SCHOLASTIC BENCHMARKS

Covered by the Secret of Flight Presentations

OUTLINES

The Secret of Flight: Control

A. *How has the invention of the airplane affected our world?* In just a century, the airplane and the aerospace industry have grown to become the largest business in the world, affecting every other industry in some way.

B. *What is an invention?* An invention solves a problem in a new and creative way.

C. *Who invented the airplane?* In Sir George Cayley proposed the idea of a fixed wing flying machine consisting of three systems – lift, propulsion, and control.

D. *Cayley also built and flew the first airplanes.* His coachman made the first recorded manned flight in 1854, but he had no control.

E. *How do you control an aircraft?* First you have to balance the aircraft in the air. Then you must be able to change direction or navigate. Balance and navigation require the motions of roll, pitch, and a secret mystery force.

F. *Lilienthal became the first pilot to successfully control an aircraft.* He shifted his weight to keep his balance in the air. This primitive system eventually got him killed.

G. *The Wright brothers decide to invent an aircraft control system.* The death of Lilienthal motivated the Wrights to begin work on an improved aircraft control system. Instead of weight-shifting, they decided to use aerodynamic control – moving surfaces that adjust the forces on an aircraft in flight.

H. *The Wrights discover the aileron principle.* It's a piece of cake to design an aerodynamic system to pitch an airplane; the Wrights simply use an elevator. Roll is more of a problem until they discover how to twist the wings of a biplane.

I. *The Wrights conduct their first aerodynamic experiment.* The build a kite or model glider to test their hypothesis about roll.

J. *The Wrights look for a laboratory in which to make manned flights safely.* They choose Kitty Hawk for its wind and sand.

K. *The Wrights build and test their first two gliders.* They make a glider in 1900 that does not produce enough lift. They come back in 1901 with a bigger glider, but it still does not fly properly. They are so discouraged they think about quitting.

L. *The Wrights redesign their experiment.* They realize that by following their present program, they can test only one aircraft design per year. They decide to build a wind tunnel where they can test hundreds of designs in a few months.

M. *The Wrights test their third aircraft*. The 1902 glider flies wonderfully, but there is still something wrong with the controls. When the Wright turn, it sometimes flies off in the opposite direction.

N. *The Wrights discover 3-axis control.* Carefully thinking the problem through, the Wrights discover the need for a third axis of control, the secret mystery force – yaw. They attach a movable rudder to their 1902 glider and find they have true control.

O. *The Wrights achieve Cayley's dream.* The Wrights spend the next year designing an engine and propellers for their airplane. Their 1903 Flyer is the first aircraft ever to combine lift, control, and propulsion systems successfully. The Wrights make the first sustained and controlled powered flights.

P. *The discovery of 3–axis control has far-reaching effects.* The development of a practical airplane brings the world closer together, changing every aspect of our lives – they way we travel, the way we do business, even the way we wage war. But 3–axis control spawns several new technologies besides aviation – space travel, submarine exploration, and robotics.

The Secret of Flight: Lift and Drag

A. *Sir George Cayley proposes a wonderful new flying machine.* In 1799, Sir George Cayley proposed the concept of a fixed-wing flying machine with systems for lift, propulsion, and control.

B. *Lift is what makes an airplane fly.* Each one of these systems incorporates forces which act on an airplane in flight. Propulsion generates the force of thrust to overcome drag. Control uses movable surfaces to generate the aerodynamic forces of roll, pitch, and yaw. Lift works against gravity to keep an airplane and its passengers in the air.

C. *Wings generate lift through air pressure.* As air moves over a wing, two things happen. First the air presses against the bottom side of the wing. Second, a low pressure area develops above the wing. The resulting air pressure pushes the wing up, generating lift.

D. *It all started with windmills.* The first person to study how air pressure can generate a force to do work was John Smeaton, who was trying to build a better windmill. He discovered that air pressure increased when the wind blew faster or the sail was bigger.

E. *Smeaton expressed this law of nature in a formula.* The size of the sail (S) times the speed on the wind squared (v^2) produced a number that corresponded to the pressure on the sail. To convert this number into a meaningful measurement like pounds per square inch, Smeaton used a coefficient – a mathematical translator. This came to be called the coefficient of pressure (C_p) or "Smeaton's coefficient."

$$\textit{Air Pressure} = S\ v^2\ C_p$$

F. *Cayley discovered two forces – lift and drag.* Cayley thought that he could build on Smeaton's work to calculate lift, but he found that the air that flows over a wing actually generates two forces – lift and drag. Each was a fraction of the total air pressure. Cayley also discovered that these forces acted at right angles to one another. He drew a diagram of them as the base and side of a right triangle.

G. *Cayley introduces two new coefficients* – Cayley built a whirling arm machine that held wing shapes and spun them. He measured the lift then calculated the drag using a special form of mathematics built around right triangles called "trigonometry." He found that he could predict the amount of lift or drag a wing would generate with two more mathematical translators – the coefficient of lift (C_l) and the coefficient of drag (C_d). The formulas for lift and drag looked like this:

$$\textit{Lift} = S\ v^2\ C_p\ C_l$$

$$\textit{Drag} = S\ v^2\ C_p\ C_d$$

H. *Scientists do some more lab studies of wing shapes.* Over the next century, several scientists – Wentham, Brown, Phillips, and Lilienthal – build on Cayley's research.

They discover things like a curved wing produces more lift than a flat wing, and most of the lift is generated along the front edge of the wing. All of this work is done with wind tunnels or whirling arms in their laboratories.

I. *The Wright brothers build an airplane.* And they use the coefficients of lift and drag developed by Lilienthal (the most recent research available to them) to figure out how big they should make the wings of their airplane.

$$\textit{Surface area} = \text{Lift}/v^2\, C_p\, C_l$$

J. *The Wrights measure lift and drag in the field.* The Wrights were the first scientists ever to measure the lift and drag of an aircraft in flight. They realized that when they flew their gliders like a kite, the tether lines described the hypotenuse of Cayley's lift-drag triangle. They measured the combined forces on the tether line with a spring scale, and then measured the angle of the tether line with a clinometer. Using trigonometry, they figured the lift and drag.

K. *The Wrights find discrepancies between Lilienthal's lab work and their field research.* The Wrights made these field measurements with two gliders in 1900 and 1901 and found the lift predicted by Lilienthal was more than what they observed in the field. They decided to do their own laboratory research to confirm their field observations.

L. *How do you design an experiment?* State your question or hypothesis, devise an experimental method to answer the question or prove the hypothesis, collect observations, data, and/or measurements, and draw conclusions.

M. *The Wrights state their question.* The Wrights decide to do a two-stage comparative study of wing shapes to study two important variables. They know that the amount of lift and drag produced by a wing change not only with the shape of the wing but the angle at which it meets the wind – the angle of attack. First, they will compare over two hundred different wings shapes at a single angle of attack. Then, they will pick out the most promising of these shapes and study them at different angles of attack. Their question boils down to this: What wing shape will produce the most lift and least drag at the angles of attack at which we fly?

N. *The Wrights design their experiment.* They build a wind tunnel and two instruments that will allow them to measure the lift and drag produced by miniature wing shapes at different angles of attack.

O. *The Wrights collect data and create graphic plots.* Over a span of several months, the Wrights collect thousands of measurements. To help compare these measurements, they make graphs – lift vs. angle of attack, drag vs. angle of attack, lift/drag ratio vs. angle of attack..

P. *The Wrights verify their data.* The Wrights compare their lab measurements for the wing shapes they used on their first two gliders to their field measurements. The lab findings match the field. This indicates that the measurements the Wrights made for other wing shapes is likely correct.

Q. *The Wrights draw conclusions*. The Wrights identify wing shape No. 12 as the shape that will produce the most lift and the least drag at the angles of attach at which they want to fly. They also conclude that Lilienthal's data was correct and the error lay in Smeaton's coefficient.

R. *We all know what happened next*. The Wright brothers used their findings to design their next glider and the 1902 Wright glider became the model for the Wright airplane patent. It is the granddaddy of everything that flies.

BENCHMARK MAPS

Key: In the following tables, the scholastic benchmarks are divided into subjects and grade levels. The subjects are social studies, science, technology, and mathematics. The grade levels are 3rd through 5th grades (3/4/5) and 6th through 8th grades (6/7/8). Following each benchmark is a code that tells which presentation addresses that benchmark. "CON" indicates the presentation on Control and "L&D" indicates Lift and Drag. The letters following the code tell where in the preceding outlines this benchmark is explained or reinforced.

Social Studies

Grade Level 3/4/5	Grade Level 6/7/8
Construct timelines to demonstrate the understanding of units of time and chronological order. ***CON C through O; L&D D through I***	Construct multi-level timelines to put events in chronological order and show relationships of events in different areas. ***CON C through O; L&D D through I***
Identify relationships between events. ***CON C through O; L&D D through I***	Interpret relationships between events –give examples of events and their consequences. ***CON A and C through O; L&D D through I***
Describe how archaeologists and historians study and interpret the past. ***CON B***	
Obtain information from primary and secondary sources. ***CON C through P; L&D M through R***	Obtain and interpret information from primary and secondary sources. ***CON C through P; L&D M through R***
	Distinguish between fact and opinion. ***CON G through M; L&D K through Q***
Use maps to locate places, regions, and physical features in North America. ***CON J, K, and M; L&D K and P***	Use keys, scales, contour lines, and icons on maps to locate and identify geographical and geological features in North America. ***CON J***
Identify manufacturing and agricultural regions in the United States. ***CON J***	Identify areas where specific natural resources can be found. ***CON J***
Describe the location of one state relative to others in the Untied States. ***CON J, K, and M; L&D K and P***	
Explain how new developments led to the growth of the United States. ***CON A and P; L&D R***	Explain the impact of transportation and industrialization on the growth of the United States. ***CON A and P; L&D R***
Explain the importance of inventors such as the Wright brothers. ***CON A and P; L&D J and R***	Explain the impact of individuals – leaders, soldiers, scientists – on events in history.
Demonstrate persistence in achieving goals. ***CON All; L&D All***	Describe personal characteristics that have enabled historically important individuals to achieve their goals.. ***CON All; L&D All***

Science

Grade Level 3/4/5	Grade Level 6/7/8
Explore through stories how men and women have contributed to the development of science. ***CON C through P; L&D A through I***	Research how men and women of all countries and cultures have contributed to the development of science. ***CON C through P; L&D A through I***
Describe how technology affects human life. ***CON A and P; L&D E and R***	Describe how technology can extend human abilities. ***CON A, B, and P; L&D E and R***
Develop, design, and safely conduct scientific investigations. ***CON H through N; L&D L through Q***	Develop, design, and safely conduct scientific investigations. ***CON H through N; L&D L through Q***
Use appropriate instruments to conduct a scientific investigation. ***CON L; L&D H and J***	Use appropriate instruments to conduct a scientific investigation. ***CON L; L&D H and J***
	Distinguish between observation and inference. ***CON K through M; L&D M through Q***
Describe one or two variables in a simple experiment. ***CON K through M; L&D M through Q***	Variables and controls can effect an investigation; one variable should be tested at a time. ***CON K through M; L&D M through Q***
Organize the observations, measurements, and data to reach a conclusion. ***CON L through N; L&D P and Q***	Analyze and interpret data from scientific investigations using mathematical skills. ***CON L through N; L&D P and Q***
Explain why an experiment must be repeated and yield consistent results before its results are accepted. ***CON K; L&D K***	
Explain the importance of keeping conditions the same in an experiment. ***CON L; L&D L through O***	
Explain discrepancies in an investigation using evidence to support findings. ***CON K; L&D K***	
Explain the importance of keeping records of observations and investigations. ***CON B and K; L&D O***	
	Explain why hypotheses are valuable even when they are proven incorrect. ***CON K and N; L&D K***
	Explain that a single example can never prove something is always correct, but a single example may prove that something in incorrect. ***CON K and N; L&D K***
	Identify faulty reasoning that goes beyond or misinterprets the evidence. ***CON K through N; L&D J and K***

Describe and illustrate the design process. ***CON K through O***	
Use a simple design process to solve a problem. ***CON K through O ; L&D Q and R***	Design a solution to a problem taking into account needs and constraints. ***CON K through O ; L&D Q and R***
Revise an existing design to solve a problem using peer review. ***CON M and N***	
Explain how the solution to one problem may create others. ***CON L through N***	
Explain how ideas change as new knowledge is gained. ***CON K through N ; L&D J through R***	
Describe forces that directly effect objects and their motion. ***CON C through N ; L&D D and F***	Describe the motion of an object and the effect of forces on that object. ***CON C through N ; L&D D and F***
	Describe how an object can have potential energy due to its position and kinetic energy due to its motion. ***CON J ; L&D D and F***
Explain that air surrounds us, takes up space, moves around us as wind, and may be measured. ***CON J through M ; L&D C through R***	
Describe how water, wind, and ice shape the earth by eroding rocks in some regions and depositing the eroded particles elsewhere. ***CON J***	
	Explain that equal volumes of different substances usually have different masses. ***CON O***

Technology

Grade Level 3/4/5	Grade Level 6/7/8
Describe how things found in nature are different from things made by humans. ***CON C through H***	
Describe how tools, materials, and skills are used to perform tasks. ***CON G; L&D J and N***	
Describe ways creative thinking, economic, and culture influences technological development. ***CON A through C and P; L&D A throughG***	Discuss ways technology is linked to creativity and innovation. ***CON A through C and P; L&D A throughG***
Explain how technology has changed economic and social development. ***CON A and P; L&D R***	Relate ways that inventions and innovation have led to changes in society and new needs and wants. ***CON A, B and P; L&D R***

	Explain how politics, culture and economics are influenced by development of technology. ***CON A***
Explain the role of inventors in social and economic development. ***CON A through C and P; L&D R***	Analyze an invention and explain its historical importance. ***CON A through C and P; L&D R***
Identify inventors who contributed to the development of technological systems. ***CON C, D, F and G; L&D A, D, H, and I***	Identify inventors and designers around the world who contributed to the development of technology. ***CON C, D, F and G; L&D A, D, H, and I***
	Cite examples of controls and how they change or direct a technical system. ***CON E through G***
List companies and businesses related to technologies. ***CON A and P***	Demonstrate how technological systems may be connected to one another. ***CON A, G, and P; L&D D***
List examples of processes associated with a technology. ***CON A***	Identify technological systems that interrelate. ***CON A, G, and P; L&D D***
Analyze common uses of technology in daily life. ***CON A and P; L&D D***	
	Identify products that have been applied to alternative settings. ***CON G and H; L&D N***
	Explain how knowledge from one field may impact the development of another. ***CON G and P; L&D D***
People use technology to create new products and the own the design to this products. They have intellectual; property rights and patents protect these rights. ***CON P; L&D R***	
Describe the purpose of the design process. ***CON B***	Describe how design is a creative planning process leading to new products and systems. ***CON A, B, and P***
	Explain that form follows function. ***CON H, M, and N; L&D R***
	Analyze and compare eras of design in a technology. ***CON C through O; L&D A through I***
	Recognize the patterns of technological evolution of an invention. ***CON All; L&D All***
List the elements of the design process – problem identification, possible solutions, refinement, analysis, decision, implementation, feedback. ***CON G through M, L&D I through R***	Describe how some inventions have evolved through a deliberate process of tests and refinement. ***CON G through O, L&D I through R***

	Identify how modeling, testing, identifying, and refining are used to transform ideas into practical solutions. ***CON L; L&D N through R***
List questions to use in evaluating solutions to a technical problem. ***L&D M***	
	Describe how brainstorming is a group problem-solving design process. ***CON L and N; L&D K***
Describe the importance of creativity in designing an object. ***CON B and N through P***	
Recognize the importance of materials used in a design. ***CON O and K***	Explain how the forces of tension, compression, torsion, bending, and shear affect structures ***CON H and K***
Describe how troubleshooting is a way to find out why something does not work so it can be fixed. ***CON N; L&D N***	
Describe how scientific principles can be used in solving technical problems. ***CON K through M; L&D All***	Describe the relationship between engineering, science, and mathematics. ***CON C and G through M; L&D All***
	Describe how some technological problems are best solved through experimentation. ***CON H through M; L&D K through Q***
Show that invention and innovation are ways to turn creative ideas into real things. ***CON B, C, and G through N; L&D A and R***	Describe how invention is a process of turning ideas and imagination into devices and systems. ***CON B, C, and G through N; L&D A and R***
	Explain ways in which invention and innovation in one field can transfer to another. ***CON G and P; L&D D***
	Identify the levels of innovation – solution, invention, discovery. ***CON B and P***
Describe how transportation systems move people and goods from place to place. ***CON A***	Describe how transportation vehicles are made up of subsystems. ***CON C and O***
Discuss how modes of transportation have changed. ***CON A and P, L&D R***	
	Explore ways energy can be used more efficiently. ***CON L; L&D Q***
	Use content specific tools, software, and simulations to support learning. ***CON All; L&D All***

Mathematics

Grade Level 3/4/5	Grade Level 6/7/8
Use mathematics in other curriculum areas and the real world, as in creating a timeline. ***CON C through O; L&D D through I***	Relate mathematics to other topics to solve problems. ***CON K through M; L&D All***
	Recognize and use mathematical language. ***L&D All***
Use a variety of methods and appropriate tools for computing with whole numbers. ***L&D D through Q***	Recognize and compare negative numbers. ***CON G; L&D M and N***
Analyze and solve multi-step problems involving addition, subtraction, multiplication, and division. ***L&D D through Q***	Identify mathematical operations to solve real-world problems. ***L&D D through Q***
	Use more than one strategy to solve a problem, and the advantages and disadvantages of each strategy. ***CON L; L&D H***
	Analyze functional relationship – change in one property cause change in another. ***CON K through M; L&D M through Q***
Create a plan for collecting data for a specific purpose. ***CON L; L&D J through P***	Collect, organize, display and interpret data for a specific purpose. ***CON L; L&D J through P***
	Determine how sample selection can influence results. ***L&D M***
Gather and organize data from experiments. ***L&D J through P***	
Create tables to record, organize, and analyze data and find patterns. ***L&D O***	Interpret data by looking for patterns and relationships. ***L&D O through Q***
	Compare experimental results from simple experiments. ***L&D O through Q***
Represent and interpret data as a graph. ***L&D O***	Represent and analyze patterns and functions with graphs ***L&D O***
	Produce graphs that represent the relationship between two variables. ***L&D O***
	Relate a table to a graph. ***L&D O***
	Induce general patterns from specific results. ***L&D O through Q***
	Make predictions based on experimental results and analyses. ***CON M; L&D Q***

Understand and use units of measure for length, weight, volume, and time. ***CON C through P; L&D D through R***	Solve problems involving distance, weight, and time. ***CON K through M; L&D B through Q***
	Select appropriate units for derived measurements, such as pounds per square inch. ***L&D E and G***
	Solve problems using derived measurements. ***L&D E, G, and J through Q***
Identify and describe quantitative changes. ***CON K and L; L&D K through P***	Select a tool and measure precisely to a specified level of precision.
	Estimate a measurement to a greater degree of precision than the tool provides. ***L&D O***
	Recognize when an estimate or an exact solution is appropriate. ***L&D J and O***
	Use appropriate levels of precision. ***L&D J, O, and Q***
Identify and draw right, obtuse, and acute angles. ***L&D F and J***	Identify and label angles. ***CON K through M; L&D F, and J through O***
	Understand units for measuring angles. ***CON K through M; L&D F, and J through O***
	Identify and use tools for measuring angles. ***CON K; L&D F, and J through O***
	Use the Pythagorean Theorem to solve problems. ***L&D F, J, and N***
	Use properties of triangles to find angles and lengths of sides. ***L&D F, J, and N***
	Identify relationship between planes – parallel, perpendicular. ***CON H through K, M and N***
	Find a specific percent of a number. ***CON L; L&D O***
	Use ratios to represent comparisons. ***CON L; L&D O***
	Use models and pictures to relate concepts of rations, proportion, and percent ***CON L; L&D O***
Represent an unknown quantity as a symbol. ***L&D E through G, I, and M through O***	Use variables to create and solve equations. ***L&D E through G, I, and M through O***
	Use formulas to solve problems. ***L&D E through G, I, and M through O***