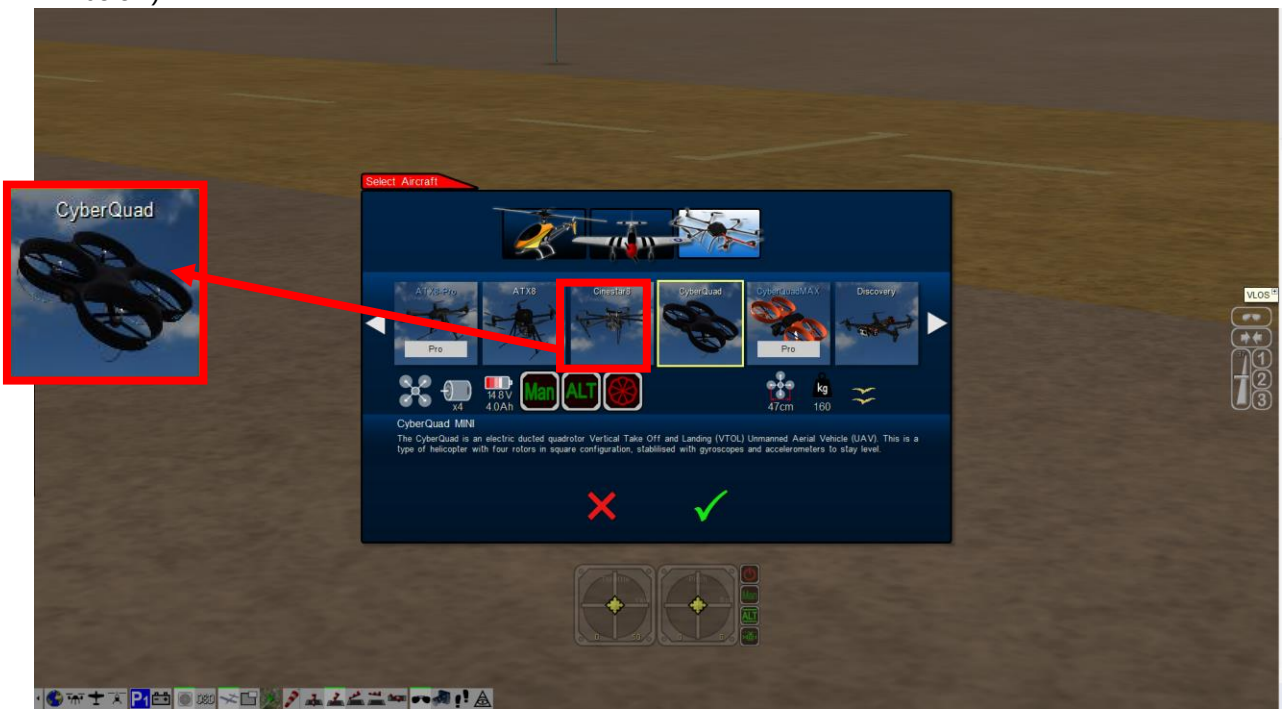


- In the toolbar, under **Sim**, select **Select Multirotor** (as seen in the image below)

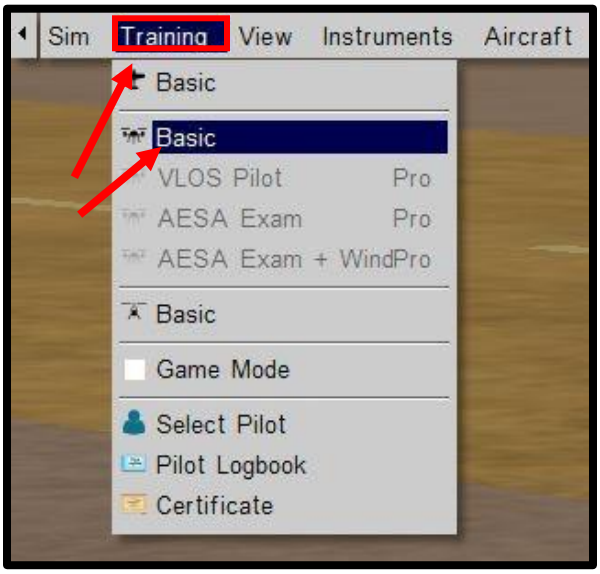


- The "Aircraft Selection" window will appear first

- Verify that the aircraft selected is the "Cyber Quad" and select the green checkmark (as seen in the image below)



- Next, go to the toolbar, under **Training**, select **Basic** (as seen in the image below)

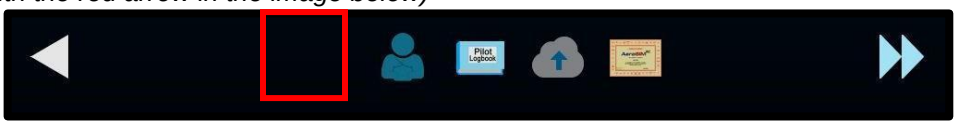


- The **"Basic Training"** window should now open *(as seen in the image below)*

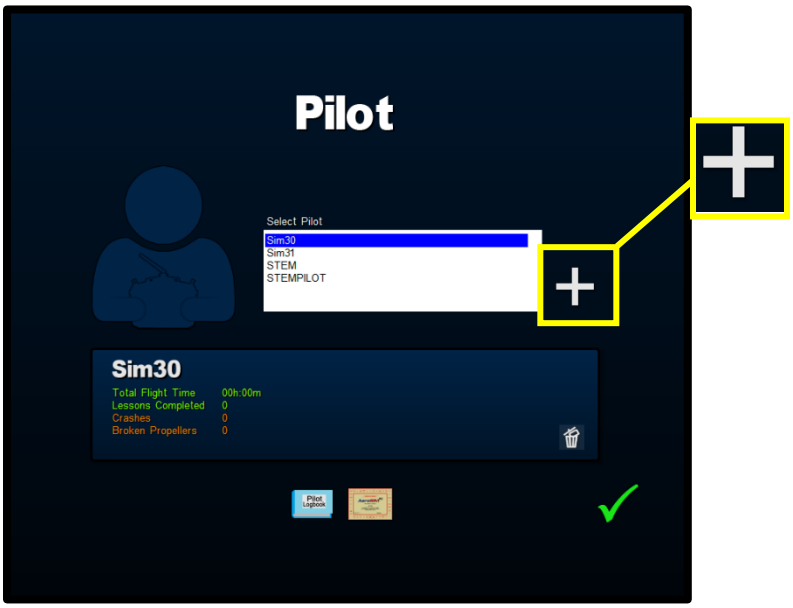
Save Student Progress

Before beginning any task, each student must select their correct user profile. If this is the first time you are opening the software, they must first create one.

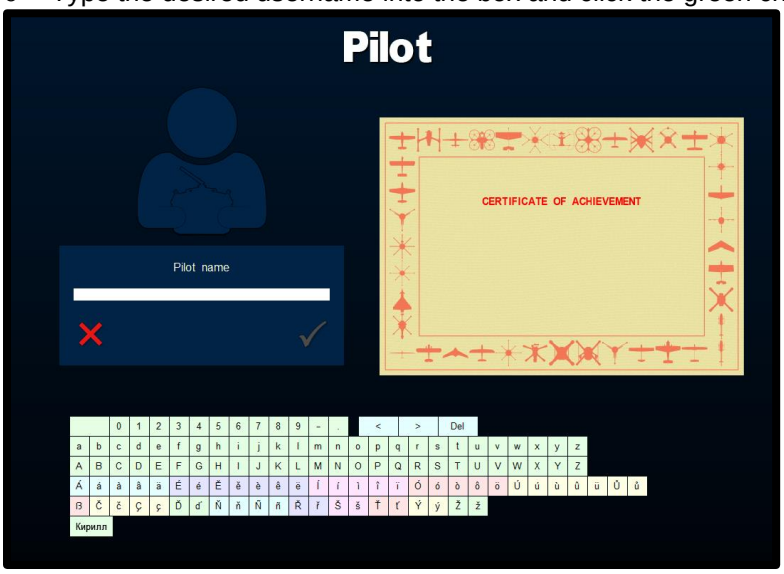
- In the **"Basic Training"** window, you will notice a small icon at the bottom of the page resembling a person/pilot. *(Indicated with the red arrow in the image below)*



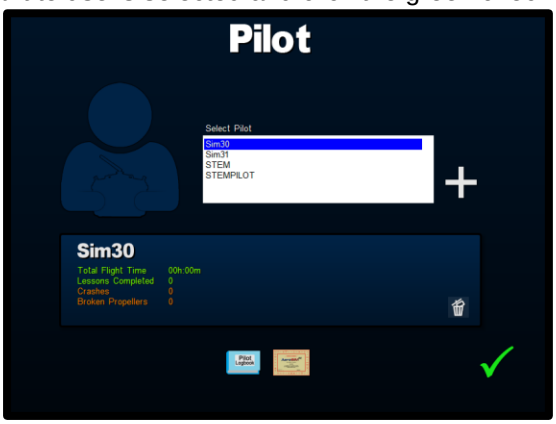
- Select the image of the pilot
- From this window you will select the user account you wish to use



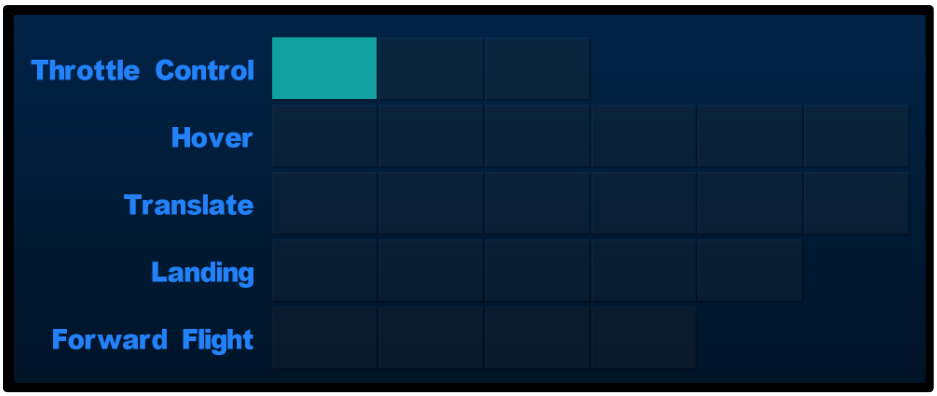
- If you need to create a user account,
  - select the "+"to open the "new user window"
  - Type the desired username into the box and click the green checkmark *(As seen in the image below)*



- You should now be back at the **"User Profile"** window *(as seen in the image below)*
  - Verify the account you want to use is selected and click the green checkmark



- Continue to the **"Basic Training"** window and select the task you wish to do *(image below)*.
  - The task order is locked by default. Green boxes indicate completed tasks and Blue boxes indicate the next suggested task/ the one you are currently on. *(example in image below)*



- Once everything is set up and ready to fly, have the students break off into their flight crews.

Drone Simulation Lessons

You will be going through a series of tutorial missions. Each one is focused on teaching a single control or aspect of flying a drone; Throttle Control, Hovering, Translating, Landing and Forward Flight. Once completed we will continue on to some activity flights that will test your ability to use all the skills you just learned together.

Training Missions *(Throttle Control Example)*

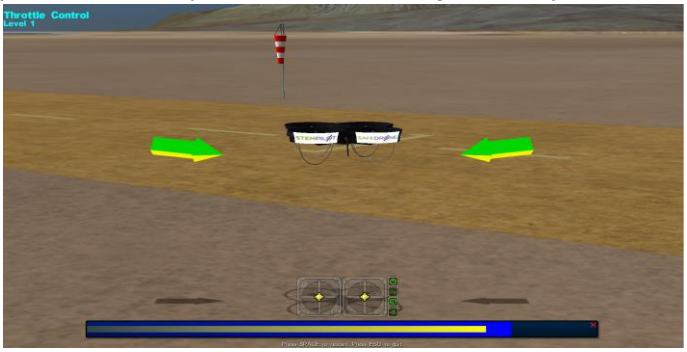
Each mission will have a task and clearly marked area for you to be in, whether it be arrows, hoops or other shapes. We have taken some screen shots of the first mission and written out the tasks performed as an example and/or reference for you.

- You will see a notification on the bottom of your window stating the motor is off.
    - The given directions state: to start your engine, pull the left toggle stick down and to the right *(as shown in images below)*.

- Push the left toggle switch gently forward to increase throttle and line up with the floating arrows *(as shown in the images below)*.

- Once the engine is on, your timer will be started *(represented by the blue shaded bar in the image below)*. Complete the task *(Your progress represented by the yellow bar in the image below)* before the time runs out or you will fail the task and must repeat it.

- Once you are lined up the arrows will turn yellow. Hold that position till they turn green, and it says you have completed the task. *(As shown in the images below)*.



- Continue on to the next task until you have completed them all *(as shown in the image below)*.

Tutorial Flight Structure

Section Goals

Each lesson has been placed in a particular group; Throttle, Hover, Translate, Land, and Forward Flight. These groups all have a specific goal or skill you will learn by completing all of its lessons.

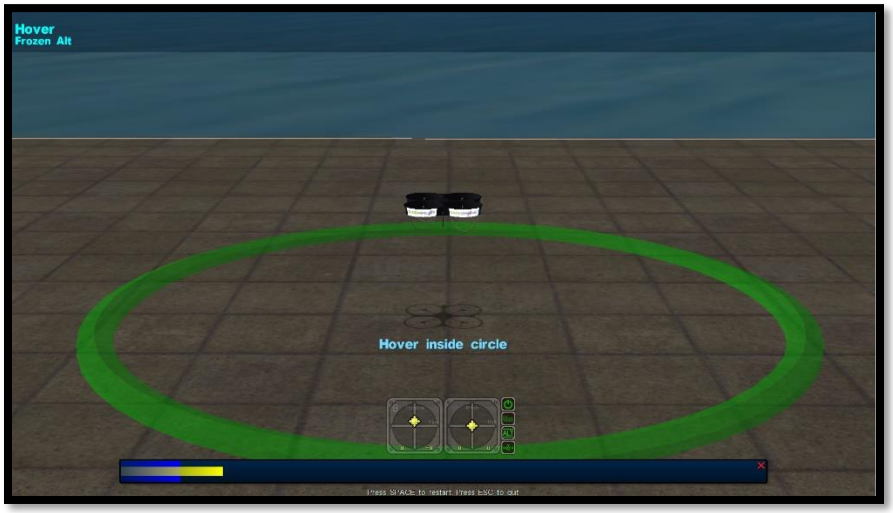
- **Throttle Control:** The faster the rotors turn, the higher the drone goes. This section focuses on just that. You will need to increase or decrease the throttle to line the drone up with the arrows and hold that altitude each time they change their altitude/vertical position.

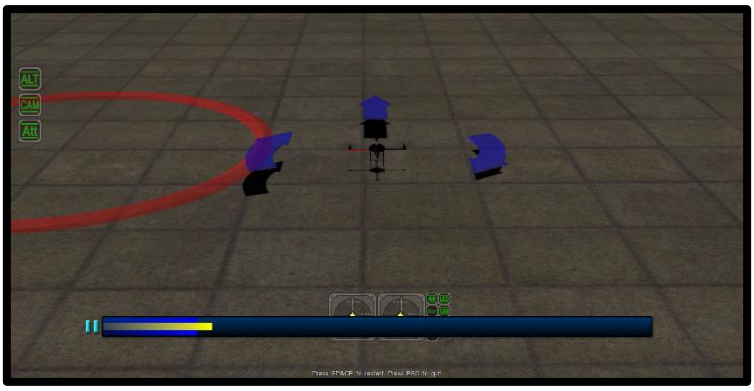
- **Hover:** The ability to hold your position is important. There is no YAW movement in this section, only ROLL as it is just as important to keep in mind how the positioning/orientation of your drone in relation to you can affect its motion (forward flight is in relation to a point on the drone regardless of where you are). Each flight will start you off with the drone's head in a different position. You must take-off and use your controls to remain inside the circle until your time's up.
    - *Lessons 1-5 the circle does not change. However, in lesson 6 the circle will shrink as the timer gets closer to completion.*

- **Translate:** Being able to control your direction of flight is equally as important. This section focuses specifically on the latitude and longitude, movement, and control. Once you take-off, circles will appear 1 at a time in accordance to the specific pattern of that flight. Your goal is to move to the active circle and hold that position until the location changes and you must move to the next circle's position.
    - *For the first lesson in this section, you will have no control over your altitude. However, for the remaining lessons you will have free movement and control over all axis.'*
- **Land:** The ability to maintain a controlled and safe descent/landing is just as important to flight, if not more, than what you do in the air. In this section you will have to take-off, fly to each circle presented and land in the circle each time its position moves on the course. Because your descent rate and horizontal orientation go hand in hand with a safe landing, if you crash/damage the drone during your landing you will fail and must restart.

Hover, Translate and Land share the course structure (drone flies to circle).

- **Forward Flight:** This section focuses on the ability to adjust your YAW and ROLL simultaneously in flight, so you are always flying forward/head-first towards your target. Like the previous couple sections, circles will appear in accordance to the specific pattern of that flight and you will have move to that circle each time it's location changes. However, it differs due to the addition of an arrow that points in the direction the drone's head must be oriented. Both positioning requirements must be met in order for the program to register you have completed the task and present you with the next location.





Software "Recommended" Order

We have established the order each lesson should be completed in. If you feel that a different order would benefit your students more, feel free to "unlock" them *(Click the "Winkey Face")*.

Section Title	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6
Throttle Control	**1**	**4**	**7**			
Hover	**2**	**5**	**10**	**13**	**17**	**22**
Translate	**3**	**6**	**8**	**9**	**11**	**12**
Land	**14**	**15**	**16**	**18**	**19**	
Forward Flight	**20**	**21**	**23**	**24**		

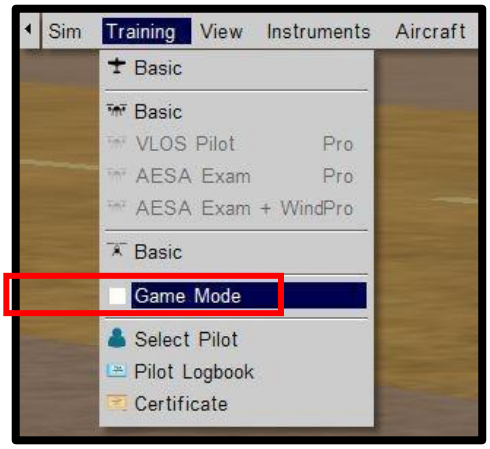
1. **Throttle Control: *Lesson 1 –*** Hold drone at 1 height
2. **Hover: *Lesson 1 –*** Nose position out *(Frozen altitude)*
3. **Translate: *Lesson 1 –*** Sideways Pattern *(Frozen altitude)*
4. **Throttle Control: *Lesson 2 –*** Hold drone at 8 different heights
5. **Hover: *Lesson 2 –*** Nose position out
6. **Translate: *Lesson 2 –*** Sideways Pattern
7. **Throttle Control: *Lesson 3 –*** Hold drone at 12 different heights
8. **Translate: *Lesson 3 –*** Left square pattern
9. **Translate: *Lesson 4 –*** Right square pattern
10. **Hover: *Lesson 3 –*** Nose position left
11. **Translate: *Lesson 5 –*** Left diagonal pattern
12. **Translate: *Lesson 6 –*** Right diagonal pattern
13. **Hover: *Lesson 4 –*** Nose position right
14. **Land: *Lesson 1 –*** Sideways pattern
15. **Land: *Lesson 2 –*** Left square pattern
16. **Land: *Lesson 3 –*** Right square pattern
17. **Hover: *Lesson 5 –*** Nose position in
18. **Land: *Lesson 4 –*** Left diagonal pattern
19. **Land: *Lesson 5 –*** Right diagonal pattern
20. **Forward Flight: *Lesson 1 –*** Left square pattern
21. **Forward Flight: *Lesson 2 –*** Right square pattern
22. **Hover: *Lesson 6 –*** Precision *(Circle gets smaller)*
23. **Forward Flight: *Lesson 3 –*** Left diagonal pattern
24. **Forward Flight: *Lesson 4 –*** Right diagonal pattern

Drone Simulation Activity Challenge

Activity Flight Setup

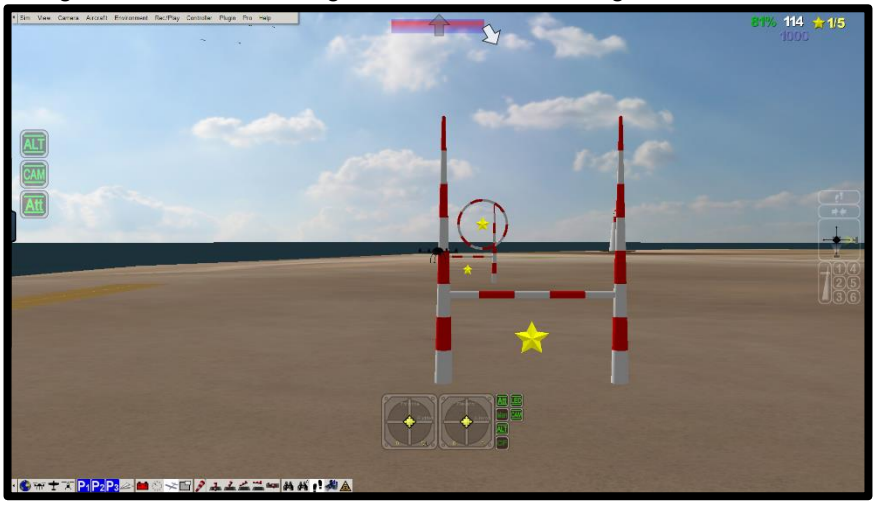
The Activity Flight Section is called **"Game Mode."** This section allows you to fly for as long as the drone's battery lasts. The goal is simple; collect as many stars and get through as many levels as possible before your battery dies.

- In the toolbar, under **Sim**, select **Game Mode** *(with the "★" icon)* to open **Star Game** (as seen in the image below)



- When you start you will be in an open field with no obstacles, just stars *(like the image below)*.

- As you complete the levels the courses will inherently become more difficult *(like the image below)*, by adding obstacles to fly through or around and changes in the terrain to navigate.



Activity Flight Goal Sheet

Pilot in Command Name: _____ Date: / /

Additional Flight Crew Members: _____

_____

Overview

How far can you get before the battery dies? In this activity you will be flying a quad copter through a series of obstacles. To move on to the next level you must collect all the stars on the field. But there is a catch. Every time you move, you drain your drone's battery and there is no way to recharge it. Even advancing to the next level will not reset your battery life *(if you end level 1 with 50% battery life, you start level 2 with 50% battery life)*.

What skill level are you? There are many variables you will be facing other than being timed. For Example, hoops and stars are awarded points, there are more than 4 levels that can be flown, and you can get more points than listed in the specifications. Because of that, we have made different achievements for you to reach and titles for you to earn.

Pre-Flight Specifications

Only the stars are required to proceed to the next level. However, all the hoops from the level will disappear once you collect the last star and advance. Choose your path wisely.

Drone Type	Battery life *(continuous flight)*	Levels Gauged
MK-Quadro	***2 min, 45 sec.***	***4***
Star Point Value	**Hoop Point Value**	**Total Points Possible** *(4 levels + no bonus points)*
10	***2***	***606***

Level Break-Down

Game				Your Totals			
Level	**Star #**	**Hoop #**	**Possible Score**	**Stars**	**Hoops**	**Points**	**Time Completed**
1	***10***	***0***	***10***				
2	***5***	***5***	***60***				
3	***24***	***3***	***246***				
4	***16***	***20***	***200***				
Total	***55***	***28***	***606***				

Achievements

For a level to be considered complete you must receive the notification that you have reached the next level before the battery dies. Stars next to the title indicate you took extra initiative during your flight.

Standard Achievements					
	Requirements				
Title	Star #	Hoop #	Score	Levels Done	Completion Badge
Student Pilot	***10***	***0***	***10***	**1**	
Co-Pilot	***15***	***0***	***150***	**1, 2**	
★ ***Co-Pilot***	***15***	***5***	***160***	**1, 2**	

Certificate of Achievement

SAFEDRONE®

Curriculum Unit
Aligned with N.G.S.S.

Course Overview

The SAFEDrone program is a versatile 21st century educational learning tool that not only helps students to apply S.T.E.M. (Science, Technology, Engineering, and Math) concepts, but learn how to be safe pilots as we move forward into a new age of programming and technology. The lessons and focus on aviation found here are shared with our STEMPilot program. Here a science teacher, a technology teacher, an engineering teacher, a math teacher, or an integrated STEM teacher can use flight simulation as powerful learning platforms to help students connect what they learn in each STEM subject to a common theme, aviation. The simulation software provided in the SAFEDrone kit can be used for any age group. However, we have focused this curriculum primarily for the middle and high school students. There is also no special teacher training required to fully benefit from the use of this program. Teachers can just follow the step-by-step process laid out in the following pages of this curriculum to introduce the world of flight to their students and to let them explore and learn about it as they also learn their S.T.E.M. subjects.

The SAFEDrone program is more than an inquiry-based learning tool for students to explore S.T.E.M.; it is meant to make students into proficient Drone/Quadcopter pilots, and more importantly safe pilots. The increasing use of drones in daily life for both personal and business uses has made it clear some of the steps in safety are missed as we rush forward into this growing technology. By implementing our S.A.F.E. (Simulated Action First Education) initiative, students can first train in a simulated, risk-free environment allowing them to focus on the control and operation of the quadcopter. Once they have passed the simulated section, they can start practicing with the real drone by first flying those same lessons they just completed in the simulator. By focusing on the familiar lessons, students have a smoother transition between the controls and a greater understanding of the operations, which decreases the probability they would experience a loss of control.

The following alignments provide you with several units for a middle or high school science class. There are also additional Aerospace and Math lessons provided for teachers to use as enrichment activities in conjunction with their curriculum.

Structure

The SAFEDrone Training unit is structured as a 3-part program, Theory, Simulation and Execution. Throughout the program students complete their lessons and tasks as part of a flight crew. Although students get their moments for individual thought when they are the "pilot in command" (or actively operating the controls), our secondary focus is to promote collaborative learning, team building skills and communication. All of these skills are important not just in aviation but in life itself and are best instilled at a young age.

Our S.A.F.E. (Simulated Actions First Education) approach to drone flight starts with theory. During the first section, students first review the theory of flight and basic concepts of operation. Once completed they begin the Simulation portion in which the students can apply their knowledge in a risk-free simulated environment. They go through a series of 24 lessons (broken up into 5 groups) teaching about control and operation. Once the lessons are complete students can then test their abilities against their classmates with the simulated obstacle course in the drone software. Once the students have passed all their lessons, they receive a certificate of achievement and move on to the application of their knowledge with a real quadcopter. In this execution section, the students repeat their basic operations lessons with the provided quadcopters, landing targets and other materials. They follow the step-by-step instructions laid out in the lesson write up as their flight crew tracks their progress.

For the lesson plans we have placed the simulated lessons in with some of the theory to help tie the lessons together. However, the number of lessons in the listed category that are executed by the students is at the discretion of the instructor. We believe that the integration of the hands-on applications in a theory focused lesson is a key tool for comprehension and later recollection of the lessons. Nevertheless, the plans themselves are just a recommended guide.

By the completion of the second unit the students should have completed all their simulation lessons and received their certificate of achievement. This goes along with our main focus and primary goal of safety. The flight application lessons paired in Unit 3 allow the students to apply the knowledge they have learned in the simulator, in the real world. The familiar actions and operations allow them to observe the drone in flight more objectively since they already are comfortable with how it is controlled. This heightened focus and understanding allows them to improve their situational awareness and account for any additional variables or obstacles in the room that could hinder their flight path, resulting in a safer flight. The room set-up is also covered in the lessons so that more than one flight crew can operate at a time without inadvertently impacting the surrounding crews or their drones.

Unit 1

Lesson 1: Introduction to SAFEDrone

Grade	*"Estimated"* Time on Lesson	*"Estimated"* Time on Simulator	Total Time to Complete
6-12	1 hour(s), 30 minute(s)	0 hour(s), 30 minute(s)	2 hour(s), 0 minute(s)

Learning Targets & Sub-Targets

- Understanding how Math, Science & Engineering can explain why a plane is able to fly.
  - Thrust, Lift, etc..
- Have a basic understanding of Quadcopter functions & what you need to know before flight
  - Knots conversion to/from MPH
- Have a basic understanding of the flight surfaces, their purpose & the controls that adjust them
  - Yaw, Roll, Pitch

	Cross-Cutting Concepts		Science and Engineering Practices
	Patterns		Asking questions & defining problems
X	Cause & effect	X	Developing & using Models
	Scale, proportion & quantity		Planning & carrying out investigations
X	Systems & system models	X	Analyzing & interpreting data
X	Energy & Matter in Systems		Using mathematics & computational Thinking
X	Structure & function		Constructing explanations & designing solutions
X	Stability & Change of Systems	X	Engaging in argument from evidence
		X	Obtaining, evaluating & communicating information
	Nature of Science		
X	Science is a way of knowing	X	Scientific Investigations Use a Variety of Methods
X	Scientific Knowledge Assumes an Order and Consistency in Natural Systems	X	Scientific Knowledge is Based on Empirical Evidence
X	Science is a Human Endeavor	X	in Light of New Evidence, Scientific Knowledge is Open to Revision
X	Scientific Addresses Questions About the Natural and Material World	X	Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Teachers Preparation

- Read the following sections in the SAFEDrone Training Unit
  - Safety *(pg.15)*
  - About the Quad Copter *(pg.16)*
  - Simulation Set-up *(pg. 17)*
  - Tutorial Flight Structure *(pg.23)*
- Review the "Activities & Discussions" section below.
- Review the "Vocabulary" section below.
- Watch/Review the videos listed for this lesson in "Videos & their Locations" *(all videos can be found on your desktop or on YouTube)*

- Watch/Review the Documents listed for this lesson in "Power Points, Referenced Material & their Locations" *(all materials can be found on your USB drive)*
- Review and print out the Handouts/Worksheets listed for this lesson in "Handouts & Worksheets"
- Collect the items listed under "Classroom Materials" as well as any additional materials you feel may be needed for the lessons

Classroom Materials Needed

- Glider *(Paper, balsa wood, foam)*
- Drone Simulator *(powered on)*

Videos & their Locations

Video Name	Location on PC	Web URL
What is a Drone?	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=rsP86OkhnPI
5 Golden Rules for building a Great Team	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=CYRpK9HBlIY
Human factors for pilots - Teamwork	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=zvfUi4kmYdw

Power Points, Referenced Material & their Locations

P.P. Title	Location on PC
Team Building and Communication	Desktop > Curriculum, Guides and More > Power Points

Handouts & Worksheets

(print from the PDF in the "Curriculum" folder, located in the "Curriculum, Guides and More" folder on the Flash drive)
SD: SAFEDrone Training Unit)

Handout	Worksheet	Title	Book	Page *(Cur.)*
		N/A		

Vocabulary

Word	Definition
Airfoil	An object/shape with curved surfaces, designed and used for its favorable ratio of drag to lift when moved through the air. *This shape is commonly used in the design of wings and/or propellers*
Air Pressure	Pressure exerted by air *(atmospheric pressure).*
Air Speed	The speed at which an object travels through the air. *Commonly measured in knots*
Angle of Attack (A.O.A.)	The acute angle between the airfoil's chord line & direction of the relative wind *Depending on the aircraft, the airfoil will be applied differently (the fixed wings on an airplane vs the horizontal rotating propellers on a quadcopter).*

Autonomous Vehicles	Any non-manned vehicle that can navigate through the terrain without human input, usually due to the application of sensors
Aviation	The study or applications of flight *There are three types of Aviation: general, commercial, and military*
Battery	A container for one or more cells that convert chemical energy into electricity and are used as a source of power. *Batteries can be rechargeable as well as have only a 1 use lifespan.*
Bernoulli's Principal	The faster molecules within a fluid move, the less Pressure they exert on objects around them
Center of Gravity (C.G.)	The point from which the entire weight of an object (at rest) is evenly dispersed, and all sides are balanced.
Chord Line	The imaginary line through the airfoil from the leading edge to the trailing edge
Critical A.O.A. (Angle of Attack)	*Each wing/airfoil has its own Critical A.O.A. Factors such as ice accumulation, physical damage, etc. disrupt the flow of air and in turn, change the critical angle of attack (usually by lowering it).*
Drone	An unmanned vehicle, equip to navigate a particular terrain/environment and can be piloted/controlled Autonomously or Remotely *Examples: UUV's (unmanned underwater vehicle), UGV's (unmanned ground/surface vehicle) and UAV's (unmanned aerial vehicle) are different types of drones you could use*
Electric Motor	An electrical machine that converts electrical energy into mechanical energy
Electronic Speed Control (ESC)	An electronic circuit that controls and regulates the speed of an electric motor (can also control the reversing of a motor and dynamic braking) *These devices are essential to modern quadcopters (and all multi-rotors) because of their dependency on variable motor speeds*
Headless Mode (Drone)	Is when the drone's point of reference is from the controller instead of having a designated front, back, left, and right side on the drone.
Inverter	A device that converts direct current and alternating current.
Knot	The unit in which the speed of a vessel is measured relative to the fluid it is traveling through. *1 knot/hr. is equivalent to 1.15078 Mph*
LiPo (Lithium-Polymer) Battery	A lightweight, rechargeable Lithium-ion type battery that uses a polymer electrolyte *(formed from highly conductive gel polymers)* instead of a liquid electrolyte. *More correctly referred to as a Lithium-ion Polymer battery*
Nautical Mile	A unit of measurement derived from its use at sea and defined as exactly 1,852 meters. *Historically speaking it was the distance of latitude that could be traveled in 1 minute, also equivalent to 1/16th of a degree of Latitude.*
Pilot in Command	The person/pilot controlling the aircraft that is also responsible for its operation and safety during the current flight.

Pitch	A rotational motion of an aircraft around its lateral axis *Nose up = Tail down, Nose down = Tail up*
Propeller	A device consisting of two or more blades (shaped like airfoils) that spin around a central hub and displace the surrounding air (like a fan). When connected to an engine, the increased speed can displace the air with a large enough force to create thrust and "propel" it forwards. *Thrust can be controlled by the Propeller's speed and in cases of adjustable propellers, the angle of the propeller in relation to its mounting point.*
Quadcopter	Unmanned Helicopter/Drone with 4 rotors
Relative Wind	The direction of the atmosphere's movement relative to the aircraft or airfoil *If there is no wind and the aircraft is moving at 20 kn, the relative wind is 20 kn.*
Remote Control	A device able to control a machine from a distance by means of signals transmitted from a radio or electronic device.
Remotely Piloted Aircraft (R.P.A.)	A type of unmanned aerial vehicle that is piloted remotely.
Roll	A rotational motion of an aircraft around its longitudinal axis *Right side up = Left side down, Right side down = Left side up*
Thrust	To push something/someone suddenly or violently in the specified direction. *(The propulsive force of a jet or rocket engine.)*
Torque	1. A resistance to turning or twisting. 2. Forces that produce a twisting or rotating motion. 3. In an airplane, the tendency of the aircraft to turn (roll) in the opposite direction of rotation of the engine and propeller. In helicopters with a single, main rotor system, the tendency of the helicopter to turn in the opposite direction of the main rotor rotation.
Unmanned Autonomous Vehicle (U.A.V.)	Any machine or vehicle that can move/navigate through terrain without the need for human input.
Yaw	A rotational motion of an aircraft around its vertical axis *Nose right = Tail left, Nose left = Tail right (stay level and pivot)*

Activities & Discussions

- Fold a paper airplane, or assemble a glider and fly it across the room
  - Discuss- Why does it fly?
    - **Thrust**, or the directional force applied to the glider from your arm and the generation of **Lift** from the shape of the wing.
- Review the following sections in the SAFEDrone Training Unit together
  - Safety *(pg.15)*
  - About the Quad Copter *(pg.16)*
  - Simulation Set-up *(pg.17)*
  - Tutorial Flight Structure *(pg.23)*
- Form Flight Crews *(Recommend; 3-4 students)*
  - Assign (or let the students create) a name for their crew *(Recommend; these students will stay together for all mission planning, flying, evaluation and projects)*
- Discuss the importance of Teamwork
  - Watch the video "5 Golden Rules for building a Great Team"
    - What are some other important things to remember when working as a team?
  - Watch the video "Human factors for pilots – Teamwork"
  - View the PowerPoint "Team Building and Communication"
- Read about MPH, Knots, and conversions *(pg. 106 of the references page)*
- Have the students gather around the simulator and demonstrate how to use it for your students
  - Review controller movements on the Simulator
  - Gently move each stick forward, back & to either side to show how it affects the drone.
- Watch the video "What is a Drone?" and discuss it as a class
- Have the students take turns flying in free flight.
- Review the vocabulary words you covered *(Vocabulary section)*

NGSS Alignment

Science Lesson	Activity Description	Mid. School	High School
Gliders vs Airplanes	Opening: What is "gliding" and how is it different from flying? Learning Target: I can explain what gliding is and how it differs from powered flight. Main Activity: ➔ Students review what they have learned about the best glide speed (lesson done in class or given as a reading assignment). ➔ Students get directions for the simulator lessons (worksheet). ➔ Students fly a glider. ➔ Students discuss how gliding is different from powered flight and how glider design is different from airplane design. ➔ Can a Drone/quadcopter glide? Discuss.	MS-PS2-1 MS-PS2-2 MS-PS2-4 MS-PS3-1 MS-PS3-2 MS-PS3-5 MS-ETS1-1 MSETS1-2 MS-ETS1-3 MS-ETS1-4	HS-PS2-1 HS-PS2-2 HS-PS3-1 HS-PS3-3 HS-ETS1-2
Introduction to flying – basics of airplane, cockpit familiarization	Opening: Review unit 1 of this document as well as the "Forces of flight" and "6 degrees of freedom" sections in the STEMPilot Curriculum book. Learning Target: I understand how a drone operates and the basic concepts of flight. Main Activity: Discuss the Flight surfaces of a drone and the terms learned in this section. Have students open the Drone simulation software and	MS-ETS1-2	HS-ETS1-2

	experiment with the controls to see its reaction. Discuss which action controls each degree of freedom on the quadcopter.		

Lesson Expansions (Extra Time)

- *(pg. 90)* Each Flight Crew selects and builds one of the 3 Glider designs, and you have a competition to see which plane flies the: farthest, highest.
  - Watch the height of the Arc.

Unit 2

Lesson 1: Introduction to Drone Flight

Grade	*"Estimated"* Time on Lesson	*"Estimated"* Time on Simulator	Total Time to Complete
6-12	1 hour(s), 0 minute(s)	1 hour(s), 30 minute(s)	2 hour(s), 30 minute(s)

Learning Targets & Sub-Targets

- Understanding of how to control the aircraft
  - What surfaces move on an airplane, where are they located & what axis movement do they control.
- Understanding of Thrust
  - Where it comes from and how it moves the aircraft
- Understanding what the center of gravity is
  - Why it is important to know your aircrafts C.G.

	Cross-Cutting Concepts		Science and Engineering Practices
X	Patterns	X	Asking questions & defining problems
X	Cause & effect		Developing & using Models
X	Scale, proportion & quantity		Planning & conducting investigations
X	Systems & system models	X	Analyzing & interpreting data
X	Energy & Matter in Systems	X	Using mathematics & computational Thinking
X	Structure & function		Constructing explanations & designing solutions
X	Stability & Change of Systems		Engaging in argument from evidence
		X	Obtaining, evaluating & communicating information
	Nature of Science		
X	Science is a way of knowing	X	Scientific Investigations Use a Variety of Methods
X	Scientific Knowledge Assumes an Order and Consistency in Natural Systems	X	Scientific Knowledge is Based on Empirical Evidence
X	Science is a Human Endeavor	X	in Light of New Evidence, Scientific Knowledge is Open to Revision
X	Scientific Addresses Questions About the Natural and Material World	X	Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Teachers Preparation

- Read," Degrees of Freedom" *(pg.55)*
- Review the "Activities & Discussions" section below.
- Review the "Vocabulary" section below.
- Watch/Review the videos listed for this lesson in "Videos & their Locations" *(all videos can be found on your desktop or on YouTube)*
- Watch/Review the Documents listed for this lesson in "Power Points, Referenced Material & their Locations" *(all materials can be found on your desktop and in the SAFEDrone curriculum book)*
  - Print out any pages/ slides you feel should be handed out to students

- Review & print out the Handouts/Worksheets listed for this lesson in "Handouts & Worksheets"
- Collect the items listed under "Classroom Materials" as well as any additional materials you feel may be needed for the lessons

Classroom Materials Needed

- Glider *(preferably Styrofoam)*
- Student Log Folders
- Drone Simulator *(powered on)*

Videos & their Locations

Video Name	Location on PC	Web URL
How Do Planes Fly?	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=bGtyR6Ah5xQ
Gravity Visualized	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=MTY1Kje0yLg
How do Quadcopters Fly?	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=DNc8o9CZLHU

Power Points, Referenced Material & their Locations

P.P. Title	Location on PC
N/A	Desktop > Curriculum, Guides and More > Power Points

Handouts & Worksheets

(Print from the PDF in the "Curriculum" folder, located in the "Curriculum, Guides and More" folder on the Flash drive)
SD: SAFEDrone Training Unit)

Handout	Worksheet	Title	Book	Page
X		Degrees of Freedom	SD	55
X		About the Quadcopter	SD	16

Vocabulary

Word	Definition
Center of Gravity (C.G.)	The point from which the entire weight of an object (at rest) is evenly dispersed, and all sides are balanced.
Force (F)	The energy applied to an object that attempts to cause the object to change its direction, speed, or motion. In aerodynamics, it is expressed as F, T (thrust), L (Lift), W (weight), or D (drag), usually in pounds.
Friction	The resistance that one surface/object encounters when moving over another
Gravity	The natural force that pulls an object towards the center of the earth *G=9.80665 m/s² (or approx.. 32.174 ft/s²)*

Lift	The name given to a force perpendicular to the airflow around an aircraft once it is great enough to oppose the force of gravity and move an object upwards. *In drone operation this is achieved by thrust and the displacement of air created by the horizontal propellers.* *- Airplanes are designed so the lift created by the wings oppose the weight force (gravity).*
Latitude	Measurement used on a map to express the angular distance of an object North or South of the (celestial) equator. E*xpressed in degrees and minutes*
Longitude	Measurements used on a map to express the angular distance of an object East or West of the (celestial) meridian. E*xpressed in degrees and minutes*
Momentum	● A property *(a quality or trait belonging and especially peculiar to an individual or thing)* of a moving body that the body has by virtue of its mass *(the property of a body that is a measure of its inertia and that is commonly taken as a measure of the amount of material it contains and causes it to have weight in a gravitational field)* and motion and that is equal to the product of the body's mass and velocity. A property of a moving body that determines the length of time required to bring it to rest when under the action of a constant force or moment
Throttle	The valve in a carburetor or fuel control unit that determines the amount of fuel-air mixture that is fed to the engine.
Thrust Vectoring	*(Also thrust vector control or TVC)* The ability of an aircraft, rocket, or other vehicle to manipulate the direction of the thrust from its engine(s) or motor(s) in order to control the attitude or angular velocity of the vehicle.
Work	A measurement of force used to produce movement.

Activities & Discussions

- Hand out and Review:
  - "The 6 Degrees of Freedom" *(pg. 55)*
- Discuss how the flight surfaces differ between Quadcopters and fixed wing aircrafts
- Discuss what the Center of Gravity is and its importance in flight.
  - Use your glider as an illustration; try to balance it on an object in the classroom.
- Discuss Gravity
  - Does a rock accelerate when dropped off a 10-story building?
    - Discuss Gravity and how it pulls a free-falling object towards the earth's center
    - *Acceleration of Gravity is 9.8 meters per second*
  - Watch "Gravity Visualized" *(can be found on the desktop or on YouTube)*
- Review how to log-in and create a username in the Drone simulation software
- Have Students break up into their flight crews
  - Hand out and Review "About the Quadcopter" *(pg. 16)*
  - Open the "Throttle Control" lessons on the Simulator
    - Each student in the flight crew should take turns flying the tutorial until all of them have completed it. *(Remember to have each student log into their own user before starting a new simulation lesson)*
    - Remember to maintain Situational Awareness.
      - *There are 3 lessons in this section. Of the 24 lessons provided these 3 are numbered 1, 4 and 7. Students should complete the first lesson in the series to complete this section. They will revisit the rest of the lessons as they progress through the series.*
  - Open the "Hover" lessons on the Simulator

- Each student in the flight crew should take turns flying the tutorial until all of them have completed it. *(Remember to have each student log into their own user before starting a new simulation lesson)*
- Remember to maintain Situational Awareness.
  - *There are 6 lessons in this section. Of the 24 lessons provided these 6 are numbered 2, 5, 10, 13, 17 and 22. Students should complete the first lesson in the series to complete this section. They will revisit the rest of the lessons as they progress through the series.*

- Review the vocabulary words you covered *(Vocabulary section)*

NGSS Alignment

Science Lesson	Activity Description	Mid. School	High School
Importance of Throttle control	Activity: Review the "Tutorial Flight Structure" section for "Throttle Control." Complete the "Throttle Control" lessons in the drone simulation software *(Remember to have each student log into their own user before starting a new simulation lesson) -(3 lessons)* Discussion: What happens when you increase the speed of the propellers? Why?	MS-PS2-1 MS-PS2-2 MS-PS3-1 MS-PS3-5 MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	HS-PS2-1 HS-PS2-2 HS-PS3-1 HS-PS3-3 HS-ETS1-2
How to takeoff and climb	Activity: Review the "Tutorial Flight Structure" section for "Hover". Complete the "Hover" lessons in the drone simulation software *(Remember to have each student log into their own user before starting a new simulation lesson) -(6 lessons)* Discussion: Why is maintaining altitude important? How is your understanding of the Throttle control important to maintaining your altitude?	MS-PS2-1 MS-PS2-2 MS-PS3-1 MS-PS3-5 MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	HS-PS2-1 HS-PS2-2 HS-PS3-1 HS-PS3-3 HS-ETS1-2

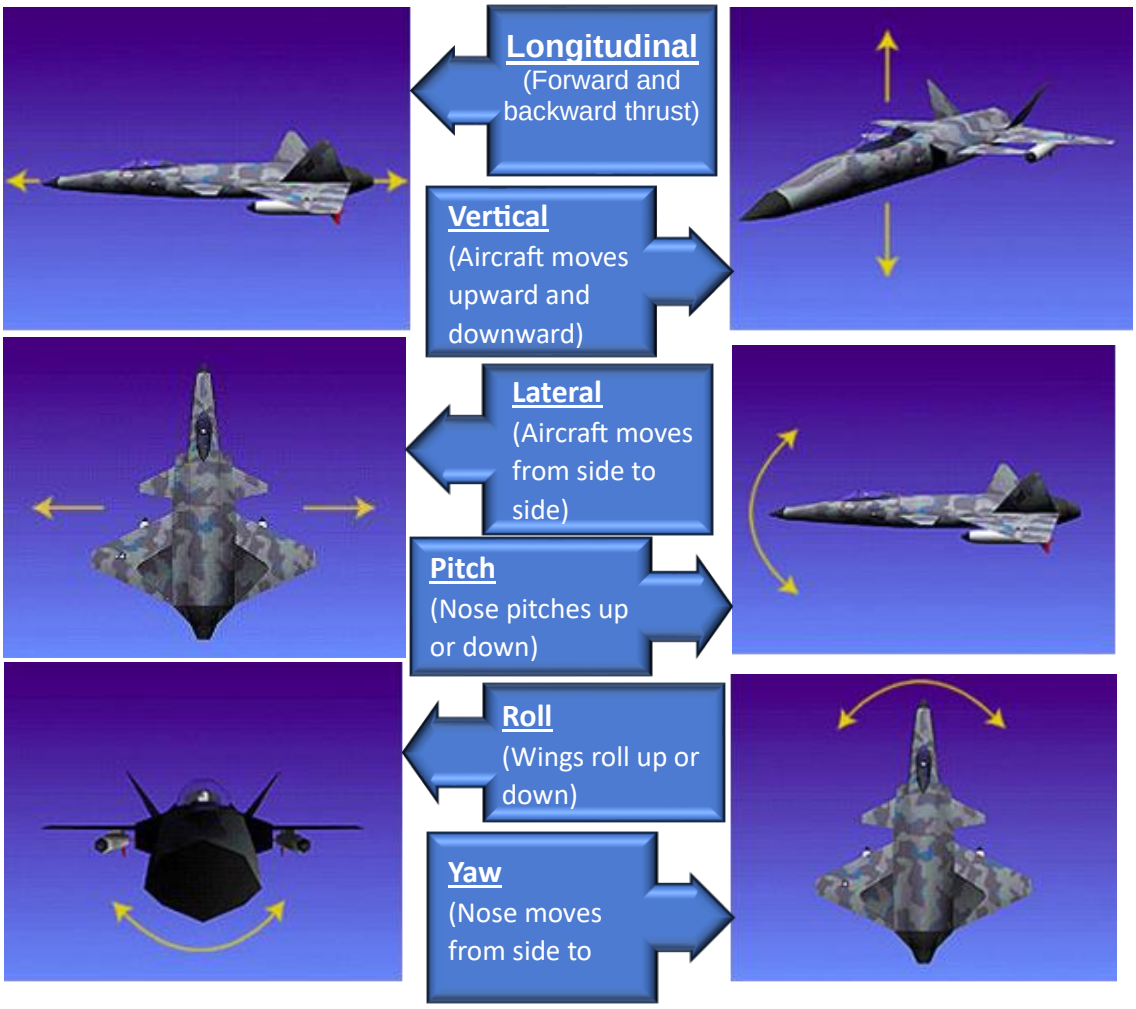
Section 1.04: 6 Degrees of freedom (DOF):

Section 1.04.A: Lesson

We can describe our relative position using 6 degrees of freedom. By placing your finger on your nose and moving it up and down saying "Pitch," Tipping Left to Right saying "Roll" and turning left and right saying "Yaw" students will understand DOF. We will focus on Pitch, Roll and Yaw using your flight controls.

- Pitch – Nose Up and Nose Down ……**Pull the Yoke Out and Push In**
- Roll – Roll Left and Roll Right……**Rotate the Yoke Left and Right**
- Yaw – Point the Nose Left and Right …**Slide the Rudder Pedals (Forward and Back)**
- Longitude – Forward and Back ……**Thrust**
- Vertical – Up and Down ……**Lift**
- Lateral – Side to Side …… **Slip**

The pictures below Illustrate these six degrees of freedom in aircraft motion. (NASA)



Lesson 2: Drones in Motion

Grade	*"Estimated"* Time on Lesson	*"Estimated"* Time on Simulator	Total Time to Complete
6-12	1 hour(s), 0 minute(s)	2 hour(s), 45 minute(s)	3 hour(s), 45 minute(s)

Learning Targets & Sub-Targets

- Understand the importance of situational awareness
- Understanding of how Physics explains Drone flight
  - Understand the basic principle of Newton's Laws
  - Understand what Gravity, Thrust and Drag are and their effect on an aircraft.
- Know about different types of engines & their operational differences for generating thrust

	Cross-Cutting Concepts		Science and Engineering Practices
	Patterns	X	Asking questions & defining problems
X	Cause & effect	X	Developing & using Models
	Scale, proportion & quantity		Planning & carrying out investigations
X	Systems & system models	X	Analyzing & interpreting data
X	Energy & Matter in Systems	X	Using mathematics & computational Thinking
X	Structure & function		Constructing explanations & designing solutions
X	Stability & Change of Systems	X	Engaging in argument from evidence
		X	Obtaining, evaluating & communicating information
	Nature of Science		
X	Science is a way of knowing	X	Scientific Investigations Use a Variety of Methods
X	Scientific Knowledge Assumes an Order and Consistency in Natural Systems	X	Scientific Knowledge is Based on Empirical Evidence
X	Science is a Human Endeavor	X	in Light of New Evidence, Scientific Knowledge is Open to Revision
X	Scientific Addresses Questions About the Natural and Material World	X	Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Teachers Preparation

- Read, "Forces of Flight" *(pg.61-63)*
- *(If you have a 3D-Printer)* Print the parts to the Jet turbine engine model
  - *Located on your Desktop in the "3D Files" folder. Contact STEMPilot at 203-527-5747 if it is missing.*
- Review the "Activities & Discussions" section below.
- Review the "Vocabulary" section below.
- Watch/Review the videos listed for this lesson in "Videos & their Locations" *(all videos can be found on your desktop or on YouTube)*
- Watch/Review the Documents listed for this lesson in "Power Points, Referenced Material & their Locations" *(all materials can be found on your desktop and in the SAFEDrone curriculum book)*

- Print out any pages/ slides you feel should be handed out to students
- Review and print out the Handouts/Worksheets listed for this lesson in "Handouts & Worksheets"
- Collect the items listed under "Classroom Materials" as well as any additional materials you feel may be needed for the lessons

Classroom Materials Needed

- Glider *(preferably Styrofoam)*
- Drone Simulator *(powered on)*

Videos & their Locations

Video Name	Location on PC	Web URL
Inertia Demo	Desktop > Videos > Lesson Plan Referenced Videos	http://www.physicsclassroom.com/class/newtlaws/Lesson-1/Inertia-and-Mass
Engineering Engines	Desktop > Videos > Lesson Plan Referenced Videos	https://www.khanacademy.org/partner-content/mit-k12/eng-and-electronics/v/engineering-engines
The Forces on an Airplane	Desktop > Videos > Lesson Plan Referenced Videos	https://www.khanacademy.org/partner-content/mit-k12/mit-k12-physics/v/the-forces-on-an-airplane
Basic Physics of Drones	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=PkbkO3e0ev0
* The Lithium Jet five-seater all-electric air taxi	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=ti3Ep4u_s1k
* The electric flight era is closer than you think – CNBC Reports	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=b-Hj2gn9gZQ
* 3 Main Reasons Why Electric Airplanes Are Better to Fly	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=aJnvc13zStw

Power Points, Referenced Material & their Locations

P.P. Title	Location on PC
Propulsion Overview	Desktop > Curriculum, Guides and More > Power Points

Handouts & Worksheets

(Print from the PDF in the "Curriculum" folder, located in the "Curriculum, Guides and More" folder on the Flash drive)
SD: SAFEDrone Training Unit)

Handout	Worksheet	Title	Book	Page
X		Forces of Flight	SD	60-62
	X	Worksheet 3-The Four Forces of Flight	SD	65

Vocabulary

Word	Definition

Acceleration	The rate of change of an object's velocity *Distance/Time²*
Center of Gravity (C.G.)	The point from which the entire weight of an object (at rest) is evenly dispersed, and all sides are balanced.
Electric Charge	A definite quantity of electricity, either negative or positive, usually regarded as a more or less localized population of electrons separated or considered separately from their corresponding protons or vice versa: the quantity of electricity held by a body and construed as an excess or deficiency of electrons.
Electric Current	A movement of positive or negative electric particles (such as electrons) accompanied by such observable effects as the production of heat, of a magnetic field, or of chemical transformations.
Electric Motor	An electrical machine that converts electrical energy into mechanical energy
Electricity	A fundamental form of energy observable in positive and negative forms that occurs naturally (as in lightning) or is produced (as in a generator) and that is expressed in terms of the movement and interaction of electrons.
Force	A measurement of strength or energy created by a physical action/movement
Fuel Efficiency	Defined as the amount of fuel used to produce a specific thrust or horsepower divided by the total potential power contained in the same amount of fuel.
Fuel Energy	The useful energy produced when a substance *(the fuel)* undergoes a chemical or nuclear reaction.
Heat Energy	*(Aka thermal energy)* A form of energy created by the movement of tiny particles *(atoms, molecules, or ions)* in solids, liquids and gasses that is transferred due to a difference in temperature.
Impulse	The product of the average value of a force and the time during which it acts *(the change in momentum produced by the force)*.
Kinetic Energy	Energy associated with motion.
Gravity	The natural force that pulls an object towards the center of the earth *G=9.80665 m/s² (or approx. 32.174 ft/s²)*
Lift	When the force upon the surface of an object created by the airflow over it becomes weaker above (pushing down) than below (pushing up) enough that the object begins to lift off the ground.
Mechanical Advantage	The advantage gained by the use of a mechanism in transmitting force *(Specifically: the ratio of the force that performs the useful work of a machine to the force that is applied to the machine)*.
Mechanical Efficiency	Measure the effectiveness with which a mechanical system performs. It is usually the ratio of the power delivered by a mechanical system to the power supplied to it, and, because of friction, this efficiency is always less than one. For simple machines, such as the lever and the jackscrew, the efficiency is the actual load lifted divided by the theoretical force delivered.

Mechanical Energy	Measure the effectiveness with which a mechanical system performs. It is usually the ratio of the power delivered by a mechanical system to the power supplied to it, and, because of friction, this efficiency is always less than one. *For simple machines, such as the lever and the jackscrew, the efficiency is the actual load lifted divided by the theoretical force delivered.*
Reciprocating Engine	An engine that converts the heat energy from burning fuel into the reciprocating movement of the pistons. This movement is converted into a rotary motion by the connecting rods and crankshaft.
Situational Awareness (S.A.)	The perception of environmental elements and events in relation to time and/or space, the comprehension of their meaning, and the projection of their status after some variable (such as time or an event) has changed.
Speed	The distance traveled in a given time.
Tangential Velocity	The tangential velocity is the velocity measured at any point tangent to a turning wheel. Thus, tangential velocity vt is related to the angular velocity of the wheel, ω, and the radius of the wheel, r.
Thrust	To push (something/someone) suddenly or violently in the specified direction. *(The propulsive force of a jet or rocket engine.)*
Vector	*(In both physics and math)* Any quantity with both magnitude and direction. *(Velocity is a vector because it describes both the direction and speed at which an object is moving)*
Velocity	The speed or rate of movement in a certain direction.
Weight	An object's relative mass or the quantity of matter contained by it, which increases the downward force acting upon it. *The force of gravity acting upon an object*

Activities & Discussions

- Discuss why the pilot in command must maintain "Situational Awareness"
  - First rule is to See and Avoid Aircrafts
- Hand out and Review
  - "The Forces of Flight" *(pg. 60-62)*
  - Watch the "Forces on an Airplane" video
  - Discuss: *(use the glider to demonstrate if needed)*
    - Air is considered a Fluid
    - Weight, Gravity, and the Laws of Motion
    - Lift, Drag and Thrust *(Throw the glider)*
      - *(Advanced) Coefficient of Drag:* C_D x (½ p V^2) x A
      - *(Advanced) Coefficient of Lift:* C_L x (½ p V^2) x S
- What are some of the similarities and differences between drones and fixed wing aircrafts? Have students compare and discuss.
- Watch "Engineering Engines" video
  - Discuss different engine types
    - Piston vs Turbine (Turbojet, Turbofan, Turbo shaft)
  - Have the students assemble the 3D-Printed Turbine
  - View the "Propulsion Overview" PowerPoint
- Discuss the differences between electric motors vs gas engines
  - Pros and cons to electric motors and battery powered flight

- Watch the provided videos on Electric planes and do some of your own research on electric flight *(all videos can be found on the desktop or on YouTube)*
  - "The electric flight era is closer than you think – CNBC Reports"
  - "The Lithium Jet five-seater all-electric air taxi"
  - "3 Main Reasons Why Electric Airplanes Are Better to Fly"
    - Do you agree with this person's opinion? Why or why not?
- Discuss who Isaac Newton is and his contributions to science
  - What does everyone already know
  - What did he study, what were some of his discoveries, concepts, and innovations?
  - Discuss his 3 laws of motion
- Watch the "Inertia Demonstration" video
- Review the vocabulary words you covered *(Vocabulary section)*

NGSS Alignment

Science Lesson	Activity Description	Mid. School	High School
How to change your latitude and longitude in a quadcopter	Activity: Review the "Tutorial Flight Structure" section for "Translate". Complete the "Translate" lessons in the drone simulation software *(remember to have each student log into their own user before starting a new simulation lesson) -(6 lessons)* Discussion: Discuss what Translation means. Why is this important to understand when operating a quadcopter?	MS-PS2-1 MS-PS2-2 MS-PS3-1 MS-PS3-5 MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	HS-PS2-1 HS-PS2-2 HS-PS3-1 HS-PS3-3 HS-ETS1-2
How to descend and land	Activity: Review the "Tutorial Flight Structure" section for "Landing". Complete the "Landing" lessons in the drone simulation software *(remember to have each student log into their own user before starting a new simulation lesson) -(5 lessons)* Discussion: How does your rate of descent affect your ability to land? Unlike an airplane, drones can go straight up and down. This means that when landing they can follow a glide slope and land in motion like an aircraft, or they can get above their location and just go straight down to land. What are the Pros and Cons of each method? What do you prefer? What situations can you come up with where one method would be better than the other (at least 1 for each)?	MS-PS2-1 MS-PS2-2 MS-PS3-1 MS-PS3-5 MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	HS-PS2-1 HS-PS2-2 HS-PS3-1 HS-PS3-3 HS-ETS1-2

Section 1.07: Four Forces of Flight:
Section 1.07.A: Lesson

Is Air a Fluid?

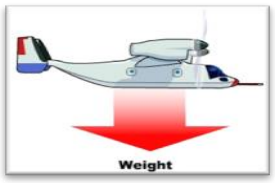
Yes, and it being a fluid (like water) is a very important concept to remember. A fluid is defined as any substance that "flows". This is not limited to liquids. Although not necessarily obvious, even gasses, like air, can be and are classified as fluids.

Try this: Open your hand. On a shallow angle (splash) bring your hand down and slap your hand against the surface of the water. Much like skipping a rock, your hand will bounce off the surface illustrating **Turbulence**.
Now, with your hand open and your fingers together, move your hand back and forth in a pool of water. The force you feel pushing against your hand is **Drag**. The force you are applying to the water propelling it forward is **Thrust**. Just like when you are swimming, each stroke you make with your arms pulls you forward. The same concept applies to the propeller. While it spins it pushes the air back causing the plane to move forward (thrust).

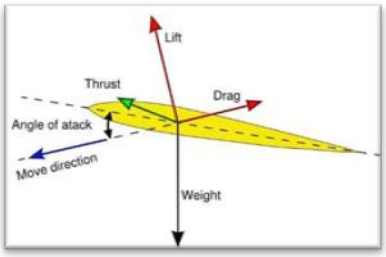
Just like the propeller uses this fluid flow to generate thrust, the wing of the plane is using it to generate lift.

Weight & Gravity *(Physics) Holds us down on the ground*

Weight is the downward gravitational force exerted on an object. According to Isaac Newton, **F = MA** where **F is Force, M is the mass of the object, and A is the Acceleration due to gravity**. Gravity pulls the aircraft downward towards the center of the earth. The heavier the aircraft, the more lift is required to overcome its weight and gravity.

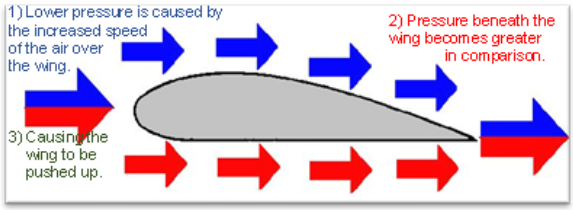


Weight: ***The downward force that causes the airplane to descend toward the center of the earth***



- **Explore** gravity, mass, inertia, acceleration, deceleration.
  Weight (F) = MA
- Terminal velocity
- Explore the interrelationships between the four forces.
- There must be enough Thrust to overcome Inertia and Drag to generate an opposing force greater than weight to cause an airplane to fly *(Lift).*

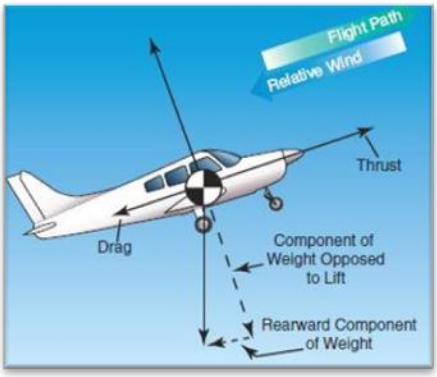
Lift *(Physics) Overcomes weight and gravity*



Lift is the component of aerodynamic force perpendicular to the relative wind. It is the upward force exerted on an airfoil created by the movement of air above and below the wing. One explanation of how lift is created is Bernoulli's Principle of fluid dynamics. This states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure or decrease in the fluid's potential energy *(Basically, faster air moving over the top of the airfoil exerts lower pressure than the slower air moving across the bottom of the airfoil. This results in the airplane being forced to rise.)*. Another explanation is Newton's third law (equal and opposite forces). As the nose of the airplane is raised up, the relative wind strikes the bottom of the wing (airfoil). The air flow pushes against the airfoil as it moves forward (drag). As the airfoil passes through the air it is pushing the airfoil

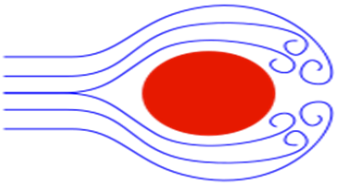
Section 1.07.A: Lesson (continued)

upward (Lift) and Backwards (drag). Both lift and drag increase with angle of attack. However, once a certain point is reached, the increased flow separation begins stalling the wing. Although Flow separation is present within any angle of attack, the attached airflow (surface the air flow touches) over the wing is still greater than below the wing with smaller angles. The steeper the angle of the airfoil; the less surface the airflow will have to act against above the airfoil, and the distance between the airflow above and below the airfoil becomes larger. Most commonly this "Stall" will occur with an angle of attack over 20 degrees, when the separated flow becomes so large the drag created by the airfoil is dominant to the lift. You cannot fly without lift. If you stall, you fall.



Drag *(Physics) What holds us back?* In fluid dynamics **drag**, sometimes called air resistance, is a type of friction or fluid resistance. Drag forces are friction caused by the relative wind hitting the aircraft and depend on the aircraft's velocity

- ***Vocabulary: Drag*** *is the component of aerodynamic force parallel to the relative wind.*



Parasite Drag is caused by the aircrafts external shape passing through the air. This force always decreases the aircraft's velocity relative to the air it is trying to pass through.

Induced Drag is caused (Induced) by **Lift**. It occurs when the relative wind caused by Thrust, causes an airfoil; Wing, Tail, Aileron, Flap or Rudder, to be pushed backwards while used to generate Upward Lift.

- **Vocabulary: *Induced drag*** *is created when Lift is produced by the relative wind hitting the bottom of an airfoil.*

Trust *(Physics) Overcomes Drag*

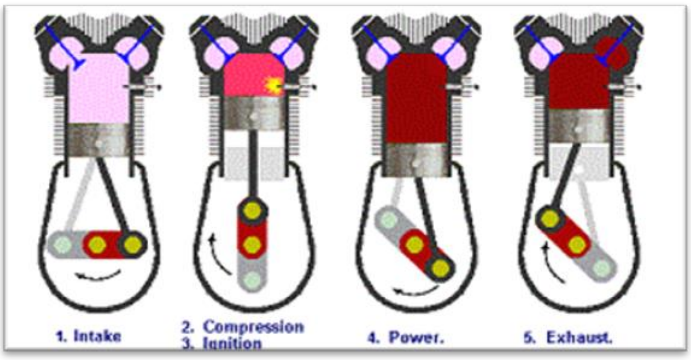
For an aircraft to move, thrust must be exerted and be greater than drag. To maintain a constant airspeed, thrust and drag must remain equal. A propeller or a jet engine creates thrust.

Section 1.07.A: Lesson (continued)

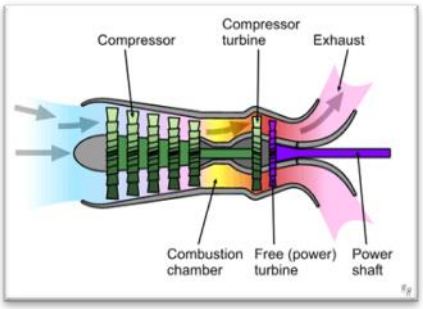
Making Thrust: *The Force that makes the airplane move forward.*

An internal combustion engine or a shafted turbine powers the propeller. The engine works by mixing an oxidizer (usually air) and fuel (usually gasoline) in a combustion chamber, where it is then compressed, ignited, and combusted. When the mixture in the combustion chamber ignites, the expansion of the high-temp and high-pressure gasses formed apply direct force to specific components in the engine. This force moves the part over a distance, essentially transforming chemical energy into mechanical energy.
This process is commonly done with a piston in a 4-stroke/2 revolution manner. The sequence is as follows

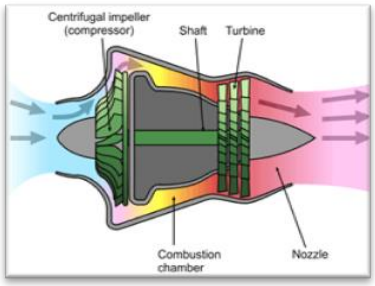
1. **Stroke 1- Intake:** The process in which air is sucked into the combustion compartment due to the vacuum created by a downward moving piston.
2. **Stroke 2 (a)- Compression stroke:** The air/fuel mixture is injected then compressed by the upwards moving piston.
3. **Stroke 2 (b)- Ignition:** Just before the piston reaches the top of the combustion compartment, fuel is sprayed into the compartment just as a spark is generated by a sparkplug igniting the fuel.
4. **Stroke 3- Combustion/power stroke:** The compressed air fuel mixture has been ignited and the combustion gasses rapidly expand, forcing the piston downwards again.
5. **Stroke 4- Exhaust:** The combusted fuel gasses left are expelled from the cylinder as the piston makes its final motion upwards for this cycle.

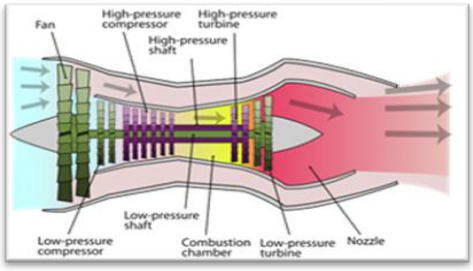


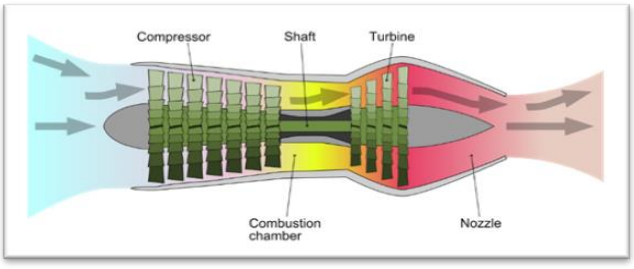
A **Jet Engine** has a rotary combustion chamber that compresses air and fuel and then ignites it. This produces a forceful exhaust gas that produces thrust. (Physics, Mechanics, Thermodynamics)



• A jet engine is a reaction engine discharging a fast-moving jet that generates thrust by jet propulsion in accordance with Newton's laws of motion. This broad definition of jet engines includes Turbojets, Turboshafts, Turboprops, Turbofans, Rockets, Ramjets, and Pulse jets and Turboprops.

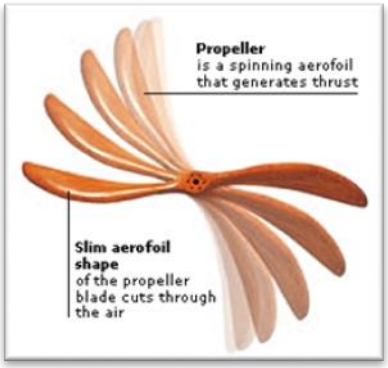






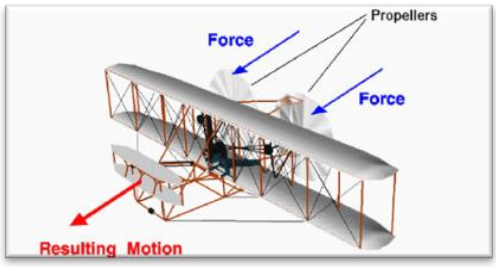
Section 1.07.B: Teachers Notes

- Explore how the propeller is shaped like a wing and pulls the air to generate thrust. (Physics) *The propeller is driven by the crankshaft and converts rotary motion to provide propulsive force.*



• The Pitch of the propeller may be adjustable depending on the aircraft.

• Turbo props, commonly found in helicopters, change the pitch of the blade to propel the aircraft forward or slow it down depending on its application.



Did you know? *The Turbo Shaft is also used in the Abrams M1 Main Battle Tank (MBT), an American third generation MBT that entered the U.S. service in 1980.*

Lift: ***The force that causes an airplane to fly.***

- Build a small balsa wood plane and fly it in the classroom
- Explore the **Bernoulli Principle** (Physics)
- Use a piece of paper draped into a radius, blow on it and watch how the rest of the page is lifted up. Why?
- Explore **Newton's Laws** (Inertia, F=MA and Action- Reaction) (Physics)

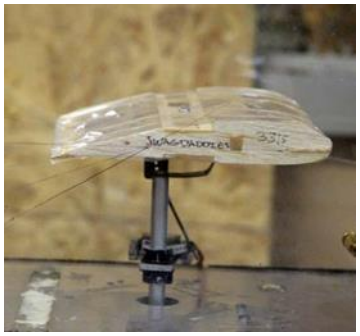
I. Every object in a **state of uniform motion tends to remain in that state of motion unless an external force is applied** to it.

II. The relationship between an object's mass m, its acceleration a, and the applied force is **F = ma.** *(Acceleration and force are vectors.)*
*The equation states the **application** of **force** is **equal** to the **speed** of the **acceleration X** it's **mass.***

III. **For every action there is an equal and opposite reaction.**

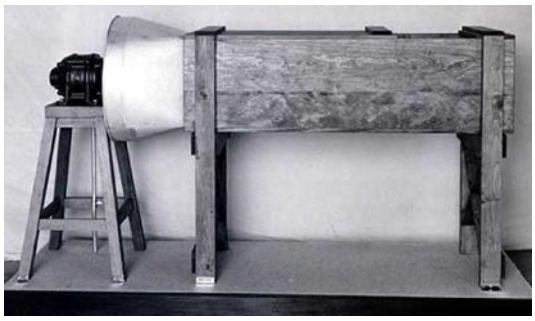
Section 1.07.B: Teachers Notes (continued)

- Construct a model wing with paper, saran wrap or other material. You can also 3D print a wing shape.
- Research the Wright Brothers original test of wings on their bike and on a home built wind tunnel (History)
- Explore the Wright Brothers. invention of the **Wind Tunnel** (History)



Balsa Wing

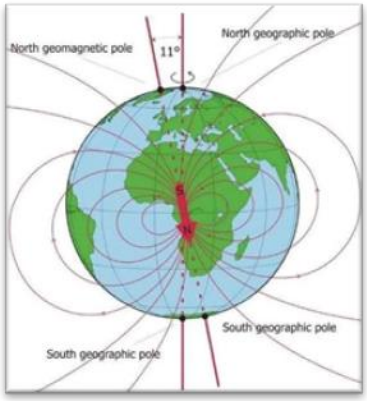
Wing Shape Test



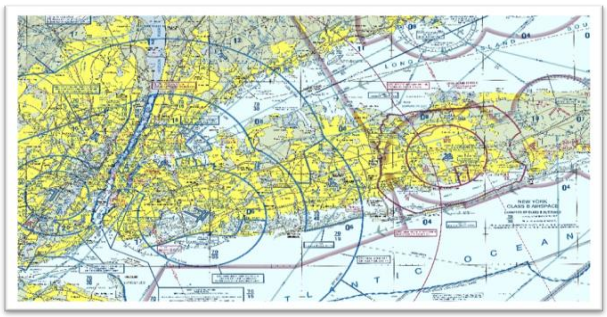
Wind Tunnel

The Wright Bros. tested wing shapes with a contraption they attached to their bicycle. To validate the conclusions reached about the amount of lift generated from their bicycle test, they designed and built the world's first Wind Tunnel.

- Research Stall Speed and lift (Physics). Stall = not enough lift to overcome the weight of the plane and it now starts to fall. (Gravity) **If you stall you fall, eventually**



- Discuss Magnetic vs True North (Earth Science).
- Use magnetic variation to convert true heading to magnetic heading (Math and Earth Science)
- Discuss how charts have a scale for measurement (Earth Science)
- Discuss Latitude and Longitude on the chart (Earth Science)
- Discuss the compass rose
- Use compass rose on a sectional chart to find Magnetic headings.



✓ Validate Student Understanding:

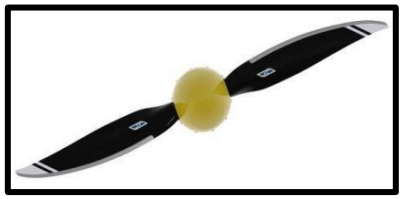
Complete Student Worksheet 3: The Four Forces of Flight

Section 1.07: Worksheet 3 – *The Four Forces of Flight*

Name: _____ Class:_____ Date:_____

1. 

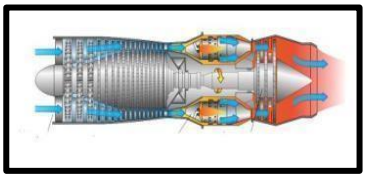
2. What force helps us get off the ground?
   _____



3. What Part of the plane is this? _____

4. What does it create and how? _____
   _____

5. What force pulls the plane toward earth?
   _____



6. What kind of airplane engine is this? _____

7. What kind of airplane is this found in? _____

8. What kind of airplane engine is this?
   _____

9. What kind of airplane is this found in?
   _____

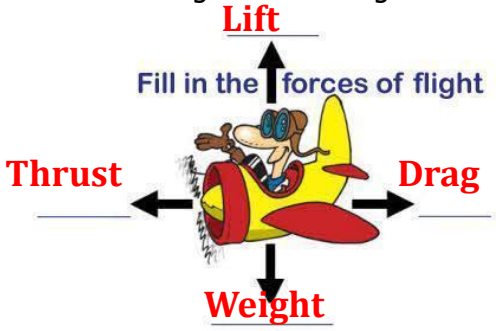
10. The Four Cycles of a reciprocating engine are

    - _____
    - _____
    - _____
    - _____

Section 1.07: Worksheet 3 – *The Four Forces of Flight*

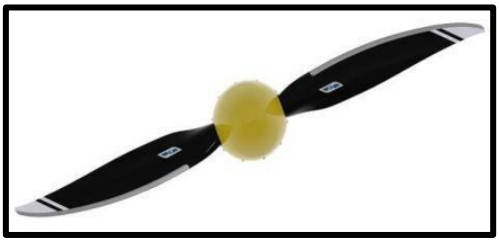
Name: _____ Class:_____ Date:_____

1. Label the four forces of flight in the image below



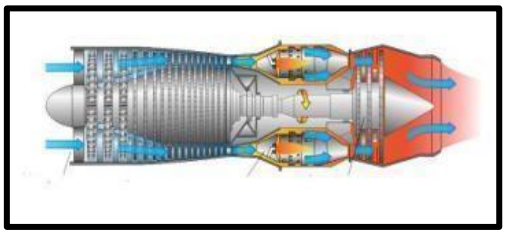
2. What force helps us get off the ground? Lift

3. What Part of the plane is this? Propeller



4. What does it create and how? Thrust by displacing the air (moving the air in front of it backwards) it pushes the plane forward, creating thrust.

5. What force pulls the plane toward earth? Gravity



6. What kind of airplane engine is this? Turbine

7. What kind of airplane is this found in? Jet

8. What kind of airplane engine is this? Piston

9. What kind of airplane is this found in? Propeller

10. The Four Cycles of a reciprocating engine are
    - Intake
    - Compression
    - Power
    - Exhaust

Lesson 3: Newton's Laws

Grade	*"Estimated"* Time on Lesson	*"Estimated"* Time on Simulator	Total Time to Complete
6-12	2 hour(s), 0 minute(s)	1 hour(s), 15 minute(s)	3 hour(s), 15 minute(s)

Learning Targets & Sub-Targets

- Have a clear understanding of who Isaac Newton is and what Newton's Laws are.
- Have a clear understanding of who Daniel Bernoulli is.
  - Have a general understanding of Bernoulli's Principle and Fluid Dynamics.
- Know who Galileo Galilei is and his contributions to science.
- Have a general understanding of gravity, acceleration and how they are related.

Cross-Cutting Concepts		Science and Engineering Practices	
X	Patterns	X	Asking questions & defining problems
X	Cause & effect	X	Developing & using Models
	Scale, proportion & quantity	X	Planning & conducting investigations
X	Systems & system models	X	Analyzing & interpreting data
X	Energy & Matter in Systems	X	Using mathematics & computational Thinking
X	Structure & function	X	Constructing explanations & designing solutions
	Stability & Change of Systems		Engaging in argument from evidence
		X	Obtaining, evaluating & communicating information
Nature of Science			
X	Science is a way of knowing	X	Scientific Investigations Use a Variety of Methods
X	Scientific Knowledge Assumes an Order and Consistency in Natural Systems	X	Scientific Knowledge is Based on Empirical Evidence
X	Science is a Human Endeavor	X	in Light of New Evidence, Scientific Knowledge is Open to Revision
X	Scientific Addresses Questions About the Natural and Material World	X	Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

Teachers Preparation

- Review the "Activities & Discussions" section below.
- Review the "Vocabulary" section below.
- Watch/Review the videos listed for this lesson in "Videos & their Locations" *(all videos can be found on the desktop or on YouTube)*
- Watch/Review the Documents listed for this lesson in "Power Points, Referenced Material & their Locations" *(all materials can be found on the desktop and in the SAFEDrone curriculum book)*
  - Print out any pages/ slides you feel should be handed out to students
- Review and print out the Handouts/Worksheets listed for this lesson in "Handouts & Worksheets"

- Collect the items listed under "Classroom Materials" as well as any additional materials you feel may be needed for the lessons

Classroom Materials Needed

- Drone Simulator *(powered on)*
- Egg drop experiment supplies *(straws, tape and other supplies per your discretion)*

Videos & their Locations

Video Name	Location on PC	Web URL
Galileo's Inertia Track	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=ijhwMIgo8GI
Newton's 1st Law of Motion *(Science 360)*	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=08BFCZJDn9w
Newton's 2nd Law of Motion *(Science 360)*	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=qu_P4IbmV_I
Newton's 3rd Law of Motion *(Science 360)*	Desktop > Videos > Lesson Plan Referenced Videos	https://www.youtube.com/watch?v=e1IzB36aHD4

Power Points, Referenced Material & their Locations

P.P. Title	Location on PC
Pilots Handbook of Aeronautical Knowledge Chap. 4: Principals of Flight	Desktop > Lesson Plans > Referenced Doc.
Pilots Handbook of Aeronautical Knowledge Chap. 5: Aerodynamics of Flight	Desktop > Lesson Plans > Referenced Doc.

Handouts & Worksheets

(Print from the PDF in the "Curriculum" folder, located in the "Curriculum, Guides and More" folder on the Flash drive)
SD: SAFEDrone Training Unit

Handout	Worksheet	Title	Book	Page

Vocabulary

Word	Definition
Acceleration	The rate of change of an object's velocity *Distance/Time²*
Bernoulli's Principal	The faster molecules within a fluid move, the less Pressure they exert on objects around them

Daniel Bernoulli	A Swiss Mathematician famous for his work in Fluid Dynamics, which created the basis for the explanation of lift. His work helped to lay the foundation for aeronautics many years later.
Drag	The name given to any opposing forces acting upon an object in motion
Fluid Dynamics	The study of how fluids move
Force	A measurement of strength or energy created by a physical action/movement
Galileo Galilei	An Italian Polymath who played a major role in the Scientific Revolution. His field of studies include, but are not limited to, philosophy, physics, astronomy, and mathematics. Galileo developed the concept of inertia which reasoned that moving objects eventually stop because of a force called Friction
Gravity	The natural force that pulls an object towards the center of the earth *G=9.80665 m/s² (or approx. 32.174 ft/s²)*
Isaac Newton	An English mathematician, astronomer, theologian, author, and physicist. He was widely recognized as one of the most influential scientists of all time, and a key figure in the Scientific Revolution.
Lift	When the force upon the surface of an object created by the airflow over it becomes weaker above (pushing down) than below (pushing up) enough that the object begins to lift off the ground.
Mass	The measurement of matter in an object *A combination of the total quantity, density, and type of atoms in an object*
Matter	A physical substance that occupies space and possesses rest mass
Molecules	A group of atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction
Newton's 1st Law of Motion	States that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. *This is normally taken as the definition of inertia.*
Newton's 2nd Law of Motion	The velocity of an object changes when it is subjected to an external force. *F(force)=m(mass)*a(acceleration)*
Newton's 3rd Law of Motion	States that for every action (force), there is an equal and opposite reaction. *If object A exerts force on object B, then object B also exerts force on object A*
Polymath	A person with a wide range of knowledge and learning
Pressure	A continuous physical force being exerted on or against an object/surface
Rest Mass	The measurement of a partials mass while being observed with no speed
Thrust	To push (something/someone) suddenly or violently in the specified direction. *(The propulsive force of a jet or rocket engine.)*

Weight	An object's relative mass or the quantity of matter contained by it, which increases the downward force acting upon it. *The force of gravity acting upon an object*

Activities & Discussions

- Read Chapter 4, Principles of Flight, in the Pilot's Handbook of Aeronautical Knowledge *(Referenced Documents)*.
- Discuss Newton's Laws of motion
  - Have students discuss how these laws of motion pertain to flight
    - What environmental and situational changes vary between Fixed wing flight, taxiing and Drone operation.
    - What variables must a pilot consider before flight because of Newton's laws *(weight & distribution/balance, thrust, speed, lift, drag, gravity etc.)*
  - Watch the "Science 360" videos on Newton's Laws of motion; "Newton's First Law of Motion", "Newton's Second Law of Motion" and "Newton's Third Law of Motion"
- Discuss who Daniel Bernoulli is and his contributions to science
  - What does everyone already know
  - What did he study, what were some of his discoveries, concepts, and innovations?
  - What is the Bernoulli Principle? P+½ pV2= constant
    - Test it: Hold a piece of paper in front of your face, let it drape over/form a radius. Now blow on it. What happens? *(Paper is lifted)*
- Review Friction
  - Why doesn't a ball roll on the floor, roll forever?
- Discuss who Galileo Galilei is and his contributions to science
  - What does everyone already know
  - What did he study, what were some of his discoveries, concepts, and innovations?
  - Watch the video, "Galileo's Inertia Track"
- Discuss the acceleration rate of gravity
  - If an object was dropped in a vacuum with only the force of gravity, theoretically that object would continue accelerating indefinitely. Why?
    - Calculate how fast different objects would be going after falling for a specific distance.
  - If you were not in a vacuum and dropped an object you would encounter drag on your way down. If we take only the air resistance into account. Theoretically the object will stop accelerating once the force of the air becomes equal to the force of the gravity.
    - Calculate how far different objects would have to fall until they no longer accelerate.
  - *(Activity)* Drop an egg off the top of the school. What happened to it? How fast was it going when it hit the ground?
    - Form teams and create an enclosure to protect your egg. Toss them off the building. How did you do?
    - *(Advanced) S*ame task but only allowed to use 50 straws and 1 yard of (scotch or painters) tape. How many eggs survived? Who succeeded with the least tape, least straws, least overall materials?
- Read Chapter 5, Aerodynamics of Flight, in the Pilot's Handbook of Aeronautical Knowledge *(Referenced Documents)*.
- *(Forward flight)*
  - Discuss as a class:
    - How does your angle affect the rate of descent and ascent (Vertical Speed)? Why?
    - How does your angle affect your air speed? Why?

NGSS Alignment

Science Lesson	Activity Description	Mid. School	High School
How to fly straight and level and turn	Activity: Review the "Tutorial Flight Structure" section for "Forward Flight". Complete the "Forward Flight" lessons in the drone simulation software *(Remember to have each student log into their own user before starting a new simulation lesson) -(4 lessons)* Discussion: What differences do you find in a flight where you are now using the Yaw and Roll motions together? Do you find it easier or harder? What are some difficulties faced when doing this lesson?	MS-PS2-1 MS-PS2-2 MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	HS-PS2-1 HS-PS2-2 HS-ETS1-2
Motion	Opening: How can we measure the motion of an object? Learning Target: I can complete the profile on the Drone simulator and measure the Drone's motion. Main activity: Students review what they have learned about motion in prior years or lessons, then apply this to flight; students explain what they expect to see when the Quadcopter takes off, increases altitude, cruises, descends, and lands; students think of what they could measure; students fly the Simulator in "Free Flight" and take notes on the changes in the instrument reading and how the Quadcopter moves horizontally and vertically; Discuss whether you can or can't measure distance in the simulator; students understand that distance is traveled as a Quadcopter changes its position; students discuss what they learned.	MS-PS2-2 MS-PS3-5 MS-ETS1-1 MS-ETS1-2 MS-ETS1-3 MS-ETS1-4	HS-PS2-1 HS-PS2-2 HS-ETS1-2