NOVA

Supersonic Dream

PROGRAM OVERVIEW

NOVA takes a look at the world's first supersonic jet, the Concorde, and its place in aviation history.

The program:

- follows Britain's and France's independent bids to build the jet and explains how rising development costs led to a partnership between the two countries.
- looks at how costs skyrocketed during the plane's 10-year development, eventually totaling £1.4 billion, ten times the original estimate.
- reviews some of the plane's notable technological developments, including its air intake, jet engine, and electronics package.
- notes the public's continuing fascination with the plane ever since its maiden flight in 1969.
- reports early successes of the plane that projected a fleet of 250 aircraft.
- notes how sentiment toward the plane began to change during an international sales tour that met with growing environmental concerns about the sonic booms created during supersonic flight.
- follows the Concorde's struggles to survive, noting key turning points such as securing landing rights in New York, raising fares, and targeting new clientele.
- looks at American efforts to build a supersonic jet.
- traces the events that led to the Concorde's retirement in 2003, including the launch of the Boeing 747, the 2000 crash of France's Concorde, and the 2001 Word Trade Center attacks that resulted in the death of many of the plane's regular clientele.

Taping Rights: Can be used up to one year after the program is taped off the air.

Original broadcast: January 18, 2005 PBS

BEFORE WATCHING

1 Have students research the location and role of the following components for a typical commercial airliner: nose, wings, fuselage, tail, and engine(s). Ask students to investigate how the design of the parts aids in flight. Then have students draw a plane and label the location of each component. When students are done, show a picture of the Concorde and compare its design features to the planes drawn. How are they similar? Different?

2 Organize students into five groups and assign each group to take notes on one of the following as they watch: design features, costs associated with the plane, public perception, advertising, and types of passengers.

AFTER WATCHING

1 Discuss the Concorde's history with students. Have student teams share their notes. What role, if any, did each factor play in contributing to the Concorde's initial success? What contributed to the plane's demise?

2 Sonic booms occur when planes fly faster than 1,207 kilometers per hour. The Concorde traveled at about 2,160 kilometers per hour, or about twice the speed of sound. What were some of the concerns people had about sonic booms? (the startling sound, shaking buildings, shattering windows) How did the owners of the Concorde respond to these concerns?

CLASSROOM ACTIVITY

Objective

To understand how fuel use affects the mass of different planes during flight and to determine the per person fuel cost of a transatlantic flight for seven airplanes.

Materials for each team

- copy of "Fueling the Burn" student handout
- copy of "Aircraft Specifications" student handout
- copy of the "Graphing Mass Change" student handout
- calculator

Procedure

1 Passengers on the Concorde could arrive at their transatlantic destination twice as fast as regular jet travelers. But how much fuel did the Concorde use to accomplish that feat? How did the Concorde's fuel use compare to that of other aircraft? How did the Concorde compare in fuel cost per passenger for a transatlantic flight to some more common jets? Students will explore these questions and others in this activity.

2 Organize students into teams. Provide each team with copies of the student handouts and review the activity with students. (You may want to note to students that the statistics represent actual specifications for commercial aircraft.)

3 Use the board to complete a sample graph of the data for one aircraft (see the "Aircraft Specifications" student handout to find out how to determine the calculations):
   - Calculate how much fuel is burned after one, two, and three hours and record the mass changes.
   - Plot these points and draw a line that passes through the points.
   - Calculate the percent change in mass of the aircraft after three hours of travel.

4 Some students may think that mass is actually lost as a plane's mass changes during flight. Make sure students understand this is not true. Explain to students that energy can neither be created nor destroyed. (Energy present in a system remains constant.) In terms of this activity, fuel is burned and converted into energy to fly the plane. Some energy is dissipated as heat; fuel (mass) is lost from the plane, but not from the universe.

5 Have students complete their calculations and fill in their data tables. (Note: If you would like, you can also have students calculate the slope of the line [slope = rise/run]. The slope indicates fuel burn in relationship to the mass of the plane.)

STANDARDS CONNECTION

The "Fueling the Burn" activity aligns with the following National Science Education Standards and Principles and Standards for School Mathematics.

GRADES 5–8

Science Standard B:

Physical Science

Transfer of energy

- In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might be involved in such transfers.

Motions and forces

- The motion of an object can be described by its position, direction of motion, and speed. The motion can be measured and represented on a graph.

Mathematics Standards:

Algebra

Data Analysis and Probability

Video is required for this activity.

Classroom Activity Author

Developed by WGBH Educational Outreach staff.

CLASSROOM ACTIVITY (CONT.)

6 Now have students consider what it costs per passenger to fly across the Atlantic. (Figures provided in the charts are based on presumptions that the planes are flying the same distance under the same conditions.) As the weight per gallon of jet fuel varies during different seasons and in different climates, students are given the conservative estimate for the weight of one U.S. gallon of jet fuel (2.715 kilograms). Ask teams to complete the calculations on the "Passenger Counts" chart and display their results in a bar graph.

7 Discuss the results as a class. Ask students why it is important to consider how fast an aircraft burns fuel. Why is it important to consider take-off weight? Why is it important to consider the percent change in mass of an aircraft in flight? What are some factors that have an effect on aircraft fuel consumption? Which plane has the highest per passenger fuel use? Which has the lowest? (See Activity Answer on page 4 for more information.)

8 Note to students that the amount of fuel burned per hour and the number of passengers are only two of many variables that must be taken into account when determining a plane's economic efficiency. Have students name three additional factors that would contribute to determining if an airplane is an economical investment for an airline company (i.e., safety record of the plane, speed at which the plane travels, and repair and maintenance costs).

9 As an extension, have students compare the fuel burn of military aircraft. How is it different from that of commercial aircraft? What might account for the differences in fuel burn?

STANDARDS CONNECTIONS (CONT.)

GRADES 9–12
Science Standard B:
Physical Science
Chemical reactions

- Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.

Conservation of energy and the increase in disorder

- The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

Mathematics Standards:
Algebra
Data Analysis and Probability

ACTIVITY ANSWER

The Federal Aviation Administration completes calculations for aircraft hourly fuel burn and considers how fuel burn increases when there is additional weight on a plane. (Hourly fuel burn calculations include an average of climb, cruise, and descend fuel burn rates.) Extra weight can impact fuel burn because the engines must work harder to maintain flight.

Students can infer from their graph the rate of fuel burn in relationship to the average take-off mass of an aircraft. The Concorde's fuel burn rate is greatest.

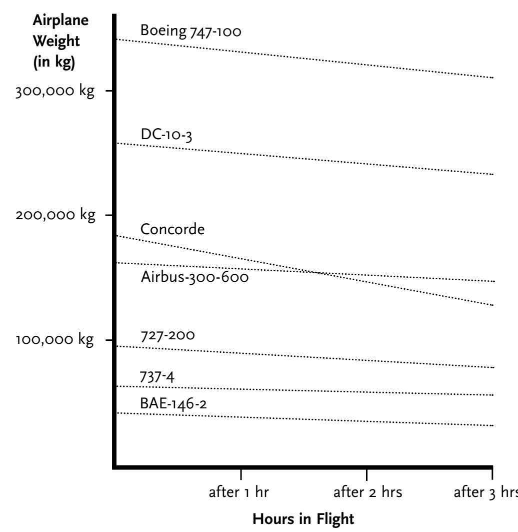
It is important to consider how fast an aircraft burns fuel because fuel has mass and alterations in mass impact flight. Because the mass of the plane has changed after the first hour of flight, there could be a slight difference in rate of fuel burn after each successive hour. (This difference is not calculated in this activity.) The fuel burn rate also has implications for the range in which an aircraft can fly.

It is important to consider the percent change in mass of an aircraft in flight because balance is an important aspect of flight. Changes in mass have an effect on the balance of some planes.

The initial mass of the plane affects how much fuel burn is needed to produce a increase in percent mass change. A greater amount of fuel burn per hour is required to increase the percent mass change for more massive planes than for less massive planes. This is why the slope of the line for Boeing 747-100 is greater than for Airbus 300-600 even though the percent mass change is the same.

Three major factors that have an effect on aircraft fuel consumption are the mass of the plane, speed of the plane, and resistance (wind). Based on fuel calculations alone, the Boeing 737-4 is the most fuel efficient per passenger; the Concorde is the least fuel efficient per passenger.

Graphing Mass Change



Aircraft Type	Mass of Fuel Burned after 3 Hours (kg)	Percent Mass Change
Boeing 747-100	29,703	8.73
Boeing DC-10-3	25,554	9.85
Concorde	55,281	29.87
Airbus 300-600	13,701	8.51
Boeing 727-200	15,054	15.84
Boeing 737-4	6,465	10.00
BAE 146-2	6,669	16.27

Fuel Burn

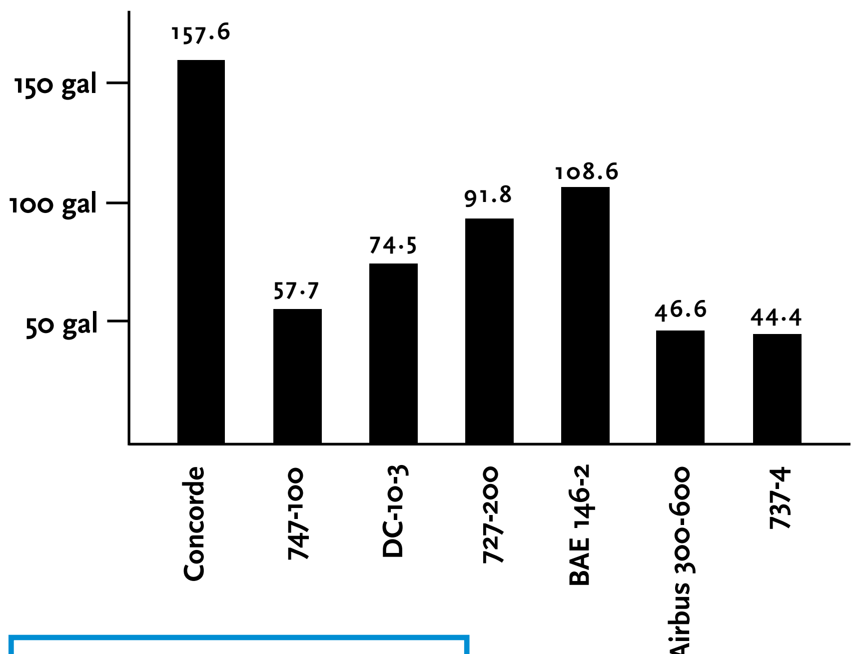
Aircraft Type	Engines	Average Take-off Mass with Fuel (kg)	Fuel Burn Rate (gal/h)	Weight of Gallon of Fuel (kg)	Mass of Fuel Burned (kg/h)	Hour 1 Mass of Plane (kg)	Hour 2 Mass of Plane (kg)	Hour 3 Mass of Plane (kg)
Boeing 747-100	4	340,190	3,638	2.7215	9,901	330,289	320,388	310,487
Boeing DC-10-3	3	259,450	3,130	2.7215	8,518	250,932	242,414	233,896
Concorde	4	185,062	6,771	2.7215	18,427	166,635	148,208	129,781
Airbus 300-600	2	161,022	1,678	2.7215	4,567	156,455	151,888	147,321
Boeing 727-200	3	95,026	1,844	2.7215	5,018	90,008	84,990	79,972
Boeing 737-4	2	64,636	792	2.7215	2,155	62,481	60,326	58,171
BAE 146-2	4	40,993	817	2.7215	2,223	38,770	36,547	34,324

ACTIVITY ANSWER

Passenger Counts

Aircraft Type	Fuel Burn Rate (gal/h)	Average Airborne Speed (km/h)	Amount of Fuel Burned (gal/km)	Passengers and Crew	Distance per Passenger per Gallon (km/gal)	Distance Traveled (km)	Gallons per Passenger (London to New York)
Boeing 747-100	3,638	825.6	4.4	423	96.1	5,547	57.7
Boeing DC-10-3	3,130	828.8	3.8	283	74.5	5,547	74.5
Concorde	6,771	2,160.0	3.1	109	35.2	5,547	157.6
Airbus 300-600	1,678	740.3	2.3	274	119.1	5,547	46.6
Boeing 727-200	1,844	703.3	2.6	157	60.4	5,547	91.8
Boeing 737-4	792	664.7	1.2	150	125.0	5,547	44.4
BAE 146-2	817	463.5	1.8	92	51.1	5,547	108.6

Gallons Per Passenger



Major funding for NOVA is provided by the Park Foundation, Sprint, and Microsoft. Additional funding is provided by the Corporation for Public Broadcasting and public television viewers.

LINKS AND BOOKS

Links

NOVA Web Site—Supersonic Dream
www.pbs.org/nova/concorde/
Find articles, interviews, interactive activities, and resources in this companion Web site to the program.

How Concordes Work
www.howstuffworks.com/concorde.htm
Describes how the Concorde worked and compares it to other jets.

Last Concorde Flights Touch Down
www.cnn.com/2003/WORLD/europe/04/10/biz.trav.concorde.quest/
Includes a special report that covers the rise and fall of the Concorde.

Concorde History
www.concordesst.com/history/historyindex.html
Presents a time line and key events section and includes photographs that span more than 20 years of the plane's history.

Books

Calvert, Brian.
Flying Concorde.
Osceola, Wisconsin: Motorbooks International, 2002.
Portrays the history and production of the Concorde and contains technical specifications of the aircraft.

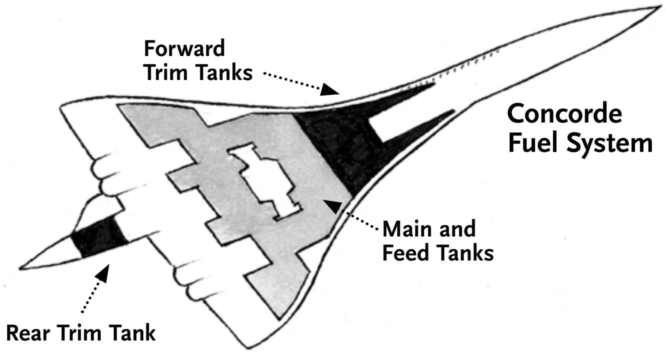
Endres, Gunter.
Concorde.
Osceola, Wisconsin: Motorbooks International, 2001.
Examines Concorde's history, design production, and service.

Grant, R.G.
Flight: 100 Years of Aviation.
New York: Dorling Kindersley Publishing, 2002.
Presents an historical view of aviation that includes photos focusing on aircraft design.

Owen, Kenneth.
Concorde: Story of a Supersonic Pioneer.
London: Science Museum, 2002.
Traces the development of the Concorde.

Fueling the Burn

Fuel is used to fly and balance planes. Burning fuel changes the mass of the plane. The data set in this activity includes the average take-off weight and the average amount of fuel burned per hour for seven aircraft. Are all commercial aircraft designed to burn fuel at the same rate? How much fuel is burned per passenger carried? Do this activity to find out.



Procedure

1 You will be calculating the changes in aircraft mass as fuel is burned after 1, 2, and 3 hours of flight. Use the data from the "Fuel Burn" chart on your "Aircraft Specifications" handout for this part of the activity.

2 Use the formulas listed on your "Aircraft Specifications" handout to determine the mass of fuel burned per hour (round to whole numbers) and the change in mass after 1, 2, and 3 hours of flight. (Although the mass of the plane changes after each hour of flight, thus affecting the fuel burn rate, to simplify your calculations you will be assuming the fuel burn rate remains constant throughout the flight.) Enter your answers into the chart.

3 Present your results as a line graph on your "Graphing Mass Change" handout.

4 Use the formulas on your "Aircraft Specifications" handout to find the mass of fuel burned after 3 hours and the percent change in mass of the plane after 3 hours of flight. Record the results in the chart below.

Aircraft Type	Mass of Fuel Burned after 3 Hours (kg)	Percent Mass Change
Boeing 747-100		
Boeing DC-10-3		
Concorde		
Airbus 300-600		
Boeing 727-200		
Boeing 737-4		
BAE 146-2		

5 Now consider airplane fuel efficiency per passenger. Use the data from the "Passenger Count" chart on your "Aircraft Specifications" handout for this part of the activity.

6 Use the formula on your "Aircraft Specifications" handout to calculate how many gallons of fuel are used per passenger for a flight from London to New York. Enter your answers into the chart.

7 Create a bar graph to represent the last column's results in the "Passenger Count" table.

Questions

Write your answers on a separate sheet of paper.

1 What might you infer from your graph that shows how airplane masses change during a three-hour flight?

2 Why is it important to consider how fast an aircraft burns fuel? How might extra weight impact fuel burn?

3 Why is it important to consider the percent change in mass of an aircraft in flight?

4 What affect does the initial mass of the plane have on the percent mass change due to fuel burn?

5 Describe three factors that have an effect on aircraft fuel consumption.

6 Which plane is most fuel efficient per passenger? Which is least fuel efficient per passenger?

Aircraft Specifications

Fuel Burn

Aircraft Type	Engines	Average Take-off Mass with Fuel (kg)	Fuel Burn Rate (gal/h)	Weight of Gallon of Fuel (kg)	Mass of Fuel Burned (kg/h)	Hour 1 Mass of Plane (kg)	Hour 2 Mass of Plane (kg)	Hour 3 Mass of Plane (kg)
Boeing 747-100	4	340,190	3,638	2.7215				
Boeing DC-10-3	3	259,450	3,130	2.7215				
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Airbus 300-600	2	161,022	1,678	2.7215				
Boeing 727-200	3	95,026	1,844	2.7215				
Boeing 737-4	2	64,636	792	2.7215				
BAE 146-2	4	40,993	817	2.7215				

Sources:

Table 3-8 Air Carrier Capacity and Utilization Factors
www.api.faa.gov/economic 742SECT3.pdf

Impact of Weight Changes on Aircraft Fuel Consumption
www.api.faa.gov/economic/ 742SECT7.pdf

Concorde Specifications
www.gizmohighway.com/ history/concorde_specs.htm

Fuel Burned per Hour
Fuel Burn Rate (gal/h) x Weight of Gallon of Fuel (kg) = Mass of Fuel Burned (kg/h)

Change in Mass
Average Take-off Mass with Fuel (kg)
- Mass of Fuel Burned (kg/hr)
= Hour 1 Mass of Plane (kg)

Hour 1 Mass of Plane (kg)
- Mass of Fuel Burned (kg/hr)
= Hour 2 Mass of Plane (kg)

Hour 2 Mass of Plane (kg)
- Mass of Fuel Burned (kg/hr)
= Hour 3 Mass of Plane (kg)

Mass of Fuel Burned
Mass of Fuel Burned (kg/h) x 3 = Mass of Fuel Burned after 3 Hours (kg)

Percent Mass Change
Mass of Fuel Burned after 3 Hours (kg) ÷ Average Take-off Mass with Fuel (kg) x 100 = Percent Mass Change

Passenger Count

Aircraft Type	Fuel Burn Rate (gal/h)	Average Airborne Speed (km/h)	Amount of Fuel Burned (gal/km)	Passengers and Crew	Distance per Passenger per Gallon (km/gal)	Distance Traveled (km)	Gallons per Passenger (London to New York)
Boeing 747-100	3,638	825.6		423		5,547	
Boeing DC-10-3	3,130	828.8		283		5,547	
Concorde	6,771	2,160.0		109		5,547	
Airbus 300-600	1,678	740.3		274		5,547	
Boeing 727-200	1,844	703.3		157		5,547	
Boeing 737-4	792	664.7		150		5,547	
BAE 146-2	817	463.5		92		5,547	

Fuel Use Per Passenger
Calculate your results to one decimal place (increase the first decimal place number by one if the second decimal number is 5 or above).

Fuel Burn Rate (gal/h)
÷ Average Airborne Speed (km/h)
= Amount of Fuel Burned (gal/km)

Passengers and Crew
÷ Amount of Fuel Burned (gal/km)
= Distance per Passenger per Gallon (km/gal)

Distance Traveled (5,547 km)
÷ by Distance per Passenger per Gallon (km/gal) = Gallons per Passenger from London to New York

Graphing Mass Change