PRE-VIDEOCONFERENCE LESSON PLAN

Pioneers in Science: The World Science Festival

Date:	Friday, May 30, 2014
NYC Arrival Time	10:45 AM EDT
Broadcast Start Time:	11:30 AM EDT
Dial-in Time:	11:00 AM EDT
Duration:	60 minutes
Virtual Participant Testing Date:	Wednesday, May 28, 2014 10:00 -10:15 AM EDT

Pioneer Biography

John Grunsfeld,

[1]John M. Grunsfeld, astronaut and physicist, was named Associate Administrator for the Science Mission Directorate at NASA Headquarters in Washington, D.C. in January 2012. Since then, he oversees the agency's $5.1 billion science budget. The Science Mission Directorate sponsors research that both enables, and is enabled by, NASA's exploration activities. They focus on:

- Mars
- Search for Earth-like planets and habitable environments around other stars
- Explore the solar system for scientific purposes while supporting safe robotic and human exploration of space.

[2]Dr. Grunsfeld previously served as the Deputy Director of the Space Telescope Science Institute in Baltimore, managing the science program for the Hubble Space Telescope and the forthcoming James Webb Space Telescope. Grunsfeld's background includes research in high energy astrophysics, cosmic ray physics and in the emerging field of exoplanet studies with specific interest in future astronomical instrumentation.

Grunsfeld graduated from the Massachusetts Institute of Technology in 1980 with a bachelor's degree in physics. He subsequently earned a master's degree and, in 1988, a doctorate in physics from the University of Chicago using a cosmic ray experiment on space shuttle Challenger for his doctoral thesis. From Chicago, he joined the faculty of the California Institute of Technology as a Senior Research Fellow in Physics, Mathematics and Astronomy.

Pioneering Highlights:

- Veteran of five space shuttle flights
- Major force behind the Hubble Space Telescope, for which we continue to receive very important information. Specialty was keeping America's most valuable space instrument (Hubble) alive, healthy and working. Dr. Grunsfeld was the Chief Hubble Repairman for over 18 years.
- Visited the Hubble Space Telescopes three times and performed 8 spacewalks to service and upgrade the observatory. Recognized for keeping the telescope serving the science community for years past its expected lifetime.
- Was on final historic servicing mission to the Hubble Space Telescope.
- Logged more than 58 days in space on his shuttle missions, including 58 hours and 30 minutes of spacewalk time—the 4th highest cumulative hours spacewalking. One of his spacewalks (8 hours) was one of the longest to date. (The longest was eight hours and 56 minutes and was performed by NASA astronauts Jim Voss and Susan Helms on March 11, 2001.)

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[2] NASA. (n.d.). Astrophysics. http://science.nasa.gov/astrophysics/.
[3] NASA. (n.d.). Astrophysics. http://science.nasa.gov/astrophysics/.
[4] NASA. (n.d.). Astrophysics. Retrieved on April 12 from http://science.nasa.gov/astrophysics/.

GUIDING QUESTION
What important discoveries have we made because of images taken from the Hubble Space Telescope?

VIDEOCONFERENCE OUTLINE:

The following is the VC format. Please refrain from asking your question until your school is called upon to speak.

I. Opening Remarks (2 minutes)
Moderator opens the videoconference and thanks all participants and introduces all of the interactive sites. Moderator also gives a general breakdown of the conference and reminds students about the basic rules of videoconferencing.

II. Introduction (10 minutes)
Moderator will provide a brief overview of the conference; then they will introduce the guest speaker, Dr. Grunsfeld. WSF will show a short clip to provide an overview of the videoconference. Dr. Grunsfeld will give brief remarks to begin the program.

III. Discussion With Peers (40-45 minutes)
Moderator will facilitate the discussion as students ask questions to Dr. Grunsfeld. Dr. Grunsfeld will also have the opportunity to pose questions to the students. The questions will be conducted in a round-robin format.

REFLECTION/PRE-VIDEOCONFERENCE PREPARATION ACTIVITY

Here is your opportunity to ask Dr. Grunsfeld questions relating to his work. Review the questions you identified in the "What I Want to Know More About" Chart and write them below:

1.

2.

3.

The following are sample questions.

- Why do you think it is important for young people to be interested in pursuing science-related careers?
- Will we send people to Mars at some point in this century?
- What are the greatest scientific discoveries from the Hubble Space Telescope?
- How do you think the James Webb Telescope will be a more powerful scientific tool?
- How do robots and humans work together in space?

IV. Conclusion (3 minutes)

Moderator thanks all students, teachers and guest speaker for participating.

VIDEOCONFERENCING TIPS FOR PARTICIPANTS:

- When beginning to speak or pose a question, ***state your name and school***.
- ***Speak loudly, slowly and clearly*** into the microphone. Express your personality but avoid using slang and be concise whenever possible. Remember to mute the microphone when you are finished speaking.
- Please ***say "Thank you" when you conclude your statements*** or questions.
- ***Look into the camera*** when speaking. Use slow, smooth, minimal gestures.
- Try to ***avoid wearing very bright colors*** during the videoconference as this can have a negative impact on the quality of the image.
- ***Ask thoughtful questions and respond to all answers with respect***. Express your opinions in a positive manner. Avoid asking off-topic or inappropriate questions. ***Stick to the subject.***
- Due to the technological constraints of videoconferencing, please understand ***only one person can speak at a time***. Be sure to wait for the delay in audio so that you avoid interrupting others. Do not speak over others; you will be called to present or respond to a question.
- Pay close attention to the speakers and the topic at hand. ***Use your facial expressions and nod or smile to express interest***, attentiveness and participation.
- Have ***paper and pencil/pen available to jot down notes or ideas*** so that you may comment on them when it is your turn.

THANK YOU FOR YOUR PARTICIPATION! ☺

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LESSON PLAN OVERVIEW AND INSTRUCTIONS	
TIME 1-2 Days, depending on structure and length of class	**GRADE** 9th - 12th Grade
LESSON OVERVIEW The following activities are designed to prepare students to participate in an informed inquiry with Dr. Grunsfeld. Activity #1 will broadly introduce students to the world of astrophysics through becoming familiar with significant scientific achievements of the past century. Activity #2 will explore the work of Dr. Grunsfeld specifically, and his work on the Hubble Space Telescope.	

ACTIVITY #1

Astrophysics

TIME	MATERIALS
1 hour	Pen/pencil; "Discovering the Universe Timeline" (Appendix 1, p. 9); Questions No One Knows The Answers To Video; "Discovering the Universe Timeline: Practice" (Appendix 2, p. 12)

INSTRUCTIONS

Introduction

[3]Astrophysics is the study of the physical and chemical properties and structures of stars, planets and other objects in outer space. The scientific study of astrophysics seeks to discover how the universe works, explore how the universe began and developed into its present form and search for Earth-like planets. Which question is most important to you? Can each of these questions be answered?

1. There are countless questions that no one knows the answers to.
   Watch video: https://www.youtube.com/watch?v=7SWvDHvWXok

2. Although there are many questions we as humans may never know the answers to, scientists over the last 100 years have made many discoveries to uncover the mysteries of the Universe. Read through the "Discovering the Universe Timeline" in small groups (Appendix 1, p. 8-10). In these groups, individually chose one event within each category, which you found most interesting. Answer the following questions and share your answers with your group members:
   - ***Why is this event interesting?***
   - ***How does this influence my life today?***
   - ***How may it influence my life in the future?***

3. As a group, come to a consensus on one event in any category to share with the class. Explain the significance of the event to the whole class. In your explanation, be sure to answer the above three questions.

4. Class Discussion:

[3] NASA. (n.d.). Astrophysics. http://science.nasa.gov/astrophysics/.

Engage in a discussion about the events selected, their importance, and their impact on you as a teenager, on your school, and on your community.

- ***Do you agree or disagree with one another?***
- ***What would you like science to accomplish in the near future? In your lifetime?***

5. Challenge Yourself:
   Test your Memory! In one minute, how much information can you recall from the timeline? (Appendix 2, p. 11).

ACTIVITY #2

Are We Alone?

Time: 1 hour	**Materials:** Pen/Pencil, Computer with internet access, "Astrophysics Basics (Appendix 3, p. 12), "Last Voyage for the Keeper of the Hubble" (Appendix 4, p. 13 - 15), "What I Know, Learned, Want to Know" Chart (Appendix 5, p. 16).

Instructions:

In this 3-Part Assignment, students will learn more about astrophysics research and the life and work of Dr. Grunsfeld. In Part I, students will brainstorm what they already know about astrophysics. Part II introduces students to the life and work of Dr. Grunsfeld on cosmology. Finally, Part III will prepare students for their upcoming conversation with Dr. Grunsfeld by encouraging them to draft questions they've developed based on what they've learned.

Part I

1. Brainstorm answers to the following question:
   - What contributions has the Hubble Space Telescope made to the study of astrophysics?
   - What does a planet need to support life?

2. Read "Astrophysics Basics" (see Appendix 3, p. 12)

3. Create a visual (diagram, picture) that shows the relationship between each of the following vocabulary words:
   - Astrophysics
   - Cosmology
   - Universe
   - Hubble Space Telescope
   - Mars Exploration

4. Dr. Grunsfeld studies astrophysics. List 5 things that you KNOW about astrophysics:

What I KNOW
1.
2.
3.
4.
5.

Part II

Now that you've brainstormed all you already know about astrophysics research, it's time to deepen your understanding!

1. **Read** the following article and **Watch** the following video clip to learn more about the Universe and the work of Dr. Grunsfeld:
   - Read: Last Voyage For The Keeper of Hubble
     http://www.nytimes.com/2009/04/14/science/space/14prof.html?pagewanted=all&_r=0

- Watch: Comedian Stephen Colbert Talks with NASA's John Grunsfeld About Curiosity Rover Landing. http://www.universetoday.com/96567/comedian-stephen-colbert-talks-with-nasas-john-grunsfeld-about-curiosity-rover-landing/#ixzz2zXcNNmZi

2. In pairs or small groups, discuss the following questions:
   - *What motivated Dr. Grunsfeld to pursue a career in astrophysics?*
   - *What can the Hubble Space Telescope tell us about the universe?*
   - *What role do you think the Hubble Space Telescope has played in helping further scientific research in astrophysics?*
   - *Do you believe that there is life on other planets?*

3. List 5 things that you LEARNED about how Dr. Grunsfeld's work has expanded our knowledge of Earth and the Universe:

What I LEARNED
1.
2.
3.
4.
5.

Part III

1. On Friday, May 30th you and your classmates will have the opportunity to engage with Dr. Dr. Grunsfeld about his research and his work. List 5 questions that you WANT TO KNOW related to the work of Dr. Grunsfeld and his role as an astronaut and fixing Hubble as well as his new role, leading the science of NASA.

What I WANT TO KNOW
1.
2.
3.
4.
5.

Final Activity

At this point, you have gathered three lists (What I know, What I learned, What I want to know). Gather your three lists together into one chart (see Appendix 5, p. 16). From the final column (What I want to know more about), select 3 questions that you would like to ask Dr. Grunsfeld.

REFLECTION/PRE-VIDEOCONFERENCE PREPARATION ACTIVITY

Here is your opportunity to ask Dr. Grunsfeld questions relating to his work. Review the questions you identified in the "What I Want to Know" Chart and write them below:

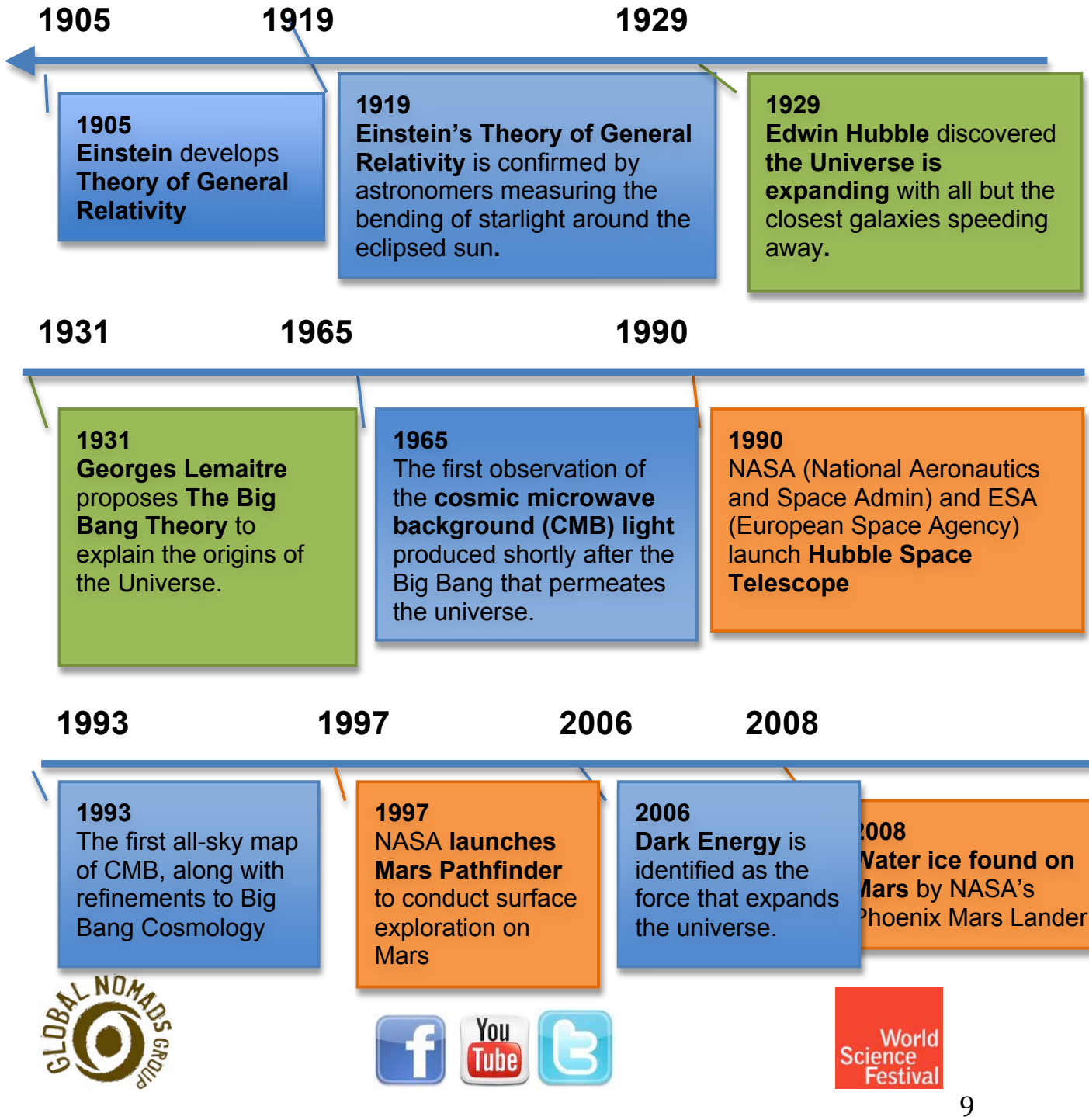
1.
2.
3.

Appendix 1

Discovering the Universe Timeline

Directions: Use the timeline to identify how scientists have been able to answer each of the questions listed below over the last 100 plus years. Which questions remain unanswered?

Categories	Related Questions
1. **How does the Universe work?**	How do matter, energy, space, and time behave under the extraordinarily diverse conditions of the cosmos?
2. How did we get here?	How did the universe originate and evolve to produce the galaxies, stars and planets we see today?
3. **Are we alone?**	What are the characteristics of planetary systems orbiting other stars, and do they harbor life?



Appendix 1 (continued)

Discovering the Universe

1905

Einstein develops **Theory of General Relativity.** Einstein determined that the laws of physics are the same for all non-accelerating observers, and that the speed of light in a vacuum was independent of the motion of all observers. This was the theory of special relativity. It introduced a new framework for all of physics and proposed new concepts of space and time.

Resources: http://www.space.com/17661-theory-general-relativity.html
http://science1.nasa.gov/science-news/science-at-nasa/2004/26mar_einstein/

1919

Einstein's Theory of General Relativity is confirmed by astronomers measuring the bending of starlight around the eclipsed sun**.** According to Einstein's Theory of General Relativity, the sun's gravity causes starlight to bend, shifting the apparent position of stars in the sky. Relativity explains gravity and motion by uniting space and time into a 4-dimensional, dynamic, elastic fabric of reality called space-time, which is bent and warped by the energy it contains. (Mass is one form of energy, so it creates gravity by warping space-time.)

Resources: http://science1.nasa.gov/science-news/science-at-nasa/2004/26mar_einstein/

1929

Edwin Hubble discovered **the universe is expanding** with all but the closest galaxies speeding away**.**

Resources: http://www.spacetelescope.org/about/history/the_man_behind_the_name/

1931

Georges Lemaitre proposes **The Big Bang Theory** to explain the origins of the universe. Building on Hubble's discovery he realized there must have been an instant in time (now known to be about 14 billion years ago) when the entire Universe was contained in a single point in space. The Universe must have been born in this single violent event which came to be known as the "Big Bang." Astronomers combine mathematical models with observations to develop workable theories of how the Universe came to be. The mathematical underpinnings of the Big Bang theory include Albert Einstein's general theory of relativity along with standard theories of fundamental particles.

Resources: http://science1.nasa.gov/media/medialibrary/2010/03/31/dark_expansion.jpg
http://science1.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/

1965

The first observation of the **cosmic microwave background (CMB) light** produced shortly after the Big Bang that permeates the universe. According to scientists, CMB is background radiation left over from the Big Bang. Scientists argue that CMB offers proof of the Big Bang Theory and provides insight into the composition of the Universe.

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Resources: http://www.space.com/20330-cosmic-microwave-background-explained-infographic.html

Appendix 1 (continued)

1990

United States National Aeronautics and Space Administration (**NASA**) and the European Space Agency (**ESA**) launch **Hubble Space Telescope**. The telescope measures the expanding universe.

Resources: *http://www.nasa.gov/mission_pages/hubble/story/index.html*
http://science1.nasa.gov/science-news/science-at-nasa/1999/ast25may99_1/

1993

The first all-sky map of **CMB**, along with refinements to Big Bang Cosmology

Resources: *http://science1.nasa.gov/science-news/science-at-nasa/2000/ast27apr_1/*

1997

Launched by **NASA**, **Mars Pathfinder** lands on Mars to conduct surface exploration and data collection.

Resources:
http://news.bbc.co.uk/onthisday/hi/dates/stories/july/6/newsid_4105000/4105727.stm;
http://www.nasm.si.edu/etp/mars/explore.html

1998

Dark energy discovered. In 1998 Hubble Space Telescope (HST) observations of very distant supernovae showed that the Universe is expanding faster today than ever before. These observations proved that the expansion of the Universe has not been slowing due to gravity, as everyone previously thought, it has been accelerating. Theorists don't know what the correct explanation for acceleration is but they have given the solution a name. It is called dark energy.

Resources: *http://science1.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/*

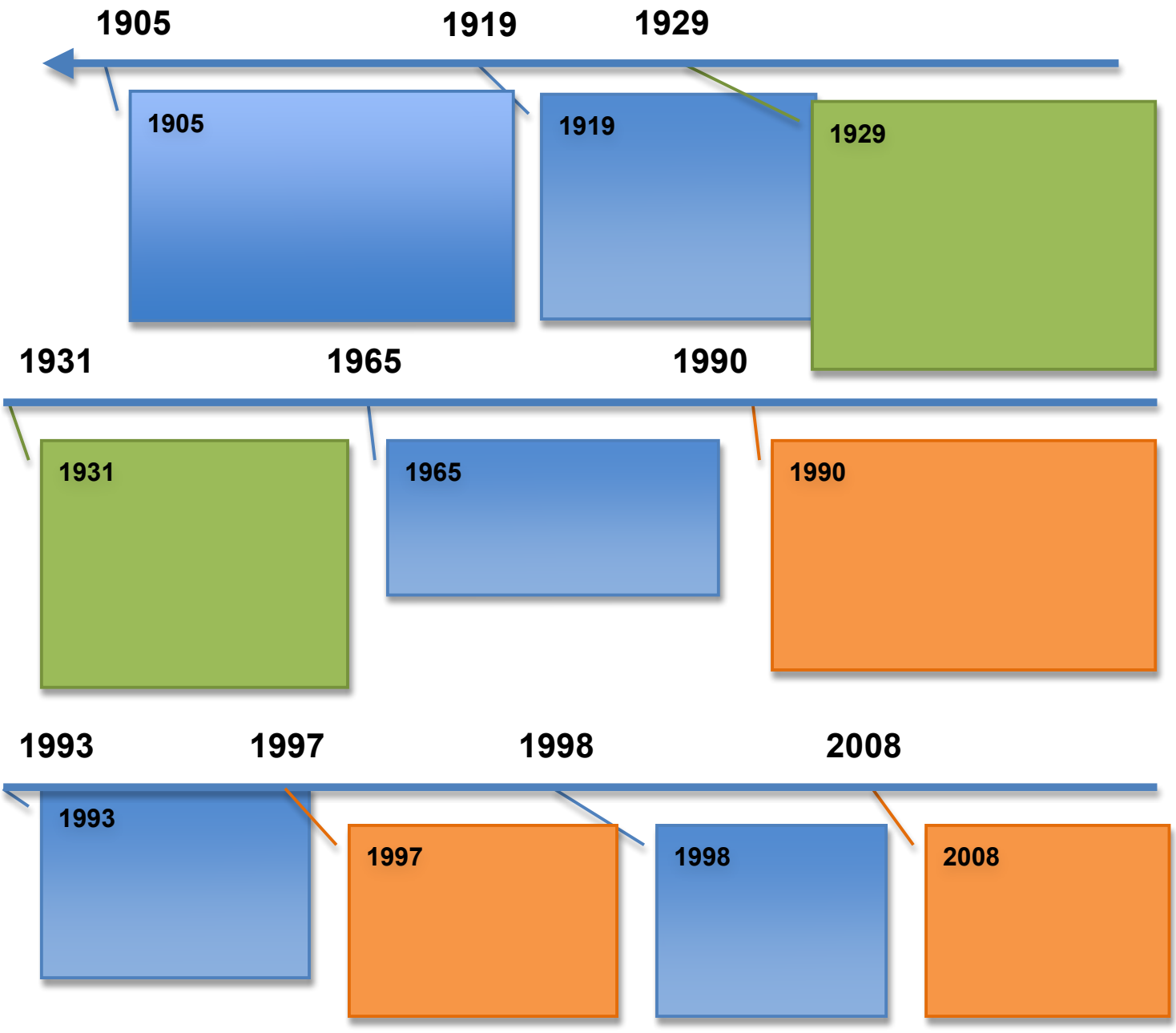
2008

Scientists confirm that they “found proof” of water ice on Mars away from the polar ice caps, a discovery made by **NASA’s Phoenix Mars Lander**.

Resources: *http://science.nasa.gov/science-news/science-at-nasa/2002/28may_marsice/*

Appendix 2

Discovering The Universe Timeline



Appendix 3

Astrophysics Basics

Astrophysics

[4]Astrophysics is the study of the physical and chemical properties and structures of stars, planets and other objects in outer space. The scientific study of Astrophysics seeks to discover how the universe works, explores how the universe began and developed into its present form and searches for Earth-like planets.

Cosmology

Cosmology is a branch of astrophysics that specifically studies the origin, evolution, and eventual fate of the universe.

Universe

Everything that exists, including the Earth, planets, stars, galaxies, and all that they contain; the entire cosmos.

Hubble Telescope

[5]Hubble is the first major optical telescope to be placed in space. Scientists have used Hubble to observe the most distant stars, galaxies and planets in our universe.

Mars Exploration

The exploration of Mars has largely focused on the question: Was there life on Mars? Exploration has revealed that Mars is similar to Earth in many ways, however, Mars continues to challenge our perception of what makes a planet work.

Instructions: Create a visual (diagram, picture) that shows the relationship between each of the vocabulary words listed above.

[4] NASA. (n.d.). Astrophysics. Retrieved on April 12 from http://science.nasa.gov/astrophysics/.
[5] NASA. (n.d.). The hubble story. Retrieved on April 17 from http://www.nasa.gov/mission_pages/hubble/story/index.html#.U1VHHkKwI5M

Appendix 4

[6]Last Voyage For The Keeper Of The Hubble

By DENNIS OVERBYE
Published: April 13, 2009

HOUSTON — John Grunsfeld was sitting in an astronomical meeting in Atlanta in January of 2004 when he got a message to come back to headquarters in Washington to talk about the Hubble Space Telescope.

To say that he was excited would be an understatement. As an astronaut, Dr. Grunsfeld had twice journeyed to space to make repairs on humanity's most vaunted eye on the cosmos, experiences he had described to a high-level panel pondering Hubble's fate only a few months before as the most meaningful in his life. He was looking forward to leading the third and final servicing mission, which had been delayed by the loss of the shuttle Columbia and its crew the year before.

Thinking that the mission was now being scheduled, Dr. Grunsfeld raced to Washington, only to learn that Sean O'Keefe, NASA's administrator, had canceled it on the ground that it was too risky. Wearing his other hat as NASA's chief scientist, Dr. Grunsfeld now had the job of telling the world that the space agency was basically abandoning its greatest scientific instrument at the same time that it was laying plans for the even riskier and more expensive effort to return humans to the Moon. He said he felt as if he had been hit by a two-by-four.

Being an astronaut, there are not a lot of things that have really shocked me in my life," Dr. Grunsfeld said in a recent interview. But, he added, "I don't think anybody could ever prepare themselves for, you know, trying to bury something that they have said, 'Hey, this is worth risking my life for.' "He went home that January night and wondered whether he should resign.

Five years later, Dr. Grunsfeld reported for work at a six million-gallon indoor pool near the Johnson Space Center in his long underwear and a red baseball cap bearing an image of Curious George in a spacesuit. The pool's blue depths contained sunken replicas of the Hubble and the International Space Station. Surrounded by divers and helpers, Dr. Grunsfeld squirmed into a 400-pound set of overalls known as a space suit. He was preparing to practice for his return to space.

On May 12, he and six other astronauts commanded by Scott Altman are scheduled to ride to the telescope's rescue one last time aboard the shuttle Atlantis. This will be the fifth and last time astronauts visit Hubble. When the telescope's batteries and gyros finally run out of juice sometime in the middle of the next decade, NASA plans to send a rocket and drop it into the ocean.

If all goes well in what Dr. Grunsfeld described as "brain surgery" in space, Hubble will be left at the apex of its scientific capability. As chief Hubble repairman for the past 18 years, he has been intertwined with the Hubble telescope physically, as well as intellectually and emotionally. "He might be the only person on Earth who has observed with Hubble and touched Hubble,"

[6] Overbye. (2009). *Last voyage for the keepers of the hubble.* New york times. Accessed on April 21 from http://www.nytimes.com/2009/04/14/science/space/14prof.html?pagewanted=all&_r=0.

said Bruce Margon, an astronomer at the University of California, Santa Cruz, and former deputy director of the Space Telescope Science Institute.

Last September, Dr. Grunsfeld and his crewmates were two weeks from blasting off for Hubble when a data router failed, shutting down the telescope until a backup could be booted up. The servicing mission was postponed so that NASA could prepare a replacement router, adding another degree of difficulty to an already crowded and high-stakes agenda.

To accommodate installing the new router, mission planners had to cut into the time allotted for the repair and resurrection of Hubble's main camera, the Advanced Camera for Surveys. That repair was originally scheduled to happen over two spacewalks, and now planners are hoping to be able to do it a few hours on one spacewalk. If it cannot be done, Dr. Grunsfeld said grimly, the pictures that have inspired people around the world, pinpointed planets around other stars and helped investigate the fate of a cosmos dominated by dark energy will be lost. If anybody is up to the challenge, it seems to be Dr. Grunsfeld, who will be making his fifth trip to space.

Michael Turner, a cosmologist and former colleague at the University of Chicago, described Dr. Grunsfeld's career as "Mr. Smith goes to space." He said: "Everything turns to magic even when things go bad. In the end it gets righted and he gets to lead the team." Dr. Grunsfeld's whole life has led to Hubble. Born in Chicago in 1958 into a family of architects — his grandfather designed the Adler Planetarium — Dr. Grunsfeld said he yearned from age 6 to be an astronaut. Science soon beckoned as an alternative. By the time he reached college at the Massachusetts Institute of Technology his interests were centered on physics and cosmology. To make some money as an undergraduate, he took a job for $4 an hour on the graveyard shift in the control room for a small satellite, known as Sas-3, which was observing X-rays. Sometimes he took his dates there.

The job led to a year in Tokyo, where he lived in a Zen monastery, meditating in the morning and teaching and working with an X-ray astronomer, Minoru Oda, at the University of Tokyo in the afternoon. When he came home early one day and found the monks watching baseball on television, a spell was broken. He returned to Chicago to get a Ph.D. doing cosmic ray research at the University of Chicago. Along the way he married a woman he had known in high school, Carol Schiff. They now have two children, and she is an accountant at the Johnson Space Center. Dr. Grunsfeld then took a job at theCalifornia Institute of Technology, and he and his wife both learned to fly.

When NASA invited him to an interview in 1991, Dr. Grunsfeld flew his own plane to Houston. On his first space flight, a 16-day mission in 1995 tending a suite of small telescopes, Dr. Grunsfeld did not want to come down. "I had this real feeling of peace, you know, that I never had here on planet Earth." Dr. Grunsfeld went up again on a 10-day mission to the Mir space station, in 1997. Then, he said, "I got lucky and got assigned to Hubble." Hubble had already been through high drama. Launched to great fanfare in 1990 as the greatest advance in astronomy since Galileo first used a telescope, it had turned out to have a misshapen mirror and was branded a "technoturkey." In 1993, in the first on-orbit telescope servicing, astronauts installed corrective optics on Hubble, restoring the telescope's vision and promise, and astronomers' faith in NASA. "The only reason Hubble works is because we have a space shuttle," Dr. Grunsfeld said. "And of all things we do, I think Hubble is probably the best thing we use it for."

By December 1999, however, Hubble was in trouble again. Four of the six gyroscopes that keep the telescope pointed had broken down, and the telescope had gone into a so-called safe mode, suspending science operations. As a result NASA officials split a planned servicing mission into two parts and rushed the astronauts up to the telescope to replace the gyros and perform other vital tasks. Coming out of the hatch on his first spacewalk, Dr. Grunsfeld had a moment of unreality. “I mean it was just too magical. Three hundred miles below me is the Earth. There I was a meter away from the Hubble Space Telescope. I couldn’t resist. I had to take a finger and reach out and touch it.”

In one of the longest spacewalks to date, more than eight hours, Dr. Grunsfeld and his spacewalking partner, Steven Smith, replaced the telescope’s gyros, a job that Dr. Grunsfeld described as “an icky task” because the gyros are in a delicate and awkward spot. He discovered that he had a knack for getting things done Out There. Dr. Grunsfeld said he could get so involved in his task that he would forget he was in a space suit wearing gloves, a feeling he calls the Zen of space. “And once you’re outside working, you know, all the rest of the world disappears.” “Once in a while the universe lets you be free alone and in peace,” he said. On his second mission to the telescope, in 2002, the cooling system in Dr. Grunsfeld’s spacesuit sprang a leak as he was about to leave the airlock, necessitating a quick change before mission control could cancel the spacewalk.

Outside the airlock, the Zen of space took over. He thought of nothing except his task of replacing 34 tightly packed connectors in a power control unit that had not been designed to be repaired in space. “And the Zen part,” he explained, “is that I had trained myself in the challenge of connecting all these connectors to only think about one connector.” It would simply be too overwhelming to think about them all at once. “So I only ever had one connector to do.” An ideal job, Dr. Grunsfeld said, would be to spend six months on the International Space Station. “I would like to live in space,” he said.

One of the attractions of that lifestyle is unique to physicists. When the shuttle passes through a zone in its orbit called the South Atlantic Anomaly, astronauts are exposed to large doses of cosmic rays, high-energy particles from the Sun or distant galaxies, which leave a wake of visible light as they pass through a dark-adapted human eyeball. “In space you can get in touch with your quantum self,” Dr. Grunsfeld said. “I was a human cosmic ray detector.” He said he could identify the different kinds of particles zooming through his eyeball by how bright the flashes were.

The loss of the space shuttle Columbia and its crew of seven in February 2003 threw the American space program into crisis. Ultimately, as a result, the Hubble Telescope faced its greatest perils on the ground. Busy with his chief scientist duties and helping to roll out the scientific aspects to President George W. Bush’s Moon-Mars initiative in the winter of 2003-2004, Dr. Grunsfeld, who describes himself as “fat, dumb and happy,” did not see the decision to cancel Hubble coming.

When it happened, he called John Bahcall, the late astrophysicist at the Institute for Advanced Study and behind-scenes-eminence for Hubble, and asked his advice. He could either stay and fight, probably losing, Dr. Grunsfeld told Dr. Bahcall, “Or I throw my badge down and, you know, walk away.” Dr. Bahcall told him not to worry. If he left, the astronomical community would regard him as a hero, he would be able to get a job anywhere he wanted. “And then there was the pregnant pause. But—” Dr. Grunsfeld recalled. If he left, Dr. Bahcall warned, he

would lose all his ability to help the rest of the science NASA was doing, X-ray satellites and gravitation-wave observatories that were dear to his heart as a high-energy physicist. There was no guarantee that anybody else would be there to protect this work. “And that had a very calming effect on me,” Dr. Grunsfeld said, “and he was absolutely right.”

A week later, Dr. Grunsfeld presided over a news conference, defending the decision that Hubble would be abandoned. “It’s a sad day that we have to announce this,” he said. The decision meant the telescope was doomed to die in orbit by 2007 or 2008 when its batteries and gyros gave out, and it sparked worldwide consternation and criticism of Dr. Grunsfeld as well as Mr. O’Keefe.The criticism of Dr. Grunsfeld was resented by astronomy insiders. “There was never any doubt that he was one of us,” said Dr. Margon, who was then deputy director of the Space Telescope Science Institute. “He handled it all with tremendous grace.”

Dr. Grunsfeld decided that his new job was to work within the system to save Hubble. With the support of Mr. O’Keefe, who was shaken by news reports of schoolchildren offering to pool their pennies to keep Hubble alive and working, Dr. Grunsfeld pushed a proposal by Frank Cepollina of the Goddard Spaceflight Center in Greenbelt, Md., to send a robot to service the telescope. The robot mission was eventually scotched by a National Academy of Sciences panel of experts. Mr. O’Keefe resigned and was replaced by Michael Griffin, who reinstated the Hubble mission. In the meantime, the engineering team at Goddard and its expertise needed for Hubble servicing had been kept alive. “If we hadn’t gone down that road,” Dr. Grunsfeld said, “NASA would have terminated all the contracts, the big contracts, and there would be no recourse.”

Since Dr. Griffin’s decision, more has gone wrong with Hubble than could have been fixed by a robot, anyway. Two of the telescope’s most important instruments — a spectrograph named STIS, which made the first atmospheric measurements of a planet around another star, and the Advanced Camera for Surveys — have failed. Neither was designed to be repaired in space. When the advanced camera stopped working in 2007, the Hubble engineers first said that prospects for repair were poor. Now they have a plan. “For the first time,” Dr. Grunsfeld said, “we’re going to go in and open boxes of tiny screws, take circuit cards out and replace the circuit cards.” The spectrograph has only one card, but the camera has four. Moreover, the camera is around a corner and behind a strut where it cannot be seen.

Before the recent underwater rehearsal on a sunken replica of the Hubble, Dr. Grunsfeld was showing off a pair of ultra-sensitive gloves that will help him to feel around the corners during the mission. When he climbed back out of the water, he reported that he and Dr. Andrew Feustel, his spacewalking partner, had once again managed the camera repair, and in jig time, although a foot restraint had broken partway through. That, he said, was good practice for the frustrations of real space work.

It will be with mixed emotions, Dr. Grunsfeld said, that he hugs Hubble for the last time — the last time that any human will touch it. “I try and tell myself it’s just a satellite,” he said. But his involvement with Hubble will continue. He has been given observing time on the telescope, which he said he will use to study the Moon’s Tycho crater, formed by an impact 70 million or 90 million years ago, about the time that an asteroid is thought to have wiped out the dinosaurs on Earth. Dr. Grunsfeld said that this would probably be his last flight. “I achieved everything I ever wanted after my first spaceflight,” he said, wearing his space monkey hat. “To be the Hubble repairman is really just unbelievable.”

Appendix 5

Dr. John Grunsfeld
Cosmology and Astrophysics

What I know about astrophysics	**What I learned about** Dr. Grunsfeld and astrophysics	**What I want to know more about** Dr. Grunsfeld and astrophysics

475 Riverside Drive, Suite 950, New York, NY 10115
212-348-1400 Fax 212-280-1601 info@woldsciencefest.org www.worldsciencefestival.com

Pioneers in Science 2014-Classroom Participant Film Release

1. I have agreed to participate in an educational program entitled "*Pioneers in Science*" (the "Program"), [as part of the 2014 World Science Festival (the "Festival"),] presented by The Science Festival Foundation ("SFF") in collaboration with Global Nomads Group ("GNG").

2. I understand that SFF and/or GNG may film/videotape, record, photograph or otherwise document the Program (such documentation, the "Footage"), and agree that my participation may be included in the Footage.

3. I understand that part of SFF and GNG's educational mission is to make their programs widely available to a diverse audience through different media. In support of this mission, I grant to SFF and GNG, their successors and other entities they may designate from time to time (such as licensees, broadcasters, and other content distributors) the exclusive right to edit, distribute, broadcast or otherwise disseminate the Footage, in whole or in part, throughout the world, in perpetuity, in any manner or media now known or hereafter developed, including the live streaming of the event over the internet. This grant to SFF and GNG includes the right to use my name, voice, biography and image in connection with the foregoing. I understand that I will receive no compensation for the above.

4. In consideration of my being permitted to participate in the Program, I irrevocably release SFF, GNG, and their respective officers, directors, employees, agents, licensees or assigns, from any claims I may have, now or in the future, arising from (i) any use of the Footage, and (ii) any use of my name or image for the purposes permitted herein.

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6. This Release is governed by the laws of the State of New York and may not be modified except in writing signed by both parties.

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Signature Name (print)

_____ _____
Address Date

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Phone Number

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Email Address

**** For Minors Under 18 years, the following must be signed by the parent or guardian**

I represent that I am the parent/guardian of _____, a minor, and I hereby consent to the foregoing on behalf of the minor and myself.

Date _____, 2014

Name (print) _____ Phone number _____
Signature _____ Address _____
Relationship _____ Email Address _____

Amazing Space Resource Links related to Telescopes and Light

Telescopes from the Ground Up
From spyglass to satellite: a virtual tour of telescope technology.
http://amazing-space.stsci.edu/resources/explorations/groundup/

Hubble Space Telescope lithograph
See outside and inside the Hubble Space Telescope.
http://amazing-space.stsci.edu/resources/print/lithos/hst_litho.pdf

Horsehead Nebula lithograph
Hubble sees a horse of a different color.
http://amazing-space.stsci.edu/resources/print/lithos/horsehead_litho.pdf

Star-Forming Nebula N90 lithograph
This hotbed of star formation lies in the Small Magellanic Cloud.
http://amazing-space.stsci.edu/resources/print/lithos/n90_nebula_litho.pdf

Graphic Organizer: Comparing the Hubble and James Webb space telescopes
Find out how the James Webb Space Telescope will differ from Hubble.
http://amazing-space.stsci.edu/resources/organizers/telescope-compare.php

Q&A: Hubble Space Telescope & SM4
Separate fact from fiction and satisfy your curiosity about NASA's most famous orbiting observatory.
http://amazing-space.stsci.edu/resources/qa/hst.php

Q&A: Electromagnetic spectrum
Separate fact from fiction and satisfy your curiosity about what makes an X-ray different from a radio wave.
http://amazing-space.stsci.edu/resources/qa/ems.php

Myths vs Realities: Hubble Space Telescope and space technology
Hubble can "see" things that are invisible to the human eye — true or false?
http://amazing-space.stsci.edu/resources/myths/tech.php

Myths vs. realities: Light & color
All radiation is harmful — true or false?
http://amazing-space.stsci.edu/resources/myths/light.php

Resource Links for Readings and Information about Dr. John Grunsfeld

National Geographic Adventurers of the Year
"Voice from Outer Space: John Grunsfeld, Astronaut"
http://adventure.nationalgeographic.com/2009/12/best-of-adventure/john-grunsfeld

This resource features a short video clip of John Grunsfeld, a link to photos from the Hubble Servicing Mission 4, and a brief question and answer session with John Grunsfeld. During the Q & A, Grunsfeld answers questions about Hubble, the servicing mission, and provides some insight into space walks and repairs on the telescope.

Nature
"Careers Q&A: John Grunsfeld"
http://www.nature.com/naturejobs/science/articles/10.1038/nj7282-835a

This resource features an interview with John Grunseld that highlights his new appointment as the deputy director of the Space Telescope Science Institute, as well as, early-life experiences that influenced his career choices and career trajectory.

National Outdoor Leadership School
"Wind River Wilderness Course Alumni Profiles: John Grunsfeld"
http://www.nols.edu/about/profiles/alumni/john_grunsfeld.shtml

In this resource, John Grunsfeld reflects back on his experience at the National Outdoor Leadership School as a teenager, and how his experience in the "Wind River Wilderness Course" impacted him. This resource also features information about Grunsfeld's education and early career as an astronaut.