"To Fly!"
IMAX Film

Theme: Flight, in all its forms, is part of the Human condition, part of our Destiny…

The educational value of NASM Theater programming is that the stunning visual images displayed ***engage*** the interest and desire to learn in students of all ages. The programs do not substitute for an in-depth learning experience, but they do facilitate learning and provide a framework for additional study elaborations, both as part of the Museum visit and afterward. See the "Alignment with Standards" table for details regarding how *"To Fly!"* and its associated classroom extensions, meet specific national standards of learning.

What you will see in the *"To Fly"!* program:

- A historical review of the development of aviation technology, from hot air balloons to the Apollo Moon missions
- Engaging vistas from aloft: spectacular scenery, aerobatics "from the inside," and more

Things to look for when watching *"To Fly!"*:

- What allowed the balloon in the initial sequence to fly?
- When the 747 is flying amongst the clouds, note the colored halo that appears to surround the plane's shadow (you will have only a few second's glimpse). This kind of halo is called "the Glory," and, along with similar atmospheric phenomena, might make a good report topic. [Be sure to visit the 747 nose on display in the America by Air Gallery!]
- The western landscapes shown include Lake Powell, Monument Valley, a waterfall at Yosemite, coastal California, and Hawaii. All would be good report topics, too, particularly in the context of being seen from "above!"

"To Fly!" is an IMAX classic. It was one of the first IMAX films, originally created as part of the Nation's Bicentennial celebration, and was premiered at the opening of the National Mall Building of the Smithsonian Institution's National Air and Space Museum in 1976. "To Fly!" has racked up the following accolades:

- "To Fly!" has been added to the Library of Congress' prestigious America's Film Archive
- Over 15 million visitors have seen "To Fly!" at NASM, the largest cumulative audience for a single film of any format in a single venue anywhere.
- "To Fly!" is the second highest-grossing IMAX film ever and in the IMAX Hall of Fame.
- "To Fly!" has been frequently used to entertain heads of State.
- "To Fly!" has received other awards and honors too numerous to list separately.

Learning Elaboration While Visiting the National Air and Space Museum

Perhaps the first stop to expand on your *"To Fly!"* experience should be our interactive How Things Fly Gallery.

Be sure to see the scale model of the very first hot-air balloon, in the Pioneers of Flight Gallery.

Much is made in *"To Fly!"* about the advantages of being able to see things from above. The entire Looking at Earth Gallery builds on this theme, for both urban and rural landscapes, and for the analysis of natural landforms and human activities. Objects with distinctive size, shape, pattern, and other features are easiest to identify from aloft, and having the "high ground" perspective allows everyday objects to be seen in new ways. Examples:

- Recall the appearance of a cloverleaf highway interchange in *"To Fly!"* Its very name is a give-away that its shape is distinctive enough for you to recognize it.
- The 1922 painting of the Eifel Tower by Delaunay near the exit of the Wright Brothers Gallery was inspired by the artist's imagination of seeing it from above, something they would not have considered without the inspiration of seeing some of the first airplanes in use. [On-line access: see http://www.nasm.si.edu/wrightbrothers/age/1909/hudson.cfm then click on "View More" under "Artifact Gallery," then Artifact 27.
- Modern satellites routinely monitor Earth resources and climatic conditions; see the "What's New" section of the Looking at Earth Gallery for the latest news.

If you enjoyed the barnstorming and hang gliding sequences in *"To Fly!"* then you also might enjoy the Wright Brothers, Early Flight, and Golden Age of Flight Galleries. The Wrights experimented with kites, then manned kites, before attempting powered flight. Several reconstructed examples of their earliest flying objects can be found in the Wright Brothers Gallery. A manned glider built by Otto Lilienthal, a European pioneer of flight, can be found in the Early Flight Gallery; it strongly resembles modern hang gliders. Other artifacts from the barnstorming days of the 1920's can also be found in Early Flight. The technological innovations in flight mandated by military and barnstorming pilots led to rapid advances in aircraft design and construction; for more, see the Golden Age of Flight Gallery.

Air transportation during the early days of flight was important commercially. Air mail and passenger transportation became increasingly common prior to World War 2; see the newly-renovated America by Air Gallery for details.

The Saturn rocket used for the Apollo missions to the Moon was also prominently featured in *"To Fly!"* You can find more about Apollo, including an ingenious depiction of the business end of the Saturn first stage, in the Apollo to the Moon Gallery and in the East Alcove (in front of the food court), where a Lunar Module (training version) and engineering versions of spacecraft sent to the Moon are on display [NASA usually builds an extra version of a spacecraft, used for near-destructive engineering testing during the design and construction phase of the mission and for trouble-shooting during the mission. When the mission is over, we do not get the spacecraft back, but NASA often turns over the engineering model to NASM.]

NASA has conducted a vigorous program of Solar System exploration using unmanned spacecraft since the making of *"To Fly!"* Our robotic surrogates have been sent to each of the eight planets of the Solar System, with another en route to Pluto. Check out the Exploring the Planets Gallery for a lot more information.

If your interest is in high-performance military aviation, be sure to visit our military flight galleries (Legend, Memory, and the Great War in the Air; World War 2 Aviation; Jet Aviation; and Sea-Air Operations); see also the IMAX film *"Fighter Pilot: Operation Red Flag."*

Thousands of books and articles have been written about aviation and aviation history, but two good starting points are the many books and related materials available at the **Museum Store** in each NASM building, and the list of research and publications of NASM's expert curators:

- ***Aeronautics***: http://www.nasm.si.edu/research/aero/research.cfm
- Center for Earth and Planetary Studies: http://www.nasm.si.edu/research/ceps/research/research.cfm
- Space History: http://www.nasm.si.edu/research/dsh/research.cfm

Post-Visit Discussion Points to Align Program Material with National SoLs

High School

See High School Alignment Table
"Strong alignment" is shown in red in the Table and in bold-faced text below

S A2: Understanding Science Inquiry

Flight test is a type of scientific inquiry. Engineers base designs on their experience and on the prevailing state of the aerospace engineering "art," but are constantly testing and improving.

S B4: Motions and Forces

Flight, in general, is all about the manipulation of the interaction of four different forces: lift, gravity, thrust, and drag. Most aircraft maneuver by moving small pieces of their wings and tails ("control surfaces"), which in turn apply forces to the aircraft that orient it and move it in the manner desired by the pilot.

S B5: Conservation of Energy; Entropy

Flight offers an excellent example of the conversion of (gravitational) potential energy to kinetic energy, and energy loss. Pilots often speak of "trading altitude for speed" or use changes in altitude to control their speed and position. For example, diving a sailplane then leveling off produces high airspeeds initially, as gravitational potential energy is converted to kinetic energy. As level flight is subsequently maintained, however, airspeed drops due to friction (drag) between aircraft and air, and example of energy lost from the Earth-plane "system."

S E2: Understanding Science and Technology

Aviation provides an example of the subset of this standard that illustrates that "science and technology are pursued for different purposes. A scientific topic might be aerodynamic fluid mechanics, while the related technological concern might be to utilize an understanding of aerodynamic fluid mechanics to build a device that would allow a person to fly. Another part of this particular standard deals with the public nature, or not, of technological knowledge. The Wright Brothers did not publicly demonstrate their flight capability for several years after Kitty Hawk, based on patent and related concerns.

S F3: Natural Resources

Seeing things from the "high ground" perspective allows a better assessment than would otherwise be possible if one were confined to view from only "ground level," where seeing the "forest for the trees" can be a big problem.

- Example: Maps are drawn in "map view," as though the terrain they represent is being seen from directly above, so that all features can be seen easily.
- Using a balloon, airplane, or satellite as an observation platform provides enormous advantages in: military reconnaissance, resource exploration, land-use planning, navigation, and in other uses.
- Example: Cornfield mazes have become popular ("maizes" or "Amazing Maize Maze" etc.; there is one at Luray Caverns in Virginia). Almost all of them have a large observation tower immediately adjacent to the maze. Someone in the maze can easily get

lost (that's half the fun!), because they cannot see the maze pattern for the walls nearby. Someone in the tower can help those lost in the maze, because their "high ground" perspective allows them to see the maze pattern all at once, without interference from the walls.

S F5: Natural and Human-induced Hazards

Flight is an example of a human-induced hazard (as is any form of transportation). But how dangerous is flight, really? It turns out that, when traveling, there is greater risk in getting to/from the airport than there is aloft. But understanding the risk probabilities requires the ability to assess/evaluate risk clearly.

S G1: Science as a Human Endeavor

In the early days, engineering experiments relating to flight could be individual or small group efforts (examples: Lilienthal, Bleriot, the Wright Brothers). But modern flight systems are so complex today that any substantive improvements are almost certain to be the end result of the combined efforts of many people; the Apollo Program is perhaps the penultimate example.

S G3: Historical Perspectives

The development of the airplane certainly fits the standard's language for having an "… important and long-lasting effect on science and society."

- See the next standard below regarding "integration of society."
- Aircraft revolutionized warfare when introduced; aerospace technology development has influenced both military strategy and tactics ever since.
- Aviation changed perspectives in areas not related to flight. Potential discussion topics:
  - A good example at NASM is the Eifel Tower painting described in the "Learning Elaboration While at NASM" section above.
  - That the "environmental movement" arose at the same time the public began seeing pictures of Earth from a Space-based perspective was no coincidence.
  - Spaceflight changes perspectives, too, with no better example than Apollo 11.

Post-Visit Discussion Points to Align Program Material with National SoLs

Middle School

See Middle School Alignment Table
"Strong alignment" is shown in red in the Table and in bold-faced text below

S B2: Motions and Forces

The concept of flight provides a familiar and engaging context that can be used to facilitate a class discussion of several parts of this standard, including the concept of position, direction, and speed; inertia; and graphing (plotting plane's position on a map). At the MS level, this standard also deals with the concept of "net," or balancing, forces. The four forces of flight (lift, drag, thrust, and gravity) and control of flight via the manipulation of those four forces makes an outstanding learning focus.

S E2: Understanding Science and Technology

That science and technology are "reciprocal" in nature (advances in one affects and/or triggers advances in the other) is a part of this particular standard. Aerospace engineering provides an interesting spin on showcasing such relationships. Improvements in our understanding of aerodynamic fluid mechanics and other scientific underpinnings of flight leads to improvements in aircraft performance, which in turn is likely to reveal areas in which our theoretical understanding could be improved through further research and testing.

Another subset of this standard is that "technological designs have constraints," and aerospace provides several illustrative examples, including:

- Friction heating limits how fast an aircraft can go at low altitude.
- Material strength of aircraft components place serious constraints on design.
- Biological characteristics of the flight crew place serious constraints on design.

S F4: Risks and Benefits

Aircraft accidents tend to be attention grabbers. But does that mean that airplanes are intrinsically more dangerous than other modes of transport? Discussing that question systematically could be an engaging way to introduce the concepts of risk analysis and management in a classroom discussion, for both personal and societal perspectives.

S G2: Nature of Science

In the examples related to "*To Fly!,*" "science" and "engineering" are more-or-less interchangeable under the "Nature of Science" category.

In the earliest days of flight, individuals working in isolation could, and did, make major contributions to fundamental issues relating to aerospace technology. However, in modern times aircraft systems are so complex, and the design/fabrication process so expensive and specialized, that large teams of specialists with a lot of working capital readily available are essential ingredients in successful aircraft development.

Post-Visit Discussion Points to Align Program Material with National SoLs

Elementary School

See Elementary School Alignment Table
"Strong alignment" is shown in red in the Table and in bold-faced text below

S B1: Properties of Objects and Materials

Some of the materials used to make things that fly have special properties. An example is a balloon, which floats only when filled with a gas lighter than the surrounding air.

- One example is shown at the start of "*To Fly!*" – a balloon filled with a light gas called ***helium***. Helium-filled blimps are commonly seen bearing advertising at major sporting events. Smaller helium balloons often are used for birthday and other decorations.
- Hydrogen is the only other gas is "lighter than air," but is no longer used for large balloons. It is very flammable, even explosive, when mixed with air in the right proportions, making it dangerous.
- The famous hydrogen-filled dirigible *Hindenburg* caught fire and exploded in 1937. Hydrogen has long been blamed for the crash, and no doubt did contribute; the highly-flammable coating on the skin of the dirigible could also have been responsible. (NOTE: "dirigibles" and "zeppelins" are lighter-than-air vehicles in which a series of gasbags are supported by a rigid internal framework; "blimps" are merely large gasbags with no framework.)

S B2: Position and Motion of Objects

Early pilots, as shown in "*To Fly!*," kept track of their position by navigating against landmarks on the ground. Navigators, when aloft, keep continuous track of their position on a chart (tracing and measuring position change with time).

S C1: Characteristics of Organisms

By the 1930's, airplanes could "outperform" the people that flew them. Flights did not last so long that water and food were critical items, but planes could fly so high that their pilots, crews, and passengers could not breathe properly. Oxygen systems had to be provided for flight safety over 12,000 feet altitude.

Providing metabolic basics during flight is only one problem. Keeping characteristics of flight from disrupting body function can be important, too. By the end of World War 2, aircraft could maneuver more abruptly than their crews could tolerate. To help pilots withstand "g-forces," special suits were worn that would restrict the flow of blood to/from the brain.

S D2: Objects in the Sky

Airplanes are explicitly mentioned in this particular standard as members of the class of objects whose "properties, locations, and movements can be observed and described."

S E2: Understanding Science and Technology

The development of aviation technology is a prime example of inventing tools and techniques to solve a problem. Aviation is a broad topic and has been around for a century;

there has been, and is, a LOT of opportunity for teamwork by a diverse group of scientists and engineers to advance aviation capabilities.

S E3: Natural / Human-made Objects

Distinguishing between natural and human-made objects is not a factor with aviation technology, however, there are very interesting links between how Nature has solved a flight-related problem (hummingbird maneuverability, for example), and how engineers solve similar problems. Da Vinci and many other scientists and engineers were inspired to dream of flight-related technology by watching birds and insects fly.

S G1: Science as a Human Endeavor

Several points from *"To Fly!"* can stimulate discussions on subsets of this standard:

- The science and technology of flight have been known for more than a century.
- Advances in aviation have been made by many people, some working alone, others in large teams.
- Many people, from all walks of life, have devoted their careers and lives to the development and utilization of aviation-related technology.

Resources for Learning Elaboration after the Visit to NASM

Thousands of books and articles have been written about aviation and aviation history, but two good starting points are the many books and related materials available at the **Museum Store** in each NASM building, and the list of research and publications of NASM's expert curators:

- ***Aeronautics***: http://www.nasm.si.edu/research/aero/research.cfm
- Center for Earth and Planetary Studies: http://www.nasm.si.edu/research/ceps/research/research.cfm
- Space History: http://www.nasm.si.edu/research/dsh/research.cfm

National Air and Space Museum Gallery Web Pages

How Things Fly: http://www.nasm.si.edu/exhibitions/gal109/gal109.html
Milestones of Flight: http://www.nasm.si.edu/exhibitions/gal100/gal100.html
Wright Brothers and the Invention of the Aerial Age: http://www.nasm.si.edu/wrightbrothers/index_full.cfm
Early Flight: http://www.nasm.si.edu/exhibitions/gal107/index.cfm
Golden Age of Flight: http://www.nasm.si.edu/exhibitions/gal105/gal105.html
Legend, Memory, and the Great War in the Air: http://www.nasm.si.edu/exhibitions/gal206/gal206.html
World War 2 Aviation: http://www.nasm.si.edu/exhibitions/gal205/gal205.html
Jet Aviation: http://www.nasm.si.edu/exhibitions/gal106/gal106.html
Sea-Air Operations: http://www.nasm.si.edu/exhibitions/gal106/gal106.html
Apollo to the Moon: http://www.nasm.si.edu/exhibitions/attm/enter.html
Lunar Exploration Vehicles: http://www.nasm.si.edu/exhibitions/gal112/gal112.html

In addition to the NASM collection and on-line information listed above, two websites are useful additional informational resources relating to aviation:

The Centennial of Flight website: http://www.centennialofflight.gov/index.cfm
The National Museum of the U.S. Air Force: http://www.centennialofflight.gov/index.cfm

An outstanding source for the student to learn more about the "Glory," haloes, rainbows, and other atmospheric phenomena, is "The Nature of Light and Colour in the Open Air," by M. Minnaert, in paperback from Dover Publications (1954; the original is much older, but no less valid!), ISBN-10: 0486291961; ISBN-13: 978-0486201962.

See also: http://science.nasa.gov/headlines/y2006/21nov_thanksgivingskies.htm and
http://www.usna.edu/Users/oceano/raylee/RainbowBridge/Chapter_8.html

NASA's Ames and Langley Research Centers are home to many exotic wind tunnels and supercomputers capable of simulating flight under a wide range of conditions. See:

http://www.centennialofflight.gov/essay/Evolution_of_Technology/advanced_wind_tunnels/Tech36.htm and
http://www.nasa.gov/centers/langley/news/factsheets/WindTunnel.html and
http://aeronautics.arc.nasa.gov

"To Fly!" was produced by MacGillivray Freeman Films; see also:

http://www.imax.com/ImaxWeb/filmDetail.do?type=nowPlaying&movieID=code__.__11380