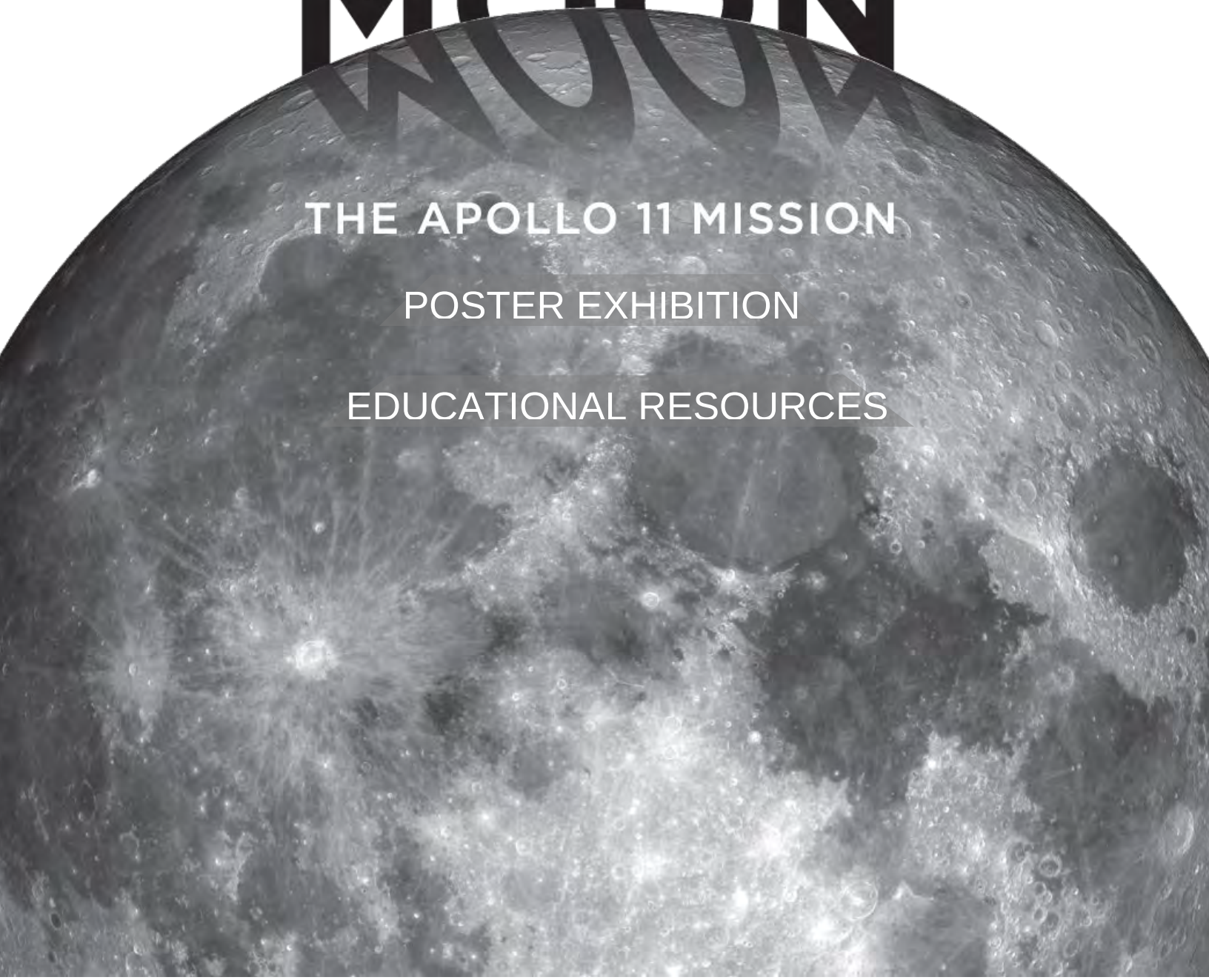
DESTINATION MOON



THE APOLLO 11 MISSION

POSTER EXHIBITION

EDUCATIONAL RESOURCES

Smithsonian

Table of Contents:

General Resources

The following resources have been gathered to help support student and visitor engagement with the poster exhibition *Destination Moon: The Apollo 11 Mission*. Learning standards are called out below each resource listing, and range from elementary to high school levels. A number of the links on this page are gathered on the Smithsonian's Learning Lab. Learning Lab is a free, interactive platform that provides users with access to authenticated digital resources and "creates a community of knowledge and learning."

- The Mighty Saturn V Learning Lab collection introduces parts and vocabulary around rocketry and forces.
  Next Generation Science Standards: Science and Engineering Practices, Analyzing and Interpreting Data, Obtaining, Evaluating, and Communicating Information; C3 Social Studies Standards: Dimension 3.1.6-8

- This Learning Lab topical collection introduces the Apollo 11 Crewmembers.
  Common Core Standards: CCSS.ELA-LITERACY.CCRA.R.7; C3 Social Studies Standards: Dimension 3: Gathering and Evaluating Sources, Developing Claims and Using Evidence, and Dimension 4: Communicating Conclusions

- *We Choose the Moon* is an animated interactive website which separates the Moon landing into 12 stages, all with original photos, videos and flight log context.
  C3 Social Studies Standards: Dimension 2: Change, Continuity, and Context, and Historical Sources and Evidence; Common Core Standards: *CCSS.ELA-LITERACY.CCRA.R.7*

- The National Archives Documents Teach program has three lessons that examine government documents in relationship to the Mercury, Gemini, and Apollo Programs.
  C3 Social Studies Standards: Dimension 2: Change, Continuity, and Context, and Historical Sources and Evidence; Common Core Standards: CCSS.ELA-LITERACY.CCRA.R.7

- *Race to the Moon* is a lesson plan that combines a primary source (child's letter to President Kennedy) with a timeline and chronology to understand the Space Race. This lesson can easily be adapted to use the timeline in the poster exhibition.
  C3 Social Studies Standards: Dimension 2: Change, Continuity, and Context, and Historical Sources and Evidence; Common Core Standards CCSS.ELA-LITERACY.CCRA.R.7

- This topical Learning Lab collection on Margaret Hamilton expands on the life of the software engineer whose team developed the on-board flight computer used during the Apollo missions.

Common Core Standards: CCSS.ELA-LITERACY.CCRA.R.7; C3 Social Studies Standards: Dimension 3: Gathering and Evaluating Sources, Developing Claims and Using Evidence; Dimension 4: Communicating Conclusions

- Explore Civil Rights hiring practices that affected NASA during this period with this Learning Lab collection, which uses oral histories and primary source materials.
  C3 Social Studies Standards: Dimension 2, specifically: D2.His.13.6-8, D2.His.1.9-12, D2.Civ.12.9-12, D2.Civ.13.9-12; Common Core Standards: CCSS.ELA-Literacy.SL.K.2, CCSS.ELA-Literacy.RI.8.2, CCSS.ELA-Literacy.RI.11-12.7

Primary Source Documents, Images, Artifacts and Video

These resources can be projected or printed out to examine with students, to enhance discussion about several of the content threads in the exhibition.

- Curated collection of 100 Apollo 11 related objects from the Smithsonian's National Air and Space Museum
- Curated collection of 11 iconic images from the Apollo 11 mission from the Smithsonian's National Air and Space Museum
- Selection of videos from the *Apollo Lunar Surface Journal* and other sources
- Online digital tour of the Command Module *Columbia* interior
- A collection of primary source materials including letters, video, audio and White House memos about the Space Race from the John F. Kennedy Presidential Library and Museum
- The Dan Beaumont Space Museum has some well-curated collections in Flickr:
    - News coverage
    - Rare photos
- A tour of the Moon from NASA's Goddard Space Flight Center provides an introduction to the Moon's geography based on data from the Lunar Reconnaissance Orbiter. This video highlights the landing site of Apollo 17.
- The University of Texas at Dallas has digitized the analog NASA audio from the Apollo 11 mission. The Explore Apollo website, created in collaboration with the University of Maryland, makes these recordings publicly available.
- NASA's Apollo Anniversary toolkit is a list of resources related to the 50th anniversary of the Moon landing
- NASA's YouTube channel playlist of 50th anniversary videos

Common Core Standards: CCSS.ELA-LITERACY.CCRA.R.1, CCSS.ELA-LITERACY.CCRA.R.7, CCSS.ELA-LITERACY.CCRA.R.9, CCSS.ELA-LITERACY.RH.6-8.1, CCSS.ELA-LITERACY.RH.6-8.7, CCSS.ELA-LITERACY.RH.6-8.9

C3 Social Studies: Dimension 3: Gathering and Evaluating Sources, Developing Claims and Using Evidence; Dimension 4: Communicating Conclusions

NOTE: Material in the links listed above may be covered under copyright law. Please observe the owner's rights.

Reading List
(as of July 2019)

Aldrin, Buzz, and Ken Abraham. *No Dream is Too High: Life Lessons from a Man Who Walked on the Moon*. Washington, D.C.: National Geographic, 2016.

Bilstein, Roger. *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles*. Gainesville: University of Florida, 2003.

Bizony, Piers. *One Giant Leap: Apollo 11 Remembered*. Minneapolis: Zenith Press, 2009.

_____. *Moonshots: 50 Years of NASA Space Exploration Seen through Hasselblad Cameras.* Beverly, MA: Voyageur Press, 2017.

Brinkley, Douglas. *American Moonshot: John F. Kennedy and the Great Space Race*. HarperCollins Publishers, 2019. (This book is available in a young readers edition appropriate for children ages 8-12, and listed in the Children and Families section, below.)

Brooks, Courtney G., James M. Grimwood and Lloyd S. Swenson, Jr. *Chariots for Apollo: The NASA History of Manned Lunar Spacecraft to 1969*. Mineola, NY: Dover, 2009.

Burrows, William E. *This New Ocean: The Story of the First Space Age*. New York: Modern Library, 1999.

Cernan, Eugene, and Don Davis. *The Last Man on the Moon.* New York: Griffin, 2009.

Chaikin, Andrew. *A Man on the Moon: The Voyages of the Apollo Astronauts*. London: Penguin, 2009.

Chaikin, Andrew, and Victoria Kohl. *Voices from the Moon: Apollo Astronauts Describe Their Lunar Experiences*. New York: Viking Studio, 2009.

Collins, Michael. *Carrying the Fire*. New York: Farrar, Straus and Giroux, multiple editions.

Craddock, R. A. *Apollo 11: Artifacts from the First Lunar Landing*. San Francisco: Chronicle Books, 2003.

Donovan, James. *Shoot for the Moon: The Space Race and the Extraordinary Voyage of Apollo 11*. Boston: Little, Brown and Company, 2019.

Eyles, Don. *Sunburst and Luminary.* Boston: Fort Point Press, 2018.

Fishman, Charles. *One Giant Leap: The Impossible Mission that Flew Us to the Moon.* New York: Simon & Schuster, 2019.

Geppert, A. Ed. *Limiting Outer Space: Astroculture After Apollo*. Basingstoke, UK: Palgrave Macmillan, 2018.

Hansen, James R. *First Man: The Life of Neil A. Armstrong*. London: Simon & Schuster, 2005.

Heyne, Floris, Joel Meter, Simon Phillipson, and Delano Steenmeijer. *APOLLO: VII - XVII*. Kempen, Germany: TeNeues Media, 2018. (Introduction by Walter Cunningham)

Kelly, Thomas J. *Moon Lander: How We Developed the Apollo Lunar Module.* London: Smithsonian Institution Press, 2001.

Kluger, Jeffrey. *Apollo 8: The Thrilling Story of the First Mission to the Moon*. New York: Henry Holt and Co., 2017.

Kranz, Gene. *Failure Is Not an Option: Mission Control from Mercury to Apollo 13 and Beyond*. New York: Simon & Schuster, 2009.

Launius, R. D. *The Smithsonian History of Space Exploration: From the Ancient World to the Extraterrestrial Future*. Washington, DC: Smithsonian Books, 2018.

_____. *Apollo's Legacy: Perspectives on the Moon Landing*. Washington, DC: Smithsonian Books, 2019.

Logsdon, John M. *John F. Kennedy and the Race to the Moon*. New York: Palgrave Macmillan, 2013.

Logsdon, John M., and Roger D. Launius, eds. *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*. Washington, DC: NASA, 2008.

Lovell, Jim, and Jeffrey Kluger. *Apollo 13.* Boston: Mariner Books, 2006.

Maher, Neil. *Apollo in the Age of Aquarius.* Cambridge, MA: Harvard University Press, 2017.

Mailer, Norman. *Moonfire: The Epic Journey of Apollo 11*. Cologne, Taschen, 2015. (50th Anniversary edition with introduction by Colum McCann, May 2019)

McDougall, Walter A. *The Heavens and the Earth: A Political History of the Space Age*. Baltimore: Johns Hopkins University Press, 1997.

Morgan, George D. *Rocket Girl: The Story of Mary Sherman Morgan, America's First Female Rocket Scientist*. Amherst, NY: Prometheus, 2015.

Muir-Harmony, Teasel. *Apollo to the Moon: A History in 50 Objects.* Boone, IA: National Geographic, 2018.

Murray, Charles A., and Catherine Bly. Cox. *Apollo: The Race to the Moon.* New York: Simon & Schuster, 1989.

NASA. *Saturn V Flight Manuel*. Los Angeles: Periscope Film LLC, 2011.

Neufeld, Michael J., ed. *Milestones of Space: Eleven Iconic Objects from the Smithsonian National Air and Space Museum.* Washington, DC: Smithsonian National Air and Space Museum in association with Zenith Press, 2014.

_____. *Spacefarers: Images of Astronauts and Cosmonauts in the Heroic Era of Spaceflight*. Washington, DC: Smithsonian Institution Scholarly Press, 2016.

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Orloff, Richard W. *Apollo by the Numbers: A Statistical Reference*. Washington, DC: Government Reprints Press, 2001.

Paul, Richard, and Steven Moss. *We Could Not Fail: The First African Americans in the Space Program.* Austin: University of Texas Press, 2015.

Piantadosi, Claude A. *Mankind Beyond Earth: The History, Science, and Future of Human Space Exploration*. New York: Columbia University Press, 2014.

Pickering, J. L., and John Bisney. *Picturing Apollo 11: Rare Views and Undiscovered Moments*. University Press of Florida, 2019.

Pyle, Rod. *Amazing Stories of the Space Age: True Tales of Nazis in Orbit, Soldiers on the Moon, Orphaned Martian Robots, and Other Fascinating Accounts from the Annals of Spaceflight*. Amherst, NY: Prometheus, 2017.

Riley, Christopher, and Philip Dolling. *NASA Apollo 11: Owners' Workshop Manual*. Somerset, UK: Haynes Publishing UK, 2010.

Schefter, James L. *The Race: The Complete True Story of How America Beat Russia to the Moon*. New York: Anchor, 2000.

Scott, David Meerman, and Richard Jurek. *Marketing the Moon: The Selling of the Apollo Lunar Program*. Cambridge, MA: The MIT Press, 2014.

Shetterly, Margot Lee. *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race*. New York: Harper, An Imprint of HarperCollins Publishers, 2016.

Siddiqi, Asif A. *The Soviet Space Race with Apollo.* Gainesville: University of Florida Press, 2003.

_____. *Sputnik and the Soviet Space Challenge.* Gainesville: University of Florida Press, 2003.

Tribbe, Matthew D. *No Requiem for the Space Age: The Apollo Moon Landings and American Culture*. Oxford: Oxford University Press, 2014.

Watkins, Billy. *Apollo Moon Missions: The Unsung Heroes*. Lincoln: University of Nebraska Press, 2008.

Weitekamp, Margaret. *Right Stuff, Wrong Sex: America's First Women in Space Program (Gender Relations in the American Experience)*. Baltimore: Johns Hopkins University Press, 2006.

Wolfe, Tom. *The Right Stuff*. London: Folio Society, 2009.

Woods, W. David. *How Apollo Flew to the Moon*. New York: Springer Praxis Books, 2011.

Worden, Al, and Francis French. *Falling to Earth: An Apollo 15 Astronaut's Journey.* Washington, DC: Smithsonian, 2011.

Young, Amanda, Mark Avino, and Allan Needell. *Spacesuits: The Smithsonian National Air and Space Museum Collection*. Washington, DC: Smithsonian National Air and Space Museum, 2009.

Books for Children and Families

Aldrin, Buzz. *Reaching for the Moon*. New York: HarperCollins, 2008.

Brinkley, Douglas. *American Moonshot Young Readers' Edition: John F. Kennedy and the Great Space Race*. HarperCollins Publishers, 2019.

Cruddas, Sarah. *The Space Race: The Journey to the Moon and Beyond*. New York: DK Publishing, 2019.

Dyer, Alan. *Mission to the Moon*. New York: Simon & Schuster for Young Readers, 2009.

Floca, Brian. *Moonshot: The Flight of Apollo 11*. New York: Scholastic, 2012.

Gifford, Clive. *The Race to Space: From Sputnik to the Moon Landing and Beyond*. London: Words & Pictures, an Imprint of the Quarto Group, 2019.

Gibbons, Gail. *The Moon Book*. New York: Holiday House, 1998.

Johnson, Katherine. *Reaching for the Moon.* New York: Simon & Schuster, 2019.

McNulty, Faith. *If You Decide to Go to the Moon.* New York: Scholastic, 2014.

Ottaviani, Jim. *T-Minus: The Race to the Moon*. New York: Aladdin, 2009.

Robbins, Dean. *Margaret and the Moon: How Margaret Hamilton Saved the First Lunar Landing*. New York: Alfred A. Knopf, 2017.

Suen, Anastasia. *Man on the Moon*. New York: Puffin, 2002.

Thimmesh, Catherine. *Team Moon: How 400,000 People Landed Apollo 11 on the Moon*. Boston: Baker & Taylor, 2015.

Film List
(as of July 2019)

The following selection of documentaries and feature films is designed to give students or visitors an opportunity to further explore the themes introduced in the poster exhibition.

Smithsonian Channel, available titles include:

- *America's Secret Space Heroes Episode 1: Saturn V* - This is the remarkable story of the engineers who built the most complex and powerful machine ever made by man, and the impact their phenomenal achievements continue to have to this day. (1)
- *America's Secret Space Heroes Episode 2: Lunar Module* - The story of the unsung heroes who built the unconventional flying machines that carried 12 Americans to the Moon on six separate missions. (1)
- *America's Secret Space Heroes* (forthcoming episode): *Survival of the Skies* - This episode will focus on spacesuits. (1)
- *The Day We Walked on the Moon* - On July 16, 1969, hundreds of thousands of spectators and an army of reporters gathered at Cape Kennedy to witness one of the great spectacles of the century: the launch of Apollo 11. Over the next few days, the world watched with wonder and rapture as humankind prepared for its "one giant leap" onto the Moon—and into history. Witness this incredible day, presented through stunning, remastered footage and interviews that take you behind-the-scenes and inside the spacecraft, Mission Control, and the homes of the astronaut's families.

Content can be viewed on the cable channel, via the Smithsonian Channel's website, or by requesting a screening license.

New Titles Released in 2019:

- *Apollo 50th Anniversary* (93 minutes, 1895 Films / National Geographic, July 2019)
- *Armstrong* (100 minutes, Gravitas Ventures / Tin Goose Productions, July 2019)
- *Chasing the Moon* (360 minutes, 3-part documentary, PBS, July 2019)

Available Titles:
Apollo's Daring Mission (53 minutes, 2018, PBS). Astronauts and engineers tell the inside story of Apollo 8, the first manned mission to the Moon. NASA decides on a risky plan to turn Apollo 8 from an earth-orbit mission into a daring trip to the Moon, relying on untried new technologies. Fifty years after the historic mission, the Apollo 8 astronauts and engineers recount the feats of engineering that paved the way to the Moon. (6)

Apollo 11 (93 minutes, 2019). An awe-inspiring documentary directed and edited by Todd Douglas Miller, the film consists primarily of newly discovered archival footage, some of which has never been seen before in a film. (5)

Apollo 13 (140 minutes, 1995). Based on the book written by Jeff Kluger and Joe Lovell, Kluger also advised on the film. NASA must devise a strategy to return Apollo 13 to Earth safely after the spacecraft undergoes massive internal damage putting the lives of the three astronauts on board in jeopardy. Winner of two Academy Awards, and the Golden Globe for Best Picture – Drama in 1996. (2)

Destination Moon (92 minutes, 1950). This sci-fi film's premise is that U.S. private industry will mobilize, finance, and manufacture the first spacecraft to the Moon. Won the Academy Award for Visual Effects in 1951. (3)

First Man (141 minutes, 2018). A look at the life of astronaut Neil A. Armstrong, and the legendary space mission that led him to become the first man to walk on the Moon. Based on the book *First Man: The Life of Neil A. Armstrong* by James Hansen. (2)

First Man on the Moon (54 minutes, 2016, PBS/NOVA). An in-depth portrait of Neil A. Armstrong, world-famous for being the first human to set foot on another celestial body. Highlights include his service in the military, as a test pilot and in the U.S. space program. Personal biographical highlights include discussions with family and friends. (2)

For All Mankind (73 minutes, 1989). *For All Mankind* creates the impression of a single space journey, and uses NASA footage and audio interviews. The only voices heard in the film are the voices of the astronauts and Mission Control. The score by Brian Eno underscores the strangeness, wonder, and beauty of the astronauts' experiences. Nominated for an Academy Award for Best Documentary in 1990. (2)

Hidden Figures (127 minutes, 2016). Adapted from Margot Lee Shetterly's book *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race*, the film focuses on three real-life African American female pioneers: Katherine Johnson, Dorothy Vaughan, and Mary Jackson, who were part of NASA's team of human "computers." Nominated for three Academy Awards in 2017 including Best Adapted Screenplay and Best Picture. (4)

The Last Man on the Moon (95 minutes, 2014). A documentary about Capt. Eugene Cernan, who holds the distinction of being the last human being to step on the Moon, during the Apollo 17 mission in December 1972. Apollo 17 was his third spaceflight, after Gemini IX in 1966 and Apollo 10 in 1969. This film combines rare archive material, compelling visual effects and unprecedented access to present an iconic historical character on the big screen. (5)

Le Voyage dans la Lune / A Trip to the Moon (12 minutes, 1902). Directed by Georges Méliès, this silent film was inspired by a wide variety of sources including Jules Verne's novels *From the Earth to the Moon* and *Around the Moon*. The film follows a group of astronomers who travel to the Moon in a cannon-propelled capsule. (3)

Magnificent Desolation: Walking on the Moon 3D (40 minutes, 2005). This program strives to give the viewer an impression of what it is like to actually be on the Moon. It provides a romantic, inspirational depiction of the Apollo astronauts' travels on the Moon, peppered by quotations of their impressions. The film's producers called upon a number of resources, including thousands of Apollo photographs from the NASA archives, the *Apollo Lunar Surface Journal*, combined with nine weeks' worth of live-action shots on a soundstage with considerable use of computer-generated imagery (CGI) to make the visuals look as realistic as possible. (2)

Missile to the Moon (101 minutes, 2017). Created by Alabama Public Television, *Missile to the Moon* tracks the evolution of Huntsville, AL, from "Watercress Capitol of the World" to "Rocket City, USA" and Wernher von Braun's journey from German Missile Engineer to American Hero and the role this unlikely combination played in the history of space exploration. Features commentary by Smithsonian National Air and Space Museum curator Michael Neufeld. (6)

Mission Control: The Unsung Heroes of Apollo (101 minutes, 2017). Along with plenty of archival NASA videos and photos, the documentary features several of the original flight-control staff who worked in the Manned Spacecraft Center (later renamed the Christopher C. Kraft Jr. Mission Control Center) at the Johnson Space Center in Houston during the 1960s and 1970s. (7)

Moon Machines (265 minutes, 6-episodes, 2008). *Moon Machines* was created for the Science Channel by the team who made *In the Shadow of the Moon* (see below) in association with NASA to commemorate the agency's fiftieth anniversary in 2008. The miniseries features interviews with around 70 of the 400,000 individuals who worked on the Apollo program during the 1960s and early 70s. These interviews are intercut with archive film, sourced from NASA's various film archives stored at the Johnson Space Center in Houston, Texas, the Glenn Research Center in Cleveland, Ohio, and from the National Archives in Washington, DC. (3)

The Saturn V Story (53 minutes, 2014). This is the story of the most powerful machine ever built, and the men and women who believed it could fly. Using visual effects, stunning NASA footage and expert interviews with Apollo space scientists, this inspirational film tells the story of the colossal challenges NASA faced to fulfill Kennedy's pledge. (2)

In the Shadow of the Moon (100 minutes, 2007). This documentary reviews both the footage and media available to the public at the time of the Apollo missions, as well as NASA films and materials. Augmenting the archival audio and video, including television footage featuring journalists such as Jules Bergman and Walter Cronkite, are contemporary interviews with some surviving Apollo-era astronauts, including Al Bean, Michael Collins, Buzz Aldrin, John Young, David Scott, Charlie Duke, Eugene Cernan and Harrison Schmitt. (3)

(1) Summaries from the Smithsonian Channel
(2) Adapted from IMDB
(3) Adapted from Wikipedia
(4) Adapted from Popular Mechanics review
(5) Adapted from New York Times review
(6) Adapted from PBS
(7) Adapted from Space.com review

Lesson Plan: Astronaut Training Activities

What are the challenges to living and working in space? Do some "Astronaut Training" to find out!

Target age: 5-12

Topic(s): living and working in space, weightlessness, spacesuit and gloves, dexterity and fine motor skills

Goals:
In this activity, students will:

- Learn the parts, materials, and design development of an EVA (extravehicular activity, commonly known as a spacewalk) or EMU (extravehicular mobility unit, commonly known as a spacesuit) glove
- Explore the hand fatigue experienced by astronauts working in space, by testing their own dexterity and flexibility wearing an approximation of space gloves
- Understand that controlling the body is a challenge in a weightless environment
- Appreciate the complexities of working in space

Standards:
Next Generation Science Standards: Science and Engineering Practices: Analyzing and Interpreting Data, Crosscutting Concepts: Structure and Function

Materials:

- Apollo 11 replica gloves (can be purchased by special request here: http://www.guard-lee.com/space_suits.php OR ski/winter gloves similar to the following: http://bit.ly/2jbFdwk)
- Pliers
- Plastic cups
- Paper clips
- Rolling desk chair
- Wrench
- Flat board with pre-drilled hole and bolt fitted into it

Process:
Invite students to try on the gloves and complete various simple movements and tasks, such as flexing the hand and wrist, and touching the tip of the thumb to the tip of each finger.

Engage students in discussion surrounding:
- *Materials, design, protection*
- *Improvements in glove technology*
- *NASA Centennial Challenges* (depending of level of students)

Next, invite students to grip or pick up everyday objects (such as pennies, paper clips or plastic cups). Use larger objects for younger participants, and decrease the size to increase the challenge.

Introduce simple tools (such as pliers) to capture everyday objects (such as pennies, paper clips, or plastic cups) using the gloves.

Engage students in discussion surrounding:
- C*hallenges such as loss of strength, grip, sensitivity, flexibility, and the high risk of injury*

Invite participants to take a seat in a rolling desk chair, and without holding on, attempt to use the wrench to screw in the bolt. This will be challenging – **the chair will roll and move**. Please make sure chair is located in a safe area before beginning this portion of the activity.

Engage students in a discussion surrounding:
- Roles and responsibilities of an astronaut living and working in space
- Challenges faced in a weightless environment

Key Background Concepts:

- Current spacesuits used by astronauts are called Extravehicular Mobility Units (EMU).
- The EMU carries air/oxygen, regulates temperatures and protects astronauts from micro-meteorites and radiation.
- The Apollo suit weighed about 180 lbs. Current spacesuits weigh about 300 lbs on Earth. This weight is not really felt in space, although astronauts do experience a bit of resistance when moving.
- Cost is hard to calculate, as much of the cost is in research and development. Spacesuits cost several million dollars to produce, but they are reusable.
- Unlike Apollo-era spacesuits that were custom-fit for each astronaut, contemporary EMU are created of standardized component parts that can be mixed and matched to make suits for several different individuals.
- A liquid cooling and ventilation garment is worn under the EMU. Ducting along the arms and legs directs oxygen and carbon dioxide from the suit to the life support system for purification and recirculation.
- There is a football-field length of tubing in the liquid cooling and ventilation garment. Water is circulated from the life support system to help maintain body temperature and keep astronauts from overheating during periods of high activity.
- NASA does not custom fit gloves to individuals anymore, but they do have a process of getting the glove to be as close to a custom fit as they can. This is an ongoing design challenge for NASA design teams.
- Astronauts have to overcome many obstacles to do work in space, but with each spacewalk, they gain greater understanding of how to survive in a foreign environment.

- During the early space race, each mission built on the lessons learned during the previous ones. This was critical to reaching the Moon in such a short period of time from the start of the space program.
- Though a weightless environment seems like fun, controlling the body while conducting experiments, vehicle maintenance and other important tasks can be a challenge.
- The big takeaway: it is hard to work with gloves. Contemporary astronauts work with staff to identify off-the-shelf gloves that fit very well and then train using those gloves. A discussion with students about the benefits and challenges of custom gloves, such as in the Apollo era, vs. today's standardized sizing system is suggested to help summarize the lessons from this activity.

Additional Resources:

- History of Spacesuits: https://history.nasa.gov/spacesuits.pdf
- Spacesuit (use "The Clickable Spacesuit" to find out more information on gloves) http://www.nasa.gov/audience/forstudents/5-8/features/what-is-a-spacesuit-58.html
- Space Work http://spaceflight.nasa.gov/living/spacework/index.html
- NASA Spacesuit Facts https://www.nasa.gov/audience/foreducators/spacesuits/facts/index.html
- NASA EMU Glove Challenge http://www.nasa.gov/audience/foreducators/holding-a-winning-hand_prt.htm

Lesson Plan: Materials Innovation Exploration

Research and design work by and for the space program has resulted in a wide array of materials and technologies we all can enjoy in our daily lives. Let's explore!

Target Age: 6-14

Topics: Industry & Innovation

Goals:
In this activity, students will:

- Be introduced to several innovations that were created as a result of the space program throughout the 20th century
- Match the materials from the space program with everyday objects
- Appreciate how space exploration improves our everyday lives
- Learn about specific objects in the Smithsonian collections

Standards:
Next Generation Science Standards: Science and Engineering Practices: Asking questions (for science) and defining problems (for engineering), Developing and Using Models, Planning and Carrying Out Investigations; K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

Materials:

- Printed and/or laminated images of items such as a space drill, an infrared telescope, and construction insulation
- Objects:
    - Memory Foam (one can purchase custom-cut squares online: for example: https://www.buyfoam.com/Store/Shapes/Square.aspx)
    - Nike "Air" Sneaker OR Avia Sneaker (available online from many sources)
    - Dustbuster® (http://bit.ly/2xaViYm)
    - Space Blanket (https://www.buyemp.com/product/curaplex-emergency-mylar-blanket/12945-EACH?gclid=EAIaIQobChMIwIX13e-V1gIVy7bACh0atgdEEAkYASABEgJlmvD_BwE)
    - Ear Thermometer (http://bit.ly/2jbrEgo)
- Investigation Worksheet (see page 23)

Preparation and Placement:
This activity can be conducted in one of several ways:

1. As workshop-based materials exploration with students divided in groups
2. As a tabletop display or a rolling cart for materials exploration

Instructions for a student group below.

Process for Discussion of Objects or Images of Objects:

Investigate the following objects in a large group format:

- Spacesuits https://www.asme.org/wwwasmeorg/media/ResourceFiles/AboutASME/Who%20We%20Are/Engineering%20History/Landmarks/ApolloBR.pdf (pages 6-7)
- Space Gloves and Helmet https://airandspace.si.edu/stories/editorial/neil-armstrongs-apollo-11-extravehicular-gloves-and-visor
- Lunar Overshoes https://airandspace.si.edu/collection-objects/boot-left-lunar-overshoe-cernan-apollo-17-flown
- Command Module *Columbia* https://3d.si.edu/

This conversation could include the following questioning strategies:

- A Visual Thinking Strategies (VTS) style of investigation which allows for students to discuss what they notice and what types of personal associations they are able to make. The questions used in this strategy are very limited—and the role of the facilitator is simply to reiterate comments from the group. Questions include:
    - What do you see?
    - What can we say about this object?
    - What do you see that makes you say that?
    - What more can we say about this object?

  Summarize comments at the end of the conversation (3-5 minutes for each object).

- Guided questioning to directly focus on materials and technologies. Questions to use here could build on the VTS conversation and might include the following:
    - How do you think this object was used?
    - What does it look like this object is made of?
    - Why might someone choose these materials? What benefits do these materials provide? (for example, durability and flexibility for the overshoes, heat protection for the Command Module, *Columbia*, or accuracy for the star chart)

  Acknowledge all responses and follow up with “What makes you say that?” for answers in which you need clarification or wish to further prompt the students to think beyond an immediate reaction. Provide correct and appropriate information about each object and its function, materials, and attributes.

  Summarize comments at the end of the conversation (5-8 minutes for each object).

Wrap-up, transition:

- The early years of space exploration required NASA and their contracted suppliers to create solutions to a wide variety of new problems.
- Many of the new materials and innovations that solved those problems also led to innovations in our daily lives.
- We're going to transition to a workshop (or investigation) where we can investigate some of the things we use every day and see what connections we can make to the Space Program and Apollo 11.

Process for Workshop-based Materials Exploration:
Divide the students into groups of 3-5. Each group will be given an object to "investigate" using the sheet provided on page 23.

Before passing out each object, encourage the following:

- Do a thorough investigation of the object, note things like color, flexibility, structure
- Create an image of your object on the worksheet provided—you can make written notes in the "description" section
- Discuss with classmates—how could this material be related to the space program? What attributes does the object have? How could those attributes be beneficial in space?

Circulate among the groups--you will almost certainly have to provide "hints" for several of the objects.

Leave time to share out as a large group—each group should present the following:

- Brief description of object and its attributes
- Educated guess about connections to space programs

Facilitator will provide:

- Background information
- Share relevant additional photos (if using printed or laminated images as described on page 17)

Memory Foam:
Four decades after its emergence, the world has come to realize that there are many uses for this material. Though the rights to the technology have been shared amongst various manufacturers, the original product-maker, Dynamic Systems, Inc., is still active, advancing the use of temper foam into new arenas. Dynamic Systems founder Charles Yost created an open-cell, polymeric memory foam material that is both high-energy absorption and soft to the touch. NASA's Ames Research Center fit this cushion-like material into a new airplane seat design that not only offered better impact protection in the event of an accident but enhanced passenger comfort on long flights. Today temper foam is branching out far from its original applications. Uses include: shock absorption

added safety in NASCAR Formula 1 Champion Auto Racing Team (CART) and Indy Racing League racecars; motorcycle and horseback saddles; amusement park rides; and military and civilian aircraft. The technology has even been incorporated into archery targets, full-sized body casts for custom-clothing design, human and animal prostheses, and of course, mattresses.
NOTE: This product does not have a direct connection to Apollo 11.

Dustbuster®:
Among the most important tasks performed by Apollo astronauts on the Moon was collection of lunar rock and soil samples for later analysis on Earth. This necessitated development of a special lunar drill capable of extracting core samples from as much as 10 feet below the surface. The drill had to be highly efficient to cut through the (sometimes) hard lunar surface layer, and, like everything that went to the Moon, it had to be lightweight and compact. Most importantly, it had to have its own independent power source. Although the tool could have operated on power from the Lunar Module, the astronauts' home and operating base, scientific requirements dictated sampling at diverse locations, some of them far from the base. The job of developing the drill was entrusted to The Black & Decker Manufacturing Company. They created a battery-powered, magnet-motor system that proved successful in lunar work. The technology was later used in several household appliances, including the handheld vacuum (also known as the DustBuster).

Nike “Air” Sneakers:
During the late 1970s to early 1980s, NASA used a process known as “blow rubber molding” to create their space helmets. Blow rubber molding consists of melted plastic being inserted into a mold, and compressed air being pumped into it, conforming it to the inside of the mold. The new design is taken out of the mold, and the area where the air was pumped into it is sealed shut, creating an air-filled pocket.

In 1979, Frank Rudy, a NASA employee at the time, came up with an idea to use this sealed cushioning system as the midsole in shoes. During that time, the midsole was almost always foam, which compressed quickly, causing the shoes to become uncomfortable in a short period of use. Using blow rubber molding, a midsole that was a sealed compartment would never deflate or compress. Rudy went to Nike and drew up a design for the first Nike air-cushioned running shoe. The air-cushioning system was put into tennis and basketball shoes three years later. The air-cushioned Nike basketball shoe, the Nike Air, is still around today.

OR

Avia Running Shoes:
Avia contracted with Alexander L. "Al" Gross of Lunar Tech, Inc., Aspen, Colorado, to design an advanced shoe that would retain its shock absorption, stability and flexibility properties over a substantially longer lifetime. Al Gross turned to space technology, being an aerospace engineer who had won a number of awards and citations for his work in spacesuit design, including NASA's Apollo Achievement Award for his

contribution to man's first exploration of the Moon. Gross worked with ILC Industries, Dover, Delaware, during and after NASA's Apollo lunar landing program, eventually becoming lead design engineer.

A task force composed of Al Gross with Avia research, design and development personnel agreed upon a solution: a "rigid/flexible" system similar to a pressurized spacesuit. Being pressurized, the spacesuit is rigid - but it must have sufficient flexibility to allow the astronaut to move. The big challenge is to provide astronaut mobility at the joints. The answer, in the Apollo suit and later suits, was the "convolute system," a series of bellows in the joint areas that expand and contract (compress) every time a motion is made. By layering or combining materials, and varying the shape, size and the number of bellows, spacesuit designers can vary joint flexibility. The spacesuit technology was applied to the Avia shoe project.

Space Blanket:
The Apollo and subsequent spacecraft have had highly effective radiation barriers; made of aluminized polymer film, they bar or let in heat to maintain consistent temperatures inside. Tech 2000, formerly Quantum International Corporation, used the NASA technology in its insulating materials, Super Q" Radiant Barrier for home industry and mobile applications. The insulation combines industrial aluminum foil overlaid around a core of another material, usually propylene or mylar. The outer layer reflects up to 97 percent of heat; the central layer creates a thermal break in the structure and thus allows low radiant energy emission. The technology is now being used in home insulation, but the basics of this technology give us “space blankets” which are often used at the end of a marathon to insulate the runner’s body (also used in emergencies, or in extreme sporting and camping).

Ear Thermometer:
Diatek Corporation*, San Diego, CA, and the Jet Propulsion Lab developed the Diatek Model 7000 (now marketed as SureTemp) aural thermometer which weighs only eight ounces, and measures temperature in less than two seconds using infrared astronomy technology to measure the amount of infrared energy emitted by the eardrum (the same way the temperature of stars and planets is measured). This method avoids contact with mucous membranes, virtually eliminating the possibility of cross infection, and permits temperature measurements of newborn, critically ill, or incapacitated patients.
*Diatek Corporation was purchased by Welch Allyn Inc.
NOTE: This product does not have a direct connection to Apollo 11.

Surprising Facts:
Tang was formulated by a General Mills food scientist in 1957, but didn’t become popular until John Glenn drank it on his spaceflight. It has since had a close association with the spaceflight program but was not created by or for NASA.

Teflon (Polytetrafluoroethylene, or PTFE) was accidentally discovered in 1938 by Roy Plunkett while he was working in New Jersey for DuPont. Teflon was applied to heat shields, spacesuits, and cargo hold liners, but similar to Tang, was not created by or for NASA.

Joysticks were used on the Lunar Rover, but were originally developed to control airplane ailerons (located on the wings) and elevators (located on the horizontal stabilizer at the rare of an aircraft). This style of controller dates back as far as 1908.

Wrap-Up:

- Reconnect investigations with the Apollo 11 objects that were pictured in the poster exhibition
- Reiterate the ways in which space exploration is changing our lives
- Thank students for their work

Process for Table-top Display and Exploration:
Arrange an inviting array of objects on a cart or table top. As visitors approach, draw them into conversation about a specific object. What catches their eye? Following similar questioning strategies as described in the Workshop process, allow visitors to note qualities of an object, and guess at how it might be related to the Space Program. Provide hints as needed to prompt the conversation.

Additional Resources:

- Memory Foam
  https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20060022025.pdf
- NASA Spinoff Technology – Cordless Tools
  https://spinoff.nasa.gov/spinoff2001/johnson_mill.html
- Sneakers
  https://www.nasa.gov/missions/science/f_apollo_11_spinoff.html
  https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020086325.pdf
- Insulation Blankets
  https://www.nasa.gov/vision/earth/technologies/silver_insulation.html
- Infrared Thermometer
  https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020086347.pdf

Space Materials Investigation Worksheet

Exploring space challenged inventors, engineers and scientists to solve new problems. Some of their inventions made our lives here on Earth easier. Investigate this object and see if you can discover how it might be connected to the space program.

Draw a picture of your object here:

Describe this object. What materials is it made from? What are the benefits of this material? What could this object be used for?