Lesson Plan **Candidate: Beth Kostka** **11/10/19**

Strategy: 6 thinking hats

Unit Name

Astronomy

Lesson Name	**Time Needed (Hours/Days)**
Humans Vs Robots	**5 days** (includes Summative)

Grade	**Subject**	**Course**
6	Earth Space Science	Science

Essential Question(s)

What should students know when lesson is completed?

Essential Question:

How can NASA best collect scientific data from over 140 million miles away from Earth?

Summary (blue hat) Question:

"If you were the head of NASA and had to decide if you would send astronauts or robots to Mars to collect scientific data on the red planet, which would you choose and why? What evidence would you use to convince your boss?"

Standards

GSE Standard

S6E1. Obtain, evaluate, and communicate information about current scientific views of the universe and how those views evolved.

c. Analyze and interpret data to compare and contrast the planets in our solar system in terms Of: size relative to Earth, surface and atmospheric features.

IB Standard: Rubric D Reflecting on Science

i. outline the ways in which science is used to solve a specific problem or issue

ii. outline the implication of science to solve a specific problem or issue

iii. apply scientific language to communicate understanding clearly and precisely

(https://www.wired.com/2012/04/space-humans-vs-robots/)

ADAM MANN SCIENCE 04.11.12 06:30 AM

Humans vs. Robots: Who Should Dominate Space Exploration?

Summary

This lesson uses 6 Hat strategy to analyze two articles to help students reflect on science content and the problem of how to collect data from over 140 million miles away of Earth.

Teacher Lesson Preparation

Prior Knowledge/Skills: Prior the lesson, students will explore scale, distance, place in universe, space travel, planets of our solar system, characteristics of Mars and the other rocky-inner planets through various stations (text, videos, websites). This background information will be critical for them to answer questions in the following six thinking hats lesson.

Gifted Identification: Students are identified as gifted through CSD testing and qualification. I have 24 students identified as gifted in science plus 16 Gifted in Math and/or Gifted in Reading and 1 twice exceptional (for a total of 41 gifted students in my class). I have asked our CSD gifted coordinator which students are gifted creatively and have not had confirmation yet (I hypothesize 3).

Goals/Standards: The goals of the lesson are for students to be able to meet the IB Reflecting on Science Rubric D standards

i. outline the ways in which science is used to solve a specific problem or issue
ii. outline the implication (strengths and limitations) of science to solve a specific problem or issue
iii. apply scientific language to communicate understanding clearly and precisely (scientific language outlined in GSE S6E1.c (see above); specifically distance, surface conditions, and atmospheric conditions.

Pre-assessment:
To pre-assess whether students have met the goals prior to this lesson and whether they are ready for acceleration, by assessing them formatively using a google form with the warm up question "How should we learn about and gather more scientific data from planets that are 140-150 million miles away from Earth? What evidence do you have to support your method of data collection?"

Misconceptions:
Based on prior assessment of student's Rubric D summatives, I know that students have misconceptions about the amount of data Earth bound telescopes can collect, the numbers of humans and Robots that have visited Moon (11 robots; 24 humans with 6 landing sites; https://moon.nasa.gov/) much less the numbers that have visited Mars (6 robots; 0 humans). Many students only think about the problems of distance to Mars, not recognizing all that has to go right once orbiting Mars (descent, landing, communication, leaving Mars' gravity, getting back to Earth.

"Grouping strategies":
Prior to this lesson, students will take a pre-assessment warm up. The pre-assessment will be graded for quantity of facts, feelings, positive ideas, and negative ideas. Students will be assigned to a hat based on their strengths in responding to the pre-assessment. Grouping was done in this manner to facilitate strong answers for all students across all hats. Thus, students who struggle to see with a positive lens, factual lens, etc. will benefit from their peers assessment and ideas, by hearing ideas they may not have identified on their own.

Text Choice:
Attempted to choose the primary reading from NewsELA, but no text was close enough aligned to the topic. As a result, two primary texts were chosen from **https://www.ucf.edu/pegasus/opinion**. Both texts were then leveled for lower lexile reading using the website rewordify.com.

Supplemental/Acceleration texts were chosen by topic through the government website NASA.gov (see materials below).

Special Population Consideration:
Supplemental/ Acceleration texts (see materials list) are provided for special populations including females (see materials list) and Minority Students. Graphic organizers and checklists (see materials list) provide structure for twice gifted students and green hat thinking and product development is provided for creatively identified gifted students.

Activating Strategy (for example: Hook/Mini-Lesson/Warm-Up/Connection to Prior Learning)

*Pre-assessment (5 minutes) warm up question (see above) comes prior to today to give time to evaluate answers and plan grouping

Hook #1 (15 min): Use the google virtual reality goggles to take a trip to mars. (students go to accessMars https://accessmars.withgoogle.com/. Connect to prior learning by having students write down in their notebooks a minimum of 5 observations, 3 inferences, and 1 question. Discuss as a class the questions that were generated.

My Observations	My Inferences	My Questions

Hook #2 (5 min): Pose the question verbally and on the smartboard: **"If you were the head of NASA and had to decide if you would send astronauts or robots to Mars to collect data to answer these questions and more on the red planet, which would you choose and what evidence would you use to convince your boss?"** Think:Pair:Share Possible answers. Facilitate the answers by writing them as reported on the board so that two possibilities are mentioned/highlighted: Sending Humans to Mars and Sending Robots to Mars to collect data on the Universe.

Instructional Sequence and Activities

Part 1: (25 min)
Introduce verbally and on the smart board the essential question from the Hook #2 above . Think:Pair:Share Possible answers. Facilitate the answers by writing them as reported on the white board so that two possibilities are mentioned/highlighted: Sending Humans to Mars and Sending Robots to Mars to collect data on the Universe.

Part 2: (Day 1)

Day 1 will begin by each group will read one primary article and then engage in the 6 thinking hat strategy In this way, 4 hats are used in part 2 and part 3; assessment will be the blue hat, and the green hat will be enacted after the assessment) to identify facts, problems, positives, and feelings around each topic.

Teacher will first, explain (verbally and with slides on the smart board) group stations (White, Yellow, Black, and Red Hats). Also, explain each of the 4 thinking hats and describe what each thinking hat means: white (facts), yellow (benefits), black (limitations/ problems), and red hat (feeling). The students will be separated into groups (see pre-lesson for grouping strategy) by

Hat color. At each table, there will be colored labeled sheets (i.e. yellow sheet in a sheet protector) to remind students of the hat color and type of questions that they will be answering during the activity. Students will answer the questions on the sheets in their lab groups (groups of 3-4 students; two lab tables pushed together) after reading **both** articles, using the lens of their thinking hat (facts, positives, negatives, feeling, creativity). Specifically, students will use their chromebook to access the articles (NewsELA, NASA.gov, and supplemental articles) via google classroom. Formative assessment by the teacher occurs during 1) moving around and listening to groups during the lesson.

White Hat Questions: Facts
1. What year did the U.S. really begin to plan for and work to send humans into space and what famous person was instrumental in pushing it forward?
2. What political issue or force helped to drive the U.S. program to send humans into space?
3. Approximately how long have we had a manned space program (a program to send humans into space)?
4. According to the author, what human trait or characteristic drives humans to travel into space?
5. What does NASA stand for? (you may need to google this).
6. How many humans and how many robots have visited to the moon (see https://solarsystem.nasa.gov/moons/earths-moon/overview/)?
7.How many humans have been sent into space? (see https://rewordify.com/t99m4jbn11k2nm).

Yellow Hat Questions: Benefits
1. What are Benefits of sending HUMANS into space?
2. How did the pursuit of sending HUMANS into space benefit America during and after the cold war?
3.. How is human curiosity a benefit?
4. What first-hand observations could humans make that robots could not when traveling to a distant planet or moon?
5. What are the benefits of sending only ROBOTS into space
6. How can sending humans into space (or to mars) help robots in their mission of collecting data?

Black Hat Questions: Problems or Limitations
1. Based on the article that you read, what are some problems or flaws of sending HUMANS into space?
2. What are some flaws of sending humans into space that you can think of that were NOT mentioned in the article?
3. Based on the article that you read what are some of the problems or flaws of sending ROBOTS into space?
4. How did the cold war and the competition of sending humans into space potentially cause problems for human space flight?

Red Hat Questions: Feelings (show three pictures; #1) picture of mars, #2) picture of astronaut planting a flag on the moon and, #3) picture of a rocket blowing up)
1. Describe how you feel about picture #1
2. Describe how you feel about picture #2
3. Describe how you feel about picture #3
4. Watch this video (https://www.youtube.com/watch?v=Nt6AM2RMJlM) and describe how you feel. For example: Do you agree? Disagree? Feel angry? Feel uncertain? Feel Excited? Be sure to explain why you feel the way you do for picture

Day 2-

Yesterday's activity will continue and like the previous day, the chromebook will be used to access articles, websites, notes, and common document. When finished, students come together into a multi-hat group (one person representing each hat from the previous day). Each group will have one time keeper, one note taker, one presenter and one facilitator. Note taker will write/post their groups notes in the shared class google doc using their chromebook and google classroom. After 10 minutes, allow presenters to share their answers in a class discussion. Formative assessment by the teacher occurs during 1) moving around and listening to groups during the lesson, 2) during the group presentations, and 3) with review of the shared google doc to determine if students understood and followed the 6 hats process correctly.

The day will end with each student making a copy of the shared doc for themselves and highlighting 3-5 each of facts, strengths, limitations and feelings they will talk about in their essay.

Part 3: Day 3

Day 3 (Part 3) Each student silently thinking and taking individual notes (collecting quotes) about which solution (Humans or Robots) they think is stronger and why (see graphic organizer below). (25 minutes) Students should individually identify and write down SPECIFIC evidence to support their own ideas using their notebook, the shared doc, the articles and the graphic organizer.

Next, each multi-hat group will then have 10 minutes (2 minute per person) to discuss which solution they like better and why. During the presentation the other group members listen and complete a checklist to evaluate their peer's evidence and reasoning for quantity, details and quality (see checklist below).

Part 4 (Day 4-5):

Blue hat summary day and Green hat creativity day. Students will write a summative CER (Claim, Evidence and Reasoning statement written in a business letter format. Students will be asked to write a "Letter to employees" to explain your decision **"If you were the Assistant Director of NASA and had to decide if you would send astronauts or robots to Mars to collect scientific data for future space travel, which would you choose-to send Robots or Humans to Mars and what evidence and reasoning would you use to convince your boss that it is the right decision?"**The summative assessment will be graded based on a rubric provided to students (see below).

As students finish their blue hat summary reflection writing, they will complete the Green Hat Creativity activity, choosing a product. Specifically students are told "Pretend you have been transported to the year 2030. Create a detailed picture, comic, cartoon, or journal/diary entry that includes your name and answers to the following question(s)." Products can be on paper or created through technology such as powtunes, toondoo, stripgenerator, google doc, powerpoint, sketch up.

1. How do you predict NASA space travel will change in the next 10 years?
2. How will humans or robots arrive on Mars to study it's surface?

Part 5: Complete metacognition reflection form

Students will log into google classroom and complete the reflection form on this lesson. Teacher will review the results and identify ways to improve the lesson for better learning and implementation.

Assessment Strategies

Evidence of Learning

- Students will be able to outline the ways in which science is used to solve the problem of collecting more data about our vast universe
- Students will be able to outline the strengths and limitations of solutions to solve the problem of collecting more data about our vast universe
- Students will be able to apply scientific language (vocabulary) to communicate understanding clearly and precisely

Assessment: Students will be formatively assessed based on classroom discussions and group 6 thinking hat work. Specifically, formative assessment by the teacher occurs during 1) moving around and listening to groups during the lesson, 2) during the group presentations, and 3) with review of the shared google doc to determine if students understood and followed the 6 hats process correctly. Summative assessment will occur based on their blue hat written reflection supported with multiple pieces of evidence and reasoning answering the question "Which solution do you agree with most and Why?" The summative assessment will be graded based on a rubric provided to students (see below).

Differentiation

Scaffolds/ Interventions/Extensions/Enrichment/Adaptations for Special Pops students

This lesson differentiates by process (grouping for 6 hats, levels of texts, types of scaffolding, and product (choice for green hat of cartoon, picture, creative writing, etc.). In addition, it differentiates by learning profile (across the 6 different ways of thinking) and content through supplemental texts/sources.

Specifically, scaffolds (graphic organizers and timeline checklist) are provided to gifted students needing help with organizational skills. Gifted students who are quick to grasp content and motivated to complete assignments have acceleration options of additional/expanded text sources (see materials section). Gifted students who are struggling writers will be provided with sentence starters, checklist and if completely necessary, "flipgrid" to aid them in verbally articulating their understandings. Struggling readers will receive differentiation with tiered lexile text, a video, sentence starters, and checklist. Finally, creatively gifted students are planned for by including points on the assessment rubric for creativity/outside the box thinking (thinking beyond the articles).

Special populations are planned for through text extensions (Women astronomers and minority astronomers)

Materials/Links/Text References/Resources

Virtual Reality (Hook)
https://www.eso.org/public/usa/videos/Mars-The-Red-Planet-VR/
https://accessmars.withgoogle.com/

Printed Materials
metacognition sheet (https://forms.gle/bifzAUmfmv1YtueT7)
Graphic Organizer for CER Letter
Rubric & Checklist

Exemplar Letter
Hat questions (see above)
Shared Notetaking doc
(https://docs.google.com/document/d/1XlJvE2i4qcTZ2eTED9HlMTIkrUlHXiDUSbCr9-3RZ7M/edit)

Primary Texts Gifted
Humans to Space:
https://docs.google.com/document/d/1_RFIDwKIRiKaKGjmTOOLnZAuV4kkIeqRas6pYCQBnRQ/edit# and
https://www.nasa.gov/hrp/5-hazards-of-human-spaceflight

Robots to Space:
https://docs.google.com/document/d/1_RFIDwKIRiKaKGjmTOOLnZAuV4kkIeqRas6pYCQBnRQ/edit#

Primary Texts-Lower Lexile (twice exceptional gifted student)
https://www.wired.com/2012/04/space-humans-vs-robots/
Humans to Space: https://rewordify.com/832drwj934dfbb
Robots to Space: https://rewordify.com/1c5d8m603g45pt
Video: https://www.youtube.com/watch?v=Nt6AM2RMJlM (GREAT!

Supplemental/Acceleration Texts

Women in Space:

CNN: https://www.cnn.com/2019/10/21/world/nasa-all-female-spacewalk-reflections-scn-trnd/index.html
NewsELA:
https://newsela.com/read/woman-year-in-space?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/woman-year-in-space?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/teen-preparing-for-mars?utm_source=email&utm_campaign=share&utm_medium=we
https://newsela.com/read/black-women-nasa-history?utm_source=email&utm_campaign=share&utm_medium=

Minorities in Space
NewsELA:
https://newsela.com/read/dream-job-planetary-geophysicist?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/black-women-nasa-history?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/elem-first-black-astronaut?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/elem-puerto-rico-astronaut?utm_source=email&utm_campaign=share&utm_medium=web

Hazards to Human Flight: https://www.nasa.gov/hrp/5-hazards-of-human-spaceflight

Preparing People to go: https://www.nasa.gov/topics/moon-to-mars/preparing-to-go
https://newsela.com/read/human-mars-mission-comedians?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/human-mars-mission-comedians?utm_source=email&utm_campaign=share&utm_medium=web
Next Generation of Space Suits
Space Communication
Supplies
Technologies needed for deep space missions
Space Radiation
Temperatures
https://www.nasa.gov/feature/progress-toward-nasa-s-exploration-missions-challenges-on-the-road-ahead
Oxygen: https://www.nasa.gov/feature/top-five-technologies-needed-for-a-spacecraft-to-survive-deep-space
Propulsion (rocket):
https://www.nasa.gov/feature/top-five-technologies-needed-for-a-spacecraft-to-survive-deep-space
Constant Communication and Navigation:
https://www.nasa.gov/feature/top-five-technologies-needed-for-a-spacecraft-to-survive-deep-space

Robotic Exploration:

(Basic) https://spaceplace.nasa.gov/mars-rovers/en/
https://newsela.com/read/elem-tiny-robot-helicopter-mars?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/NASA-rover-bites-mars-dust?utm_source=email&utm_campaign=share&utm_medium=web
(Advanced) https://www.nasa.gov/mission_pages/mars/main/index.html
https://newsela.com/read/mars-gets-first-visitor?utm_source=email&utm_campaign=share&utm_medium=web
https://newsela.com/read/marsquake-nasa-spacecraft?utm_source=email&utm_campaign=share&utm_medium=web

Materials/Resources
(Convert text lexile) http://rewordify.com/
(video option for struggling writers) https://flipgrid.com/
(Mars Exploration) https://www.nasa.gov/topics/moon-to-mars
(Moon Exploration) https://moon.nasa.gov/
(Virtual Reality Info) https://www.youtube.com/watch?v=0DvF5J6Evx4

Citations: Example Lesson from Gifted Course 2: "Casey_Hilgefort_Thinking_Hat_Lesson_6_SC"

Extension Game
(Mars Rover Game): **https://spaceplace.nasa.gov/mars-rovers/en/**

Day 2 Graphic Organizer

Question: If you were the head of NASA and had to decide if you would send astronauts or robots to Mars to collect data to answer questions on the red planet, which would you choose and what evidence would you use to convince your boss?		
Problem Statement (What is the problem?)		
Facts about the Problem		
	Pro Robots	Pro Humans
Cite Evidence: (Quotes from article):		
Explain quote- -why it is evidence: *(**This** shows **that** is supported because…)*		
Feelings:		
	Limitations of Robots	Limitations of Humans
Cite Evidence: (Quotes from article):		
Explain quote -why it is evidence: *(**This** shows **that** is supported because…)*		
Feelings:		

Checklist for Peers and Rubric

What is the Problem we are researching and considering?

- ❏ The problem is clearly stated
- ❏ The problem includes that humans want to learn more about space and Mars and it isn't easy to do so?

What are the Facts about the Problem?

- ❏ distance
- ❏ no oxygen
- ❏ how return to Earth
- ❏ radiation
- ❏ time/years NASA
- ❏ NASA stands for…
- ❏ Politics of time
- ❏ Supplies (food, water)
- ❏ # humans to space
- ❏ # of robots to space
- ❏ Technology
- ❏ Other_____

What is your answer to the question? (What is your Claim?)

- ❏ Your answer (claim) to which solution is better is clearly stated
- ❏ Your answer (claim) is written in full sentences

What are the Strengths for your preferred solution?

- ❏ strength #1_____ because_____
- ❏ strength #2_____ because_____
- ❏ more than one positive quote is included

What are the limitations for your preferred solution?

- ❏ limitation #1_____ because_____
- ❏ limitation #2_____ because_____
- ❏ more than one positive quote is included

Why did you not pick the second solution?

- ❏ one reason _____ was not picked is because_____
- ❏ a second reason _____ was not picked is because_____

What are your feelings for or against the solution discussed?

- ❏ feelings for the preferred solution was discussed

OR

- ❏ feelings for the solution that was not chosen was discussed

Comments from Peer Reviewer:

Things the writer did well:

-
-

Things the writer could change to make their writing stronger:

-
-

IB Rubric

1-2 problem NOT included. does answer the question. **States** 1 piece of evidence. strengths and limitations not completed.	3-4 problem NOT included. does answer question. **Describes** 1 piece of evidence with detail. No reasoning provided	5-6 problem & answer included **Describes** 2-3 pieces of evidence in detail with reasoning. Creative outside box thinking attempted	7-8 16-18 boxes checked **Explains** problem, evidence, reasoning & con statements. Includes quotes. Includes definitions of science vocabulary. Creative outside bo thinking included

Rewordify Test (Humans are Important Modified Lexile Text)

Humans Are Extremely important for Space Exploring (Modified)

by

Joshua Ph.D.(Modified) Colwell

Humans Vs Robots Summative Kostka

Robots vs [Astronauts]: Do we really need humans to explore space? Or are machines a better choice to reach into the solar system and beyond?

Joshua Colwell, Ph.D., is a planetary scientist, professor of physics, associate chair of the Department of Physics and Assistant Director of the Florida Space Institute.

Humans Are Extremely important for Space Exploring
"We choose to go to the moon in this ten years and do the other things, not because they are easy, but because they are hard." With these words, President John F. Kennedy awakened America's support of space exploring in 1962. He also recognized the politics and competition with the Soviet Union that gave the driving force to make people's greatest technology solution possible. After the Cold War, our program to send humans into space has gotten old and lost money available for the last 40 years. We must return to the spirit of humans exploring space as shown by the Apollo program. The need to see what is over the next (line in the distance where the Earth and sky meet) -- and not to simply see it, but to actually touch it -- is an important part of being human. Those horizons call to us from space rocks, the moon, and Mars.

Human trying to explore space is one of our best (features/ qualities/ traits) -- curiosity. To be curious we need to participate and keep doing it. My co-worker correctly says that sending robots to space costs less and improves our scientific knowledge of the universe, and I could not agree more. Even though valuable knowledge have been gained by of sending humans into space, there is more important things that new scientific knowledge. It is instead about something equally important as science -- the inspiration of humans is to chase higher goals.

Space scientists often make the mistake of assuming that the budget for ending humans into space takes away money that could be used to fund high reaching and scientifically valuable robot-based missions. It is a lack of understanding to expect that politicians would change and spend those same billions of dollars on scientific exploring alone. If the human space traveler program was canceled today, its budget would disappear, never to be spent on space exploring of any kind, including robots. In contrast, the U.S. human space traveler space program enables NASA to maintain a space research program that is by far the largest in the world. We need to move past the debate of human or robot space programs and accept that they serve different yet matching roles and that both strengthens the other.

Rewordify Test (Humans are Important Modified Lexile Text)

Robots Are Key to Future Space Exploring things

Daniel Britt, Ph.D., is a professor of (the study of outer space) and a member of multiple famous scientific (communities of people). Every NASA wanderer (robot) that's been sent to the red planet, including the current Curiosity wanderer (robot), has included equipment Britt designed and built.

On the plus side, humans in space provide flexibility, inspiration, and intelligence. On the minus side, human flexibility comes at a high cost. Humans are heavy, delicate and breakable, dirty, capable of being hurt, picky about their surrounding conditions, and have a low tolerance for the conditions of space (i.e., high energy radiation, extreme heat and cold, etc.). Also, humans are delicate and breakable. They hate to risk someone dying. Finally, humans need for food, water and oxygen demands a lot of space and large amounts of money to pay for it. To meet a human's needs, items need to be invented and large support crews hired to baby-sit every aspect of a space traveler's daily life while in space.

For crewed space flight, the planets of Venus and Mercury are impossibly hot so humans cannot fly there. The "space rock" belt and Jupiter are way too cold for humans to survive. The longer times it takes to fly to these planets as well as radiation exposure, bone and muscle loss, would hurt and possibly kill a human. Once on a planet, humans can be both positive and negative for collecting scientific data. Imagine trying to search for life on Mars with human explorers who are (adding unwanted things to/making dirty) the planet just by breathing and stepping on the planet's surface.

There is no real choice between robotic and human exploring things of space. Both are connected and dependent on each other. Robotic exploring things is necessary to enable humans to explore space by providing critical information, the spacecraft, and reducing the risk to human life. Imagine how the Apollo program would have functioned without robots -- It needed a Moon-related Orbiter to map the moon's surface. It needed a robot Ranger to get close-up pictures of areas to show where to land, and Surveyor to explore the surface, figure out what it is made of and practice soft landings. Without these robots, it would have been impossible to know where to go on the moon, to design the landing machine, or to have any real idea of what to do once we got there -- other than plant the flag.

Is there a choice between humans and robots exploring space? Not really. Thinking of the current limited range of human space travel, using robots is important to allow future human space missions. Robotic exploring things is the only realistic game in town.

https://www.ucf.edu/pegasus/opinion/ **NOT MODIFIED**

Robots vs Astronauts

Do we really need humans to explore space? Or are machines a better alternative to reach into the solar system and beyond?

Humans Are Essential for Space Exploration

Joshua Colwell, Ph.D., *is a planetary scientist, professor of physics, associate chair of the Department of Physics and assistant director of the Florida Space Institute. His research interests are the origin and evolution of the solar system. He leads the Center for Microgravity Research, which conducts fundamental research enabled by microgravity.*

"We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard." With these words, President John F. Kennedy roused America's support of space exploration in 1962. He also acknowledged the geopolitical competition with the Soviet Union that provided the impetus to make mankind's greatest technological achievement a possibility. Absent that Cold War motivation, our manned space program has languished in low Earth orbit for the last 40 years. That drought drives home the point that we must return to the spirit of human exploration of the final frontier exemplified by the Apollo program. The need to see what is over the next horizon — and not to simply see it, but to actually touch it — is a fundamental aspect of human nature. Those horizons beckon on countless asteroids, the moon and Mars.

The manned exploration of space is an expression of one of our finest aspects — curiosity. To truly satisfy that curiosity we need to be participants. My colleague correctly points out that the robotic space program is a far more cost-effective means of advancing our scientific knowledge of the universe, and I could not agree more. While valuable advances have been made because of the manned program, it cannot and should not be justified on the grounds of scientific advancement. It is instead about something equally important as science — the inspiration of our species to pursue lofty goals.

Space scientists frequently make the mistake of assuming that the space exploration budget is a zero-sum game, lamenting the money spent on the manned program that could be used to fund ambitious and scientifically valuable robotic missions. It is naïve to expect that politicians would spend those same billions on purely scientific exploration. If the manned program was canceled today, its budget would disappear, never to be spent on space exploration of any kind. In contrast, the U.S. manned

space program enables NASA to maintain a scientific program of space exploration that is by far the largest in the world. We need to move past the debate of manned versus unmanned programs and recognize that they serve different yet complementary roles, and that each endeavor ultimately strengthens the other.

Robots Are Key to Future Space Exploration

> **Daniel Britt, Ph.D.**, *is a professor of astronomy and a member of the International Astronomical Union and the American Astronomical Society. His research focuses on using remote sensing tools to determine the composition and evolution of solar system objects such as asteroids, comets and Mars. Every NASA rover that's been sent to the red planet, including the current* Curiosity *rover, has included equipment Britt designed and built.*

On the plus side, humans in space provide operational flexibility, inspiration and native intelligence. On the minus side, that flexibility comes at a steep price. Humans are heavy, fragile, dirty, vulnerable, picky about their environment, and have a low tolerance for the space environment (i.e., high energy radiation, extreme heat and cold, etc.). The fragility of humans, our aversion for risking human life, and the all-too-human need for consumables (food, water and oxygen) require vast amounts of money to pay for the extra engineering and multiple redundant systems we demand to reduce risk to astronauts, as well as for the vastly larger support crews needed to baby-sit every aspect of daily life during a manned space mission.

For crewed spacecraft, Venus and Mercury are impossibly hot, and the asteroid belt and Jupiter are impossibly cold. The longer travel times to these worlds would be a death sentence from radiation exposure, not to mention bone loss and muscle atrophy. Once at an exploration target, humans can be a mixed blessing. Imagine trying to search for life on Mars with human explorers who are shedding pollutants and terrestrial contamination with literally every step and breath.

Fundamentally there is no real choice between robotic and human exploration of space, however. Both are synergistic and mutually dependent. Robotic exploration is necessary to enable human exploration by setting the context, providing critical

information, and reducing the risk to humans. Imagine how the Apollo program would have functioned without its robotic precursors — Lunar Orbiter to map the moon's surface, Ranger to get close-up views of areas that helped perfect NASA's navigation skills (remember that NASA missed the moon with two of the first three Rangers to get that far), and Surveyor to explore the surface, determine its composition and practice soft landings. Without these robotic precursors it would've been impossible to know where to go on the moon, to design the landing hardware, or to have any real idea of what to do once we got there — other than plant the flag.

Is there a choice between human and robotic exploration? Not really. Considering the current limited range of human exploration, robotic exploration is essential to enable manned missions. For the rest of the solar system, robotic exploration is the only realistic game in town.

Shared Group Notes- Robots Vs Humans

(Mixed hat groups)

Question: "If you were the head of NASA and had to decide if you would send astronauts or robots to Mars to collect data to answer questions on the red planet and space, which would you choose and what evidence would you use to convince your boss you are right?"

Mixed hat group #1

	Facts	Strengths	Limitations	Feelings about it
Sending Humans				
Sending Robots				

Mixed hat group #2

	Facts	Strengths	Limitations	Feelings about it
Sending Humans				
Sending Robots				

… see doc at https://docs.google.com/document/d/1XlJvE2i4qcTZ2eTED9HlMTIkrUlHXiDUSbCr9-3RZ7M/edit