PLTW GTT FS Science Frameworks

PLTW Course: GTT Flight and Space

Science Strand being addressed: The Nature of Science and Engineering

Science Sub-strand being addressed: The Practice of Engineering

Overview:

Science Standard and Benchmarks: 9.1.2.2.2

Science Standard 9.1.2.2: Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem.

Benchmark 9.1.2.2.2: Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.

Correlation to AAAS Atlas:
MN 9.1.2.2 = AAAS 3B/H6

Essential Understandings/Big Ideas:

Aeronautics is the science and art of flying through the air. It refers to all aspects of flight in the atmosphere, from design and manufacturing to operation and maintenance of aircraft and spacecraft. To design an air or spacecraft, engineers must understand the elements of aerodynamics, propulsion, materials and structures, and stability and control. In this unit your students will be exposed to all of these elements as they discover the science of flying, design and test propulsion systems, use simulations to create airfoils to test in a wind tunnel, and then use their knowledge to design, build, and test an airfoil.

What should students know and be able to do [at a mastery level] related to these benchmarks?

- Distinguish between the forces of lift, drag, weight, and thrust that affect an object moving through a fluid. Understand the importance of each force.
- Examine how center of gravity affects an aerospace vehicle in distributing weight.

- Discover how Newton’s laws apply to flight and space.
- Discover Bernoulli’s Principle through exploration
- Recognize the tools and purpose of aeronautic design and testing.
- Identify the characteristics of an airfoil and how they compare and contrast with the characteristics of wings.
- Analyze the features and benefits of different types of wings.
- Describe the major parts (fuselage, empennage, high lift devices, wings, undercarriage, propulsion, instruments, and controls) of aircraft and how they can affect the overall balance of an airplane during flight.
- Research and design an airfoil that will create lift using a wing tester.

Misconceptions:

Student Misconceptions

- Why aircraft are categorized into heavier-than-air and lighter-than-air vehicles.
- Design requirements that enable an airplane to fly.
- Difference in propulsion systems of aircraft and spacecraft.
- The forces of lift, drag, gravity, and thrust in relationship to the flight of an airplane.
- Newton’s laws.

Teacher Resources:

Four Forces of Flight

Discovery of Forces:
Discuss how we make science discoveries -- observation, applying prior knowledge, and making inferences based upon observations.
Show video *The Magic of Flight* or the video clip of an airplane in the air found at http://www.archive.org/details/NasaSciFiles-TheFourForcesOfFlight
Several videos are available for members of United Streaming.

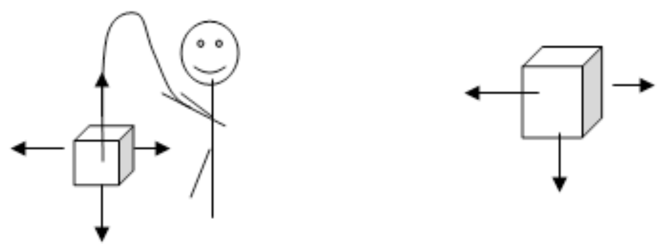
http://streaming.discoveryeducation.com/

Discuss how the plane stays in the air.

Notes for Four Forces of Flight: Use the Four Forces of Flight PowerPoint

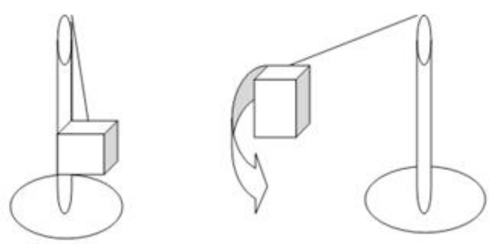
Teacher Demonstrations

1. Suspend a block from a string over a pulley. Ask students the following questions:
   - What do the plane and the block suspended in the air have in common?
   - What are the forces acting upon the block suspended in the air?
   - Why does the block stay in the air?
   - Students will draw a diagram and label the forces.
   - What forces would be acting upon the block if it were sitting on the table? Students will diagram and explain.
   - What are the forces acting upon the plane?
   - When the string is pulled, the block moves up and down. Why?
   - How do the forces change, or do they remain the same?



Newton's Laws

1. Two blocks are suspended from a string on two separate stands. The teacher turns one block around so that it rotates while the other is stationary. Students explain in their own words what is happening. The students are explaining Newton's first law.



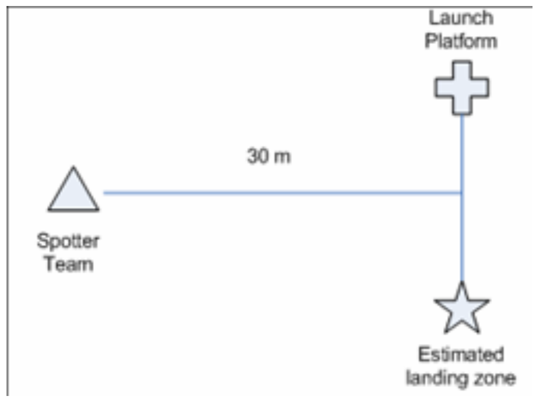
- Add a propeller to one side of the block. If the propeller provides thrust, will the block move?
- Think of the block as an aerospace vehicle. What forces are acting on it?

Use this website to review Newton's laws as each demonstration is completed:
http://teachertech.rice.edu/Participants/louviere/Newton/

Options for Measuring Height of Water Bottle Rocket Launches
Two methods could be used for measuring the altitude of the water bottle rockets.

The first is to tie fishing line to the neck of the water bottle, and as the rocket is launched, the fishing line will pay out. After landing, the length of the fishing line that was played out can be measured. A disadvantage of this method can be if the bottle shows significant drift during its flight.

The second method is to use an Estes Rocket Altimeter, or construct something similar. The spotters should set up 30 meters away from the launch platform in a direction perpendicular to the wind direction. The rocket should fly neither toward nor away from the spotters when launched. It should fly to the side of the team. The altitude tracker relies on knowing the distance from the spotter to a point directly under the rocket as it reaches its peak altitude. If the rocket flies toward or away from the spotters, you will not be able to observe this critical distance and the estimate of peak altitude will not be very accurate. The diagram shows the location of the spotter team.



This disadvantage of this method would be the altitude measuring equipment. It is often very difficult to get an accurate reading.

Perhaps the best solution would be to use both methods as a check to each other.

Other suggestions:

- Use colored bottles – easier to see in the air
- Mark a "measure" line on the bottle for multiple fills at the launch site
- Visit www.tinyurl.com/re6f4r for more information on Newton's Laws and water bottle rocket flight.

Analysis of the Stages of Flight and Newton's Laws of Motion: (Text in red is what the students should put in their summary chart.)

	Newton's 1st Law of Motion (Law of Inertia)	Newton's 2nd Law of Motion (F = m x a)	Newton's 3rd Law of Motion (Action and Reaction)	Energy (Potential, Kinetic, and Mechanical)
1st Stage of Flight (Water bottle sitting on launch pad.)	No external force acting on the rocket, so the rocket is staying at rest.	No force, so no acceleration.	Bottle is pushing down on the launch pad, and the launch pad is pushing back. Forces are balanced, so no movement.	Potential Energy
2nd Stage of Flight (Charging the	No external force acting on the	No force, so no acceleration.	Bottle is pushing down on the	Your PE is converted to ME

water bottle with compressed air)	rocket, so the rocket is staying at rest.		launch pad, and the launch pad is pushing back. Forces are balanced, so no movement.	when pumping air into the system. That ME is converted back to PE as the air is compressed in the bottle.
3rd Stage of Flight (Pin is pulled and water bottle is launched.)	Force of the compressed air pushes out the water, causing the bottle to move.	Acceleration occurs because of the force of the compressed air pushing the water out of the bottle	Water is pushed out the bottom of the bottle (action: down) and bottle moves opposite of the water (reaction: up.)	PE (compressed air) is converted to KE (pushing water out.

Bernoulli's Principle and Air Pressure Demonstrations:

Option 1:
http://www.tandl.vt.edu/scied/lessons/DV/bernoulli_principle.htm
Option 2:
http://www.csulb.edu/~lhenriqu/AFSEdemos.doc
Option 3:
Illustrate the Bernoulli principle using a hair dryer and a roll of toilet paper on a pencil. Aim the air over the top of the roll while the pencil is held at each end. This is a dramatic way for students to see the Bernoulli Principle at work.

May want to view YouTube video "Understanding Density Altitude – Aviation Video #28" for more information on Density Altitude.

The airfoil simulation can be found at:
http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html

Also, visit http://planemath.com for more information and on-line student activities.

Aeronautics

In this activity students will answer questions while the teacher gives the Tools of Aeronautics presentation

- Tools of Aeronautics

This presentation, as well as those others following, will give students background information for the activities associated with each. Notes are included in each of the presentations to assist the instructor.

Wind Tunnel

The wind tunnel simulation can be found at:
http://wright.nasa.gov/airplane/tunnlint.html (manually record data and plot results), or, http://wright.nasa.gov/airplane/tunnl2int.html (records data and produces plots within the program).

The applet can be downloaded to each machine or can be run through the Internet depending on your computer access.

Be sure to explain the differences in model shapes:
Shape and area – long and thing (rectangle) versus short and fat (square)
Camber (Cam) – the smaller the denominator, the bigger the camber (curvature)
Aspect Ratio – a mathematical relationship that compares the length of an airfoil to the length of its cord (the bigger the number, the longer and thinner the airfoil.)

Airfoils

The airfoil simulation can be found at:
http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html

The applet can be downloaded to each machine or can be run through the Internet depending on your computer access.
The airfoil project may be completed in partners or completed individually. This is to be determined by the instructor. Factors in the decision should include cost of the project and ability level of the students. It might be better if younger students work with a partner.

Determining the Thickness of the Airfoil

Depending on the substrate you purchase to build airfoils, you will need to determine the maximum thickness for your students' airfoil. In the following pages, the maximum thickness was specified as 1". However, that amount may need to be changed based on the apparatus you use for testing the airfoils. In FoilSim, notice that the "Thickness" slider is not labeled in feet, similar to our previous adjustments. This slider is measured in a percentage of the chord. Use the following equation to determine your thickness percentage.

$$T = (P / 100) \times \text{chord}$$

T is the maximum thickness of the wing.
P is the unknown thickness percent.
Chord is the length of your chord in inches.
Example: The project specifies to use a chord of 4 inches, so that equation for the ¼" minimum thickness would be:

$$\tfrac{1}{4} = (P / 100) \times 4$$

Divide both sides by 4

$$\tfrac{1}{4} \div 4 = (P / 100) \times 2 \div 4$$

$$0.0625 = P / 100$$

Multiply both sides by 100

$$P = 0.0625 \times 100$$

$$P = 6.25\%$$

The minimum thickness in percentage of the cord equals 6.25%.
Repeat the procedure to determine the maximum % thickness.

Students will learn how to use the Precise Input tool in the Autodesk Inventor® software by creating "Jack" (a jack-o-lantern). Students will transfer that knowledge to create the pattern of their airfoil using FoilSim data.

If you have access to a laser cutter, consider having the students cut the fuselage using the laser cutter. Also, Pitsco sells a hot wire foam cutter especially designed for cutting airfoils.

Limits on airfoil size should be determined by the sized required by apparatus used to test it. Airfoils may be tested in a wind tunnel, if available, or by any other wing testing apparatus that may be commercially purchased or built. An affordable, easy to use, relatively accurate wing tester may be purchased from Pitsco. Purchase of wing testing equipment is purposely left open ended for budget considerations.

Propulsion Systems

Teacher Demonstration

Suggest starting the activity with the following demonstration, showing the effect of surface area on the reaction rate of potential "rocket fuels".

- Fill a jar or beaker half full with water
- Have the students predict how long it will take for an effervescent table to dissolve in water. Drop a non-broken table in the jar. Use the stopwatch to time how long the tablet takes to dissolve.
- Empty the beaker, and refill with water.
- Wrap another tablet in paper and place it on a tabletop. Break the tablet into a few pieces.
- Predict how long it will take for the crushed tablet to dissolve. Drop the pieces into the beaker. Use the stopwatch to time how long the tablet takes to dissolve. Record your answer in your data table.
- Repeat the experiment one more time, totally crushing the tablet.
- Form a conclusion about surface area versus reaction rate.

If film canisters are hard to find, the activity can be completed without the paper rocket "dressing", allowing the canisters to be re-used if thoroughly rinsed out.

The film canister MUST be one with a cap that fits INSIDE the rim instead of over the outside of the rim. Sometimes photography shops have extras that they will happily give you.

Reinforce that the rocket is a constant in their testing; all rockets should be made exactly the same. Keep in mind, as with real rockets, the less your rocket weighs and the less air resistance (drag) it has, the higher it will travel.

Propulsion Systems – Fuel Use Analysis

- You are an acrobatic pilot getting ready to go to an air show. The air show is being held at an airport 500 nautical miles (NM) away. Given the cruising speed of the *Extra 300* you are flying, how long will it take to fly to the air show?
  2.8 hours
- In the situation above, will you be able to fly to the air show without refueling along the way? **NO**
  Why or why not? **The range of the Extra 300 is only 462 NM.**
- A *Cessna Skylane* has a range of 820 NM and a cruising speed of 140 KTS. How many hours will it take you to fly 820 NM? **5.85 hours**
- Since the *Skylane* has a fuel capacity of 88 US GAL (including 10% in reserve), how many gallons of fuel per hour does it use? **13.67 gal/hour**

- You are flying a *Cessna Skylane* at a speed of 120 KTS. You are flying on a trip that will take you 520 NM. How long will it take you to get to your destination? **4.33 hours**
- In the situation above, given that your *Cessna* holds 88 US GAL of fuel (with 10% held back as reserve fuel), how much fuel will you use? (Hint: you will need your final answer from Question 4 above to find this number.) **59.19 gal**
- You are a WW-I *Sopwith Camel* fighter pilot chasing the infamous Red Baron. You are traveling at a speed of 115 KTS. You know that your enemy is 40 NM away from you. How many minutes will it take to reach him? **21 minutes**

If students have extra time, they can download the Range Games java applet from:

http://www.grc.nasa.gov/WWW/K-12/airplane/ngnsimr.html

-or- EngineSim from:

http://www.grc.nasa.gov/WWW/K-12/airplane/ngnsim.html

These simulations will allow students to solve problems involved with determining an aircraft's motion and performance.

Optional Activity

To reinforce this lesson, the teacher may want to consider the purchase of glider kits or some other type of kit such as Right Flyer kits for students to build, fly, and troubleshoot.

Flight Simulators

http://www.airplane-collectible-best-net-resource.com/free-flight-simulator.html.
http://www.microsoft.com/games/flightsimulatorx/
http://www.flightsim.com/
http://flyawaysimulation.com/downloads.html

What is it that students struggle with the most and how can the teacher most effectively help students learn the concepts?

- Knowledge that aircraft designs can come from many options. Picking and choosing methods for each project works well.

Additional Instructional Resources

- Newton’s Laws PowerPoint; Google Docs GTT Resources / Flight and Space
- Airfoils, Lift and Bernoulli’s Principle PowerPoint; Google Docs GTT Resources / Flight and Space
- Parts of an Aircraft PowerPoint; Google Docs GTT Resources / Flight and Space
- Tools of Aeronautics PowerPoint; Google Docs GTT Resources / Flight and Space
- Propulsion Systems PowerPoint; Google Docs GTT Resources / Flight and Space
- Four Forces of Flight PowerPoint; Google Docs GTT Resources / Flight and Space

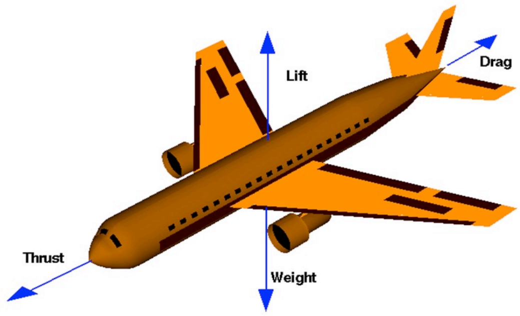
New Vocabulary

Acceleration	The rate of change of velocity with respect to time.
Aileron	The controlling surface that regulates an aircraft’s roll.
Airfoil	A part or surface, such as a wing, propeller blade, or rudder, whose shape and orientation control stability, direction, lift, thrust, or propulsion.
Angle of Attack	The acute angle between the direction of the relative wind and the chord of an airfoil.
Aspect Ratio	The ratio between the wingspan and average chord of a wing.
Bernoulli’s Principle	As the speed of a fluid increases, its pressure decreases.
Camber	A measure of the curvature of the airfoil.
Chord	The width of an airfoil or wing.
Dihedral Angle	The angle between an aircraft wing and a horizontal line.
Drag	Resistance of the air (technically a fluid) against the forward movement of an airplane.
Elevator	The controlling surface that regulates an aircraft’s pitch.
Empennage	The tail assembly of an aircraft, including the horizontal and vertical stabilizers, elevators, and rudder.
Flaps	Control surfaces attached to the trailing edge of the wing extending outward from the fuselage to the midpoint of each wing. Flaps can increase the lifting efficiency of the wing and decrease stall speed.
Fluid	A gas or liquid that tends to take the shape of its container.
Force	Transferring of energy to an object, typically by pushing or pulling on that object.
Fuselage	The central body of an aircraft where wings and stabilizers are attached.
Glider	An airplane with no attached source of thrust.
Gravity	The force that attracts a body toward the center of the earth or toward any other physical body having mass.
Heavier-Than-Air	An aircraft of greater weight than the air displaced.
Horizontal Stabilizer	An airfoil (usually at the back of an airplane) that resists up and down changes in motion.
Hypersonic	Relates to speed five or more times that of sound in air.
Leading Edge	The front, usually rounded, edge of an airplane wing or airfoil.

Lift	The force that directly opposes the weight of an airplane and holds the airplane in the air.
Lighter-Than-Air	An aircraft of less weight than the air displaced.
Mach 1	760 MPH. When a plane travels faster than this speed, it is breaking the sound barrier.
Mass	The quantity of matter, which a material contains.
Newton's 1st Law	Objects at rest stay at rest and objects in motion stay in motion unless an external force is applied. It is known as the law of inertia.
Newton's 2nd Law	The relationship among an object's mass (m), acceleration (a), and an applied force (F), is Force equals mass times acceleration (F= ma).
Newton's 3rd Law	For every action there is an equal and opposition reaction.
Pitch	The up or down movement of an aircraft.
Precise Input	A method of placing geometric entities at precise x and y coordinates on a plane.
Propellant	A chemical mixture that is burned to produce thrust.
Propeller	An airfoil mounted on a revolving shaft. It creates low pressure in front of it, thereby moving an aircraft forward because of the high-pressure area behind the propeller.
Propulsion	The means by which aircraft and spacecraft are moved forward. It is a combination of factors such as thrust (forward push), lift (upward push), drag (backward pull) and weight (downward pull).
Ramjet	An engine that can operate only when moving at high speed since it has no moving parts and no device for drawing in air.
Rocket Engine	An engine that produces thrust by expelling hot gases from a rear nozzle.
Roll	The clockwise or counterclockwise rotating motion of an aircraft.
Rudder	A controlling surface on an aircraft's tail that regulates yaw.
Slats	Protrusions from the leading edge of a wing that, when combined with the flaps, result in a significant increase in lift.
Spoiler	Device used to destroy lift. Found on top of the wing and in varying sizes.
Thrust	A force applied to a body to propel it in a desired direction. The force that moves an aircraft through the air.
Trailing Edge	The rear edge of a wing.
Turbine	A rotary engine that extracts energy from fluid turning blades.
Vertical Stabilizer	A vertically oriented airfoil at the back of an airplane that resists left and right movements.
Velocity	A vector quantity that includes the speed and direction of an object.
Weight	The force generated by the gravitational attraction of the earth on the airplane. Lift must be equal to weight in order to sustain flight.
Wing	The major horizontal surface on an airplane that provides lift.
Yaw	A side-to-side motion of the nose of the aircraft.

Vignette:

After several lessons using resources listed in this document, the teacher sets out a model of an airplane (similar to the example below) to be used during the following discussion.



Teacher: A force may be thought of as a push or pull in a specific direction. A force is a vector quantity, so it has both a magnitude (size) and a direction. So when we describe these forces, we have to specify both the magnitude and the direction. Our demonstration today discusses forces that act on an airplane in flight, which includes Lift, Weight, Drag, and Thrust. We're going to look at each of these individually as they apply to the flight of a plane. What is weight?

Student: Weight is a force that is always directed toward the center of the earth.

Teacher: Yes. The magnitude of the weight depends on the mass of all the airplane parts, plus the amount of fuel, plus any payload on board (people, baggage, freight, etc.). The weight is distributed throughout the airplane. But we can often think of it as collected and acting through a single point called the **center of gravity**. Flying encompasses two major problems; overcoming the weight of an object by some opposing force, and controlling the object in flight. Both of these problems are related to the object's weight and the location of the center of gravity. During a flight, an airplane's weight constantly changes as the aircraft consumes fuel. The distribution of the weight and the center of gravity also changes. So the pilot must constantly adjust the controls to keep the airplane balanced.

Teacher: What is lift?

Student: It's the upward force that works against the downward pull of gravity

Teacher: Yes. To overcome the weight force, airplanes generate an opposing force called lift. Lift is generated by the motion of the airplane through the air and is an aerodynamic force. "**Aero**" stands for the air, and "**dynamic**" denotes motion. Lift is directed **perpendicular** to the flight direction. The magnitude (size) of the lift depends on several factors including the shape, size, and velocity of the aircraft. As with weight, each part of the aircraft contributes to the aircraft lift force. Most of the lift is generated by the wings.

Teacher: What is drag?

Student: Resistance of the air against the forward movement of an airplane.

Teacher: Correct. Drag is a mechanical generated by a solid force moving through the air (technically a fluid). As the airplane moves through the air, there is another aerodynamic force present. The air resists the motion of the aircraft and the resistance force is called drag. Drag is directed **along and opposed** to the flight direction. Like lift, there are many factors that affect the magnitude of the drag force including the shape of the aircraft, the "stickiness“ of the air, and the velocity of the aircraft. Like lift, we collect all of the individual components' drags and combine them into a single aircraft drag magnitude.

Teacher: What is thrust?

Student: The push that moves an airplane forward.

Teacher: Yes. Thrust is a mechanical force generated by the engines to move the aircraft through the air. The direction of the thrust force depends on how the engines are attached to the aircraft (teacher points to engines on the model). On some aircraft, such as the Harrier, the thrust direction can be varied to help the airplane take off in a very short distance. The magnitude of the thrust depends on many factors associated with the propulsion system including the type of engine, the number of engines, and the throttle setting.

Assessment:

Assessment Methods

Interpretation

- Students will understand why different aerospace vehicles are designed to perform different tasks.

Application

- Students will develop an infomercial that explains their understanding of the impact a flight vehicle has had on the evolution of the aerospace industry.

Perspective

- Students will engineer a model of a futuristic aerospace vehicle.

Differentiation:

Gifted and Talented

- Students can increase the complexity of analysis and their project designs.

Special Education

- Students on an IEP and those who struggle could have extra handouts and related materials (computer simulations, videos and Internet links) made available to them.

English Language Learners

- Much of the vocabulary used in this area can be difficult for the ELL student. Using pictures that are shown in build sheets could help. Completed examples of the design process would be of assistance to the ELL students.
- This information would have to be reinforced through the help of the ELL teacher

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are:	**Teachers Are:**
Building airfoils	Questioning students
Documenting problems	Monitoring progress
Adjusting and making changes	Reinforcing success
Testing and Evaluating	Redirecting problems

Professional Learning Communities:

Reflection – Critical Questions regarding the teaching and learning of these benchmarks:

- In what areas did students perform best and what weaknesses are evident?
- How can this content be connected to other benchmarks in learning?
- Do students see the connection between flight and their models?
- Are students interpreting information correctly?
- What areas did students perform best and what weaknesses?

Materials – suggested articles and books for book study with PLC:

Four Forces of Flight

Parent Resources:

- http://www.cartoonstudio.co.uk/Pages/EngineeringAndTechnologyMap.html
- http://wright.nasa.gov/airplane/tunnlint.html
- http://www.grc.nasa.gov/WWW/K-12/airplane/foil2.html

References:

- Project Lead the Way, Gateway To Technology, Flight and Space course curriculum
- Minnesota Academic Standards - Science K - 12 2009 version
- AAAS Benchmarks
- **http://www.project2061.org/publications/bsl/online/index.php?home=true**
- NASA
- **https://www.nasa.gov/**