

Bridging Earth and Mars (BEAM): Front-End Evaluation Report



Courtesy NASA/JPL-Caltech

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EXECUTIVE SUMMARY

This report summarizes front-end research with Saint Louis Science Center visitors on the topics of Mars, Mars exploration, engineering, and robotics. This work was conducted by the Research & Evaluation Department of the Saint Louis Science Center. This front-end study was designed to inform the content development of the Bridging Earth and Mars (BEAM) exhibition. The main objective of the research was to gather information from Science Center visitors about their familiarity with, interest in, and knowledge of Mars, Mars exploration, and the engineering and robotics used in pursuit of that exploration. This was done to help guide the exhibition development team in creating a unique experience for visitors, regardless of their familiarity with the topics. Demographic information regarding participants' age, observed ethnicity, and observed gender was collected to allow for limited comparisons between subgroups.

Between July 14 and September 10, 2014, 20 visitors were interviewed in three locations throughout the Science Center. Both adults and children were interviewed, with written consent gathered prior to the interview. Interviews were comprised entirely of open-ended questions, but, while guided by the same main questions, followed a different structure based on each participant's responses and the subsequent probing questions asked. A targeted sampling method was used to gather information from a broad sample of visitors. However, teenaged males are not represented in this sample.

Key Findings and Recommendations

- Participants provided much more personal responses when asked why we were exploring Mars than when asked why people may find Mars interesting.
 - This indicates that visitors are looking for that personal connection of why Mars matters to them.
- Visitors knew that the rovers search for signs of water and signs of life, but many did not demonstrate an awareness of why these things are important.
- Most participants knew only the very basic facts about Mars - that it is red, that evidence of water was found, and that the climate and atmosphere make it unsafe for human life.
- Several visitors believed that humans had traveled to Mars and that humans on Mars could drive rovers.
- Participants exhibited confusion about what the rovers look like and what they do on Mars.
 - Some respondents thought rovers run on belts, have a claw or scoop to pick up rocks, and/or were uncertain about how the rovers are powered.
 - It will be important to address what the rovers are, what they are made of, how they are powered, and what they look like, as visitors seem unfamiliar with these specifics.
 - There was general agreement that the rovers were taking pictures and samples of rocks, but little mention that the rovers have scientific instruments and/or perform experiments.
 - The ability of the rovers to carry out scientific procedures on Mars and send the information to Earth needs to be addressed in the exhibition.
- There was a misconception that the rovers are operated directly from Earth using a joystick or remote controller. Overall, participants were unsure of the level of preprogramming or autonomy the rovers have.

- The ways in which the rovers are controlled should be clarified.
 - Visitors are aware that the rovers face limitations and were able to name some of them.
 - Limitations may not be difficult for visitors to understand if conveyed in the exhibition.
 - Participants indicated an understanding that there is a testing process that takes place when designing and operating the rovers.
 - This provides a foundation for beginning to understand the engineering design process and how it plays a role in rover design and mission control.
 - Scientists and the general public define terms differently.
 - Clarification of words and phrases (“collecting sample,” etc.) from a scientific perspective needed.
 - More than half of the participants stated they have a personal interest in Mars or Mars exploration.
 - Three-quarters of the participants stated they have a personal interest in robotics and engineering.
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BACKGROUND

In order to inform decisions related to the development of a new experience about the science, engineering, and exploration of the Mars rovers, the Science Center's Research & Evaluation Department conducted front-end interviews with a sampling of general public visitors. Questions addressed respondents' familiarity with, interest in, and knowledge of Mars, Mars exploration, and the engineering and robotics used in pursuit of that exploration. A copy of the main questions used to guide the interviews can be found in **Appendix A**.

METHODOLOGY

Between July 14 and September 10, 2014, a total of 20 interviews were conducted with Science Center visitors by Research & Evaluation staff. A targeted sampling approach was used in order to include a broad cross-section of visitors in this study. The interview was comprised entirely of open-ended questions. Interviews were guided by the same main questions, but followed a different structure based on each participant's responses and the subsequent probing questions asked. Audio recordings were made of all interviews. From adult participants, interviewers obtained written consent. For child participants, interviewers obtained written consent from parents and verbal assent from the children. Parents were able to observe the interview process. Interviews were conducted in three closed areas adjacent to Science Center galleries and lasted an average of 13.7 minutes.

CHARACTERISTICS OF THE SAMPLE

As the sample is small, it is intended to be broad rather than representative of the Science Center's general audience. Limited demographic information was collected. Following the interview, participants were asked their age; gender and ethnicity data were gathered via observation. Detailed characteristics of the sample can be found in **Appendix B**.

Interviewers spoke with five male adults (aged 22, 30, 36, 48, and 65), five female adults (aged 21, 22, 30, 42, and 58), five male children (aged 9, 10, 10, 10, and 13), and five female children (aged 7, 11, 14, 15, and 17). Despite multiple attempts, interviewers were unsuccessful in recruiting teenaged males to participate in the study.

FINDINGS

Interview comments were analyzed and similar responses were grouped together. Patterns emerged from these groupings, leading to the findings below. Respondent quotes presented throughout the findings are selected to show examples of the types of responses that support each finding.

Why Is Mars Interesting?

The first question asked was "why do you think people might find Mars interesting?" Though participants provided a variety of answers, three reasons were repeated by 25% or more of the sample. Some participant responses were coded to more than one answer. .

- Seven participants (35%) discussed the *possibility of life on another planet*.
 - "Well there is evidence I've heard of water on Mars in the past which means there is a possibility of maybe life in the past on Mars. So if there's even a possibility of life on another planet that's definitely something people want to know about, right?" (#2, male adult)
 - "I think because they think there's another planet out there that has a life form on it." (#8, female adult)
- Five participants (25%) talked about *general curiosity and humanity's desire to explore*.

- "...just we as people since the beginning of people, we've always been going to new and different areas since like the 1800s, Columbus going trying to find new routes to India, finding America and people already being in America, there were ton of nomadic tribes all around and all kinds of cultures, so just the idea of exploring new areas has just always been a part of us as a species and Mars is like the next step." (#5, female child)
- The fact that *Mars is the close to Earth* was mentioned by five participants (25%).
 - "It's closest, it's nearby, we're sending rovers there already, it's in the news a lot." (#7, male adult)
 - "It always has been presented as the nearest planet that could potentially support life. And because of its proximity it's of more immediate interest to people I guess." (#12, female adult)

Why Are We Exploring Mars?

Participants were next asked why they thought we were exploring Mars. Once again, although respondents provided varied answers, a few stood out after being repeated by 25% or more of participants. Some participant responses were coded to more than one answer.

- Seven respondents (35%) thought we are exploring Mars *to see if there is life or if there is the potential for life on Mars*.
 - "Well I'm not a big alien person, but you never know. Someone living up there something new, something interesting. Some species or a protozoa. Something interesting up there." (#18, female adult)
- Six respondents (30%) thought we are exploring Mars either because *it may be inhabited by humans one day or to determine if it could be habitable for humans*.
 - "Well there's a possibility that we can terraform it to where it could be inhabitable at one time or eventually." (#6, male adult)
 - "Because maybe people want to colonize it and claim it and have people living on it. I mean I read a book and it said in like such and such years we might be able to have colonies on Mars and stuff." (#19, male child)
- Six respondents (30%) thought we are *looking for minerals or resources we can use on Earth*.
 - "Yeah like atmosphere and like maybe water and stuff that maybe we can use as resources." (#3, female child)
- Five respondents (25%) talked about exploring Mars *so we could learn and discover more about it*.
 - "I think it's kinda interesting to explore another planet that we can actually, eventually get to, and that's why people are so excited." (#6, male adult)
 - "To reach beyond our planet and see what's there." (#16, female child)

Answers to the question, "Why are we exploring Mars?" elicited more personal responses than those to the question, "Why do you think people might find Mars interesting?" The action of exploring Mars seems to be tied more with things that could personally affect them as humans, such as the habitability of Mars and resources they may need. This indicates that regardless of interest, visitors need a personal connection and reason for why we are exploring Mars.

Things People Know

During these interviews, it became clear that, overall, respondents were familiar with and knowledgeable about certain topics related to Mars and Mars exploration. This ranged from very simple factual information to more in-depth concepts. Given the level of familiarity most visitors already have with this information, these may be used as an educational foundation upon which to construct the exhibition.

What People Know

- *Mars is red.*
 - “Yeah, yeah The Red Planet and everything.” (#10, female adult)
 - “How did it become red?” (#14, male child)
- Nine participants (45%), six adults and three children, stated that *Mars cannot currently sustain human life or that the climate and/or atmosphere are unsafe for humans.*
 - “...seeing can we inhabit it? Can we make it inhabitable? Can we put an atmosphere around it somehow?” (#5, female child)
- Fifteen respondents (75%), nine adults and six children, know *we sent robots to explore Mars.*
 - “Um, you have a rover up there?” (#14, male child)
- *We are looking for rocks or testing the soil and/or atmosphere to learn more about Mars.*
 - “They have cameras on them, they send them out, and they take pictures of the ground and take samples don’t they?” (#16, female child)
 - “They’re trying to collect things on the surface to see if we can live on there or like discover life and stuff, yeah, pretty much...like maybe certain air or like, I can’t think of what I’m trying to say.” (#3, female child)
- Ten participants (50%), three adults and seven children, mentioned that the *rovers have a camera.*
 - “There’s like cameras and like stuff so you can see.” (#3, female child)
 - “Because it has that little eye with the camera I think.” (#14, male child)
- *The rovers have wheels.*
 - “Like robots with wheels I guess.” (#16, female child)
 - “I know they’ve got multiple wheels.” (#6, male adult)
- *Communicating with the rover involves sending information from Earth.* Explanations given included radio waves and digital data. A few participants mentioned satellites and some children mentioned the antennae on the rovers.
 - “Radios and mostly radio instructions for the rovers...Mostly antennae from the rovers and then from control panels here on our planet.” (#4, male child)
 - “It’s somehow radio. We have some sort of radio antennae that can send a message out there, but I don’t really know the process.” (#7, male adult)
 - “Satellite maybe?... And then it like gets to the rover.” (#14, male child)
- *There is a time delay in communicating between Earth and Mars.* The estimated time varied wildly (minutes, hours, a day, weeks, a month, even a year), but 16 participants (80%), nine adults and seven children, thought that there was some sort of time delay in communication.
 - “...the signal would take a long time to get there, even light speed it would be delayed for it to get there.” (#10, female adult)

- “Well it takes a long time to get information from there. [How long?] Oh heavens I have no idea. A year.” (#8, female adult)
- “I would say minutes.” (#9, male adult)
- *Working with the rover is a team effort.*
 - “I think there would be a big team. Maybe just involved with the rover, maybe like 100.” (#17, female adult)
 - “It’s probably a collaboration, it’s got to be a collaboration, there’s tons of people working on it. They’re probably going to be disputes along the way, but they just have to work it out from every single turn.” (#5, female child)
- Eight respondents (40%), four adults and four children, know that *the rovers undergo testing on Earth before being sent to Mars.*
 - “It probably takes them a bunch of times to get it to move and they probably have to try it on fake terrain like in the lab, they have to control it around the lab kinda.” (#19, male child)
 - “They train you with technology and probably practice with the rover on Earth.” (#20, male child)

Respondent-Named Limitations

Respondents had a good idea of some of the limitations faced by the Mars rovers, scientists, and engineers. No one listed all, or even most, of the limitations, but the knowledge was spread amongst the participants.

The limitations that were identified included:

- Nine respondents (45%), five adults and four children, mentioned *physical obstacles and difficulty navigating the topography of Mars.*
 - “Well obstacles like there’s rocks and they can’t go over them and it’s going to take a while to go around them and stuff like that. That would be a challenge.” (#16, female child)
- Five respondents (25%), one adult and four children, said that *connection/contact issues that could arise between the rover and Earth.*
 - “Probably have a bad connection” (#14, male child)
 - “Like um, where it’s located, like if it’s...sometimes it might disconnect because it’s long distance.” (#15, male child)
- Five participants (25%), four adults and one child, stated *there would be no one on Mars to fix the rover if it broke.*
 - “Well, there’s no mechanics there. If it breaks down they’re out of luck.” (#10, female adult)
- *Limitations of power*
 - “The batteries might die and it would instantly shut down.” (#20, male child)
- Four participants (20%), two adults and two children, mentioned *difficulties in dealing with the time delay.*
 - “I think they’re limited in being able to, well there’s the delay in getting messages to it saying hey, see there’s that time delay, we might miss the opportunity. You know, kinda like hey, that looks interesting but by the time the message gets there, I’m not sure if you can back up and it

may already be contaminated by the rover going past it so if you're trying to get a clean sample of that area, you know, well we've already kind of disturbed this." (#7, male adult)

Why Rovers?

Respondents offered answers to the question "Why do we use robots/rover to explore Mars?" Although not all of the replies are factually accurate, they provide insight on visitor perceptions for rover exploration.

- Seven participants (35%), five adults and two children, stated that *machines can do things humans cannot*.
 - "So they send the machines because they can do things that we can do and not die." (#5, female child)
 - "And then they can mass produce these or produce them easily or more easily than something other than just like sending a baby. It would be bad to do that." (#5, female child)
 - "They're nonstop, they can go 24 hours a day without having to stop or do anything." (#6, male adult)
 - "They make less mistakes than humans." (#6, male adult)
 - "This is an easier, faster, and probably cheaper way to, you know, go explore." (#7, male adult)
 - "And it would probably be easier to be able to go across long distance with a rover or a mechanical thing to be able to go further distance and see more than a person walking on foot would be able to." (#18, female adult)
- Seven participants (35%), four adults and three children, mentioned that *rovers are used as Mars/space travel to Mars is unsafe for humans at this time*.
 - "It's safer that way. No humans are in danger and we can send them out there." (#6, male adult)
 - "For safety reasons I assume and we don't know what kind of atmosphere you know us conducive for life forms, how long it takes to get there, heat, cold, hot... The robots can survive." (#8, female adult)
 - "Because we don't know what all... we can get a man there without getting him back home safely we haven't figure that part out." (#9, male adult)

Perceived Types of Life on Mars

Twelve respondents (60%), nine adults and three children, answered that the *rovers search for some type of life on Mars*. Of these, five participants (25%), all adults, responded with a generic "the rovers are looking for life" statement. More specific answers included:

- *Microbial Life*
 - "Mainly bacterial, if I'm not mistaken. Simple life forms." (#6, male adult)
- *More advanced life forms*
 - "Probably the only things we probably would find would be like microorganisms and stuff like that. Really small fossils and if there is more advanced life forms, that'd be interesting to see, too. I think life would be the main thing that they're looking for. (#2, male adult)
- *Space animals*
 - "Maybe not aliens, but maybe something living up there. An animal or something living in the soil or something. I would think so." (#18, female adult)

- *Bugs*
 - “You know maybe like a space animal or something. Or some sort of like new thing of bugs or something.” (#19, male child)
- *Martians/Humanoid aliens*
 - “They’re trying to see if the fact that ‘martians’ really live there, maybe. ... [What do you think a martian would look like?] Well I had this like little toy martian and it was kinda like, it has a green body, big red eyes. It was like, I mean you could kinda say it almost looked human. Kind of.” (#19, male child)

Misconceptions / Gaps in Knowledge

The interviews also revealed many areas in which respondents held either misconceptions or gaps in knowledge. The exhibition design team will need to address these areas in order to correct misconceptions and fill in gaps in visitors’ knowledge that align with the educational goals of the exhibition.

The misconceptions and gaps in knowledge can be found below:

Misconceptions about Gravity

Misconceptions *about gravity and how it works in space and on Mars* were mentioned by six respondents (30%), two adults and four children.

- “Well there’s no gravity in space, I know that. So there’s kinda no way it can probably fall over because if it would fall over it would just float up.” (#14, male child)
- “Isn’t the sun in front of Mars?...If it is then you’re going to have to deal with the sun...’cause that would be really hard with the gravity also. So you’re going to have to deal with gravity probably pulling you towards it. [Pulling you towards the sun?] Mhmm...Because the Earth is sustained by the sun ‘cause of the sun’s gravity...because like the reason the stays by the sun is because of the sun’s gravity...I think Mars is also helped by the sun too with the gravity held up by the sun too.” (#20, male child)

Misconceptions about Mars’ Location in the Solar System

Sixteen respondents (80%), nine adults and six children, mentioned misconceptions that included inaccurate or vague information about Mars’ location in the solar system.

- Twelve respondents (60%), seven adults and five children, stated either an *inaccurate distance/time for how long it takes to get to Mars or a vague “far away.”*
 - “Yea, there’s no air on Mars, is there? So you would have to take everything with you. And it’s so far away.” (#12, female adult)
 - “It’s a long time away.” (#11, female child)
 - “I’m guessing it’s kind of hard because they have to get all that electricity and they have to get a lot of electricity because it takes like four years to make it to Mars or something and a lot of times they want to make it come back to Earth because if it’s stuck sometimes they have the pictures lost because if one of them did take a picture of a martian or something, but it got stuck there and then no one will know if they existed. Or water or something, something important.” (#19, male child)
- Perception that *Mars is the closest planet to Earth* was shared by two respondents (10%), both adults.

- “We’ve tried looking in other solar systems for planets that could harbor life, so it’d be really interesting to see if the planet closest to us has or had the potential for life.” (#2, male adult)
- Two participants (10%), both children, *confused Mars and Mercury*, which may suggest confusion related to the fact that both names begin with “M” and the use of pneumonics to learn the order of the planets.
 - “Um, because it’s the first planet to the sun.” (#15, male child)

Misconceptions about Space Travel

Misconceptions that *people have traveled to or currently travel to Mars* were mentioned by three respondents (15%), one adult and two children.

- “Well [you’d need] someone to pilot the ship, a couple scientists to do scientist stuff, do experiments, they need probably an engineer in case there’s something’s wrong with the ship, someone who is good with communication, a cook maybe. Stuff like that?” (#18, female adult)
- “Because not many people have been there...because it’s really far away. [How many people?] Couple. [When do you think they were there?] 19 something.” (#20, male child)

Misconceptions about Mars

Two incorrect perceptions about Mars were each stated by a combined total of four respondents (20%).

- Two respondents (10%), one adult and one child, thought that *Mars is hotter than Earth*.
 - “More hotter there.” (#1, female child)
- Perception that *Mars does not have an atmosphere* was shared by three participants (15%), two adults and one child.
 - “You don’t want to be out on Mars with no atmosphere, with no oxygen to be able breathe to do research.” (#18, female adult)

Misconceptions about the Rovers

At least 65% of respondents, four adults and nine children, had one or more misconceptions about the Mars rovers: what they look like, how they function, and how they are powered.

- Five respondents (25%), three adults and two children, stated that *rovers have a claw or scoop used to pick up rocks*.
 - “It’s got like a circle head and it’s got like a machine arm that’s a claw that picks rocks and stuff up.” (#14, male child)
 - “Probably like a little pod or a robot and it has like legs to land on or wheels to roll around and collect things like a shovel or some kind of scoop or something.” (#17, female adult)
- Perception that *the rover runs on tracks or belts* was shared by four participants (20%), two adults and two children. An additional two respondents (10%), both adults, could not decide whether the rovers moved using wheels or belts.
 - “Tracks, wheels, tracks. Kind of like tanks, but many, a lot of cameras.” (#4, male child)
 - “Um a belt.” (#15, male child)
- Two respondents (10%), one adult and one child, shared the perception that *people can get inside and drive the rover*.

- “I think you maybe could or you could or do it while you’re in it if you can get in one. So like, isn’t there one where you can drive? Or was there one?” (#3, female child)
- “Or maybe riding in it, that would be even more cool.” (#18, female adult)
- Nine respondents (45%), three adults and six children, thought that *the rover is remote controlled from Earth by joystick or remote control*.
 - “It could be like controller joysticks, it could be like an airplane. It depends on how it’s all set up and how they programmed it.” (#5, female child)
 - “Probably from like a joystick.” (#20, male child)
- Misconceptions in *how the rover is powered*.
 - “Electricity from here.” (#1, female child)
 - “I think it would have fuel, batteries, probably solar panels.” (#9, male adult)
 - “By like charging before you ship it, like put it on to Mars. Like electric, I guess.” (#3, female child)

Misconceptions about Designing and Operating the Rover

Respondents’ answers revealed misconceptions about who works with the Mars rovers, what their educational background is, and where they are geographically located.

- *More mentions of roles for engineers than scientists*.
 - “Programmers, engineers, mechanics, I don't know how many different ones you'd need. It would be an elaborate team.” (#9, male adult)
 - Well there’s someone involved in planning and then the execution of the plan, development of the process, and building of the device, and testing and then there’s probably people thinking about people actually going. I’m sure there’s an extensive amount of people thinking about this, although I still can’t imagine that ever happening. [Can’t imagine what happening?] People actually going there.” (#13, male adult)
 - “The message, the controller, and camera one.” (#14, male child)
 - “Like some people that knew, that designed the rover and stuff, and people that control the panel or whatever they use, and the information.” (#16, female child)
- *Disconnect between described roles of those who work with rovers and the pathways believed necessary to become those roles*. Though more engineering roles were mentioned, there was more discussion of necessary science education. Nine respondents (45%), four adults and five children, highlighted the importance of studying science or scientific fields.
 - “Pretty elaborate engineering degree if I had my guess. Several different degrees, a lot of college. I don’t think you’re going really gonna get hands on unless you have a degree.” (#9, male adult)
 - “Study a lot about space.” (#14, male child)
 - “Well if you studied, I guess if you studied in that type of stuff...Outer space and technology.” (#16, female child)
- *Lack of awareness that people who work with the rovers are located all across the country*.
 - “I think there’s a control center here not in St. Louis but I wanna say is it JPL in California where there’s people that tell the rovers where to go.” (#10, female adult)
 - “I would imagine lot of them are people who were hired in to NASA. Also other universities that are probably affiliated.” (#7, male adult)

Misconceptions about the Science Conducted by the Rovers

Participants had limited or inaccurate understanding of the scientific instruments on the rovers and how they are used.

- Four respondents (20%), one adult and three children, *used the term “collecting samples” in a very colloquial way.*
 - When visitors talk about the rover “collecting samples” it sounds correct to a scientist, but the way respondents use this phrase suggests that they are imagining a process that is quite different than what the current rovers actually do. For participants, “collecting samples” meant collecting a tangible, physical rock, which many believed would be sent back to Earth for study. This misconception was prevalent in the answers:
 - “Puts them in like a bucket in the back, like a box, a metal box.” (#14, male child)
 - “Well that they go to a planet, they’ve been to the moon too. I don’t know. And they take pictures and samples and send them back.” (#16, female child)
- In general, *respondents did not seem to be aware that the rovers conduct science experiments on Mars.*
 - Though the collection of rocks was brought up by participants, there was *little to no discussion or understanding of why Mars rocks are important.*
 - Answers focused on rover exploration and the discovery of water.
 - Fifteen respondents (75%), eight adults and seven children, mentioned either that water/ice has been found on Mars or that the rovers search for water.
 - “Isn’t there water on like the poles, there’s like ice on the poles of Mars I thought...So then there’d be water.” (#2, adult male)
 - “Yeah like atmosphere and like maybe water and stuff that maybe we can use as resources.” (#3, female child)
 - “Well, I know they’ve had the three rovers up there that’s about it. And I know the rovers have found some things that indicate there was maybe water there at one time.” (#10, female adult)
 - “Because if people have to live there, then you have a water supply ‘cause you can’t have all the water forever so we need to help put some water on that planet.” (#19, male child)
- *The scientific instruments on the rovers were never named specifically.* When they were mentioned at all, which was by approximately a quarter of respondents, all adults, they simply described the rover as having instruments or gadgets on it. A “camera” was mentioned by ten participants (50%), three adults and seven children, though no one seemed to realize how many cameras there are or that there are different cameras for engineering/navigational purposes and scientific purposes.
 - “Well there’s no seat because there nobody sitting in it, and just cameras and test equipment. Assortment of miscellaneous gadgets.” (#13, male adult)
 - “Well I think someone probably controlling it and they have a way to maybe take samples or to use a little robot arm to gather things and take things back to the spaceship, something like that.” (#18, female adult)

Problem Solving

Respondents' mixed levels of knowledge about Mars and the rovers meant that they responded with both correct and inaccurate information; however, even if they did not know the answer to a question, many respondents were able to use their problem solving skills to address the issues posed to them.

- “No gravity so it’s just probably harder to get around. Um... [How do you think they get around then without gravity?] Maybe they have this claw that like holds them to the ground, like stay in. [(Makes movement of claw pulling around.) So they hook themselves into the ground with the claw and sort of pull themselves?] Yes.” (#14, male child)
- “They gotta have some kinds rechargeable energy source because obviously there’s not a power cord there I feel like an electricity generator wouldn’t be feasible. So I would assume some sort of solar energy but then at night it would have to have certain power cells. So I assume it has to be solar powered with battery cells so it can store the energy during the day and use it at night.” (#12, female adult)

Interest in Mars / Mars Exploration

Participants were asked if they were personally interested in the topics of Mars and Mars exploration. Of the 20 respondents, 65% claimed to be interested in the topic; seven adults and five children. When asked why they found this topic interesting, reasons given ranged from wanting to learn more about the unknown to an interest in the potential habitability of Mars. Reasons participants found this topic interesting can be found below.

Reasons for a Personal Interest in Mars and Mars Exploration

- Four respondents (20%), two adults and two children, mentioned *exploration* as a reason for their interest.
 - “Just the exploration. There’s the possibility of life anywhere. For there to not to be... life out there is kind of ignorant and I don’t know. But Mars is a stepping stone.” (#6, male adult)
- *Learning more* (about the unknown)
 - “I’m interested in the unknown and seeing what's up there and learning more. I'm a teacher so being able to find stuff to share with my students.” (#18, female adult)
- Four participants (20%), three adults and one child, expressed their curiosity in the *possibility of life on Mars*.
 - “That we could go to and explore and stuff. Maybe like new animals and insects and stuff.” (#3, female child)
- Three respondents (15%), one adult and two children, stated their interest in the *potential habitability of Mars*.
 - “That nobody don’t live on there and like it would be cool if we found some things, like if we found out that we could live on Mars.” (#15, male child)
- *Finding water/ice on Mars*
 - “Well I’ve heard, couple of my textbooks at school, that they’ve seen ice on Mars so there was water there... Well that there’s something related to our planet on Mars.” (#16, female child)
- Using information learned about Mars to *better understand Earth*.
 - “And then that Mars is similar to Earth. Maybe if we can find out why Mars became the way it is now maybe we could use that information to prevent some of the climate change and things

that are happening on Earth it would be helpful for scientists to know so that we don't lose all our water or lose our atmosphere." (#10, adult female)

- The *geology of Mars* and volcanoes
 - "And I found out that it had volcanoes and I kinda like study volcanoes and I like to study geology and I'm part of the cub scouts and we're planning to take some scouts to get their geology badge, which I'm not sure when we're going to do it, but we might get to do it and do geology." (#19, male child)

Reasons for a Lack of Personal Interest in Mars and Mars Exploration

Those who are not interested in Mars or Mars exploration cited that it was not relevant to their lives or that they have a general disinterest in space.

- Three respondents (15%), all adults, stated that they did not find Mars interesting because it is *not relevant to their lives*.
 - "Well it's too far in the future and it's just not a part of my life." (#13, male adult)
 - "On a scale? 30% [interested]. I just think we have more stuff we need to be dealing with before we go out there. We need to fix our own planet. Prioritize." (#9, male adult)
 - "I don't think probably in my life time I'll live long enough to know what's there or what they have found I think that's the main reason." (#8, female adult)
- *Not interested in space*
 - "I don't know. There's gotta be a reason but I don't know. Oh wait, yeah, I'm not a big fan of space." (#14, male child)

Interest in Robotics / Engineering

Participants were asked if they were personally interested in the topics of robotics and engineering. Of the 20 respondents, 75% claimed to be interested in the topic; seven adults and eight children. When asked why they found this topic interesting, reasons given ranged from wanting to learn how things were done to an interest in the sheer ingenuity that people are coming up with the new technologies. There were also references to how robotics and engineering affect humans, indicating that this topic seems more personally relevant to participants. Reasons participants found this topic interesting are outlined below.

Reasons for a Personal Interest in Robotics and Engineering

- Five respondents (25%), four adults and one child, stated their interest in the fact that *human ingenuity came up with the technology being used*.
 - "Well the fact that people made it so they could control it from Earth or wherever they are from another planet. That's cool." (#16, female child)
 - "The way that scientists have to be really creative in how they think and come up with really new solutions that no one's tried before to make the rover and send it there. I've seen illustrations of what the rover probably looks like when it's landing with balloons and things and it's neat that they come up with solutions to this problem that no one's really had before." (#10, female adult)
- Four participants (20%), three adults and one child, mentioned the *broader applications of robotics and engineering*.
 - "That's pretty interesting. Engineering it's a lot minds working to build that stuff. We could use more minds like that running around even if we don't send it to Mars. Make that kind of stuff

work for us here. We could make trains and heavy equipment and stuff like that. That's the kind of minds it takes." (#9, male adult)

- "I think that down the road a lot of that technology will be incorporated into possibly into our own cars, like self-guided cars or you know, we can use robotics for remote, like drones. I think that a lot of the technology we're using to get rovers to Mars will eventually, if it's not already been, will be incorporated into things that we see here on Earth. Like throughout this whole facility, see things that are like, well that's been incorporated into our lives even though years ago it was a science experiment." (#7, male adult)
- Four respondents (20%), all children, expressed an interest in wanting to *learn how to make or build robots*.
 - "How they build it. Like I have no idea how they do it." (#14, male child)
 - "You get to build something...and tamper with technology." (#20, male child)
 - "It would be fun to build one myself, yes." (#19, male child)

Reasons for a Lack of Personal Interest in in Robotics and Engineering

Those who are not interested in robotics and engineering typically commented that it was too difficult of a subject to wrap their heads around.

- Two respondents (10%), one adult and one child, stated that they found the topics of *robotics and engineering too difficult*.
 - "I can't wrap my head around computer programming and engineering. That's just not what I've ever been able to easily understand but people who do understand that are very impressive to me. I love to see what other people are doing in that field and see what is attainable and what is possible there." (#12, female adult)
 - "I think it'd be too difficult to get all the stuff to work and probably take a lot of effort and keep on trying and retrying to get it to work." (#3, female child)

CONCLUSIONS AND RECOMMENDATIONS

In this front-end study, information was gathered about visitor familiarity with, interest in, and knowledge of Mars, Mars rovers, and the engineering and robotics used in the pursuit of exploration. Analysis of interviews shows a wide range of familiarity among participants with these topics. Knowing what areas participants were knowledgeable about and familiar with can help the exhibition design team better understand which areas of their educational goals need to be clearly addressed, and which are more likely to already be known by the general visitor. This information can then be used as an entry point in the exhibition. Those areas in which participants' comments indicate unfamiliarity with or misconceptions about important topics should point the exhibition design team towards areas on which they may wish to focus their energies.

Purpose of Exploring Mars

When asked why they thought we were exploring Mars, respondents provided much more personal responses than when asked why people may find Mars interesting. This indicates that most visitors are looking for that personal connection of why it matters to them.

Respondents thought that the rovers search for minerals, evidence of potential human habitability, and signs of life, but many did not demonstrate an awareness of why these things are important. Discussing the reasons for the exploration of Mars and how it connects to visitors' lives would be beneficial.

Mars

When generalized, most respondents knew only the very basic facts about Mars - that it is red, that evidence of water was found, and that the climate and atmosphere make it unsafe for human life. There were many misconceptions about the climate and atmosphere of Mars, gravity, Mars' location in the solar system, and amount of time it would take to travel between Earth and Mars. Overall, very little knowledge of Mars was mentioned (although a couple of outliers did know quite a bit). It is clear that there will need to be significant attention paid to basic information about Mars in this area.

Mars Exploration

Most respondents were aware that we have sent rovers (or robots/probes) to Mars. They were aware that the rovers look for rocks or test the soil and/or atmosphere in order to learn more about Mars. This indicates that most visitors will walk into the exhibition already familiar with the idea of a Mars rover, allowing for further scaffolding of learning from that foundation.

There were also some noteworthy misconceptions about Mars exploration. Many of these seem to indicate a confusion of space travel in general with Mars exploration. There were several participants who believed that humans had traveled to Mars and a few who believed that people on Mars could drive rovers. These misconceptions need to be clearly addressed within the exhibition.

Rover Design and Operation

Most respondents knew the rovers had one or more cameras and operated on wheels. Some participants, however, thought that the rovers moved using tracks or a belt, similar to a tank. Many talked about the rover having some sort of a claw or scoop used to pick up rocks. This description of a claw cropped up repeatedly throughout the interviews.

There was general agreement that the rovers were taking pictures and samples of rocks, but respondents did not mention that the rovers have scientific instruments (other than cameras) and perform experiments. Respondents made general references to "gadgets" or "instruments", but without articulating their purpose. The ability of the rovers to carry out scientific analyses on Mars and send the information to Earth needs to be addressed in the exhibition.

Some participants thought rovers could be driven by people. There was also an array of thoughts on how the rover is powered. Answers varied from solar energy to fuel to "electricity from here." The exhibition will need to address what the rovers are, what they are made of, how they are powered, and what they look like, as visitors may be unfamiliar with these specifics.

Most respondents knew that we communicate with the rover by sending information from Earth, with many people talking about sending information via radio waves or satellite. Almost everyone knew that there is a time delay in communicating between Earth and Mars, although estimations in the length of this delay varied wildly. Given that there seems to be some level of familiarity with the basic concepts in this area, it may be somewhat easier to delve deeper on this topic to address the specifics of how the information is conveyed between the rovers and Earth, and how and why there is a time delay.

One of the misconceptions encountered in this study was that the rovers are operated directly from Earth by using a joystick or remote controller. The ways in which the rovers are controlled should be explained. There is also a potential disconnect between the understanding that there is a time delay in communication between Earth and Mars and the misconception that the rovers are directly controlled via joystick. It may be important to clearly illustrate how the time delay affects daily rover operations.

Taken all together, respondents had a good idea of some of the limitations a rover faces on Mars. This indicates that these limitations may not be difficult for visitors to understand if conveyed within the exhibition.

Most respondents indicated an understanding that there is a testing process that takes place when designing and operating the rover. Many talked about testing the rover on Earth before sending it to Mars. This is an excellent foundation for beginning to understand the engineering design process and how it plays a role in rover design and mission control.

Most respondents understood that designing and operating a rover is a team effort; however, who and how many people work with and on the rovers seemed less clear. Participants stated that engineers were likely to be involved on the team, but when asked for the qualifications of who works on the rover project, they listed science degrees and areas of academic interest more frequently. This suggests that visitors have a broad idea of who may be involved with the rovers on a regular basis, but that an explanation of their roles may help them to understand how the rover functions.

There are some key terms that scientists and the general public use differently. A number of respondents thought that rocks were being physically collected by the rovers to be sent back to Earth for testing (i.e. “collecting samples”), as opposed to the rover carrying out scientific experiments and analyses directly. There may be additional terms with similar challenges that did not emerge in these interviews. It will be important to keep this in mind throughout the exhibition planning process and identify any other terms that may be misunderstood.

Interest in Mars, Mars Exploration, Robotics, and Engineering

The majority of respondents stated they have a personal interest in Mars or Mars exploration. In particular, they expressed interest in exploration, learning about the unknown, geology, scientific discoveries that may lead to more knowledge of Earth, and the possibilities of life, water, and potential habitability. Respondents who were uninterested in the topic indicated that they were not fond of space or did not find the subject relevant to their lives.

Three quarters of the respondents stated they have a personal interest in robotics and engineering. In particular, they expressed interest in the fact that humans created the rovers, that they saw the personal relevance to the subject, and that they wanted to learn how to use or build robots. Respondents who were uninterested in the subject believed it to be too difficult or complex.

Appendix A: Interview Guide

Mars/Exploration

- Why is Mars interesting? Why are we exploring Mars?
- What have we already done?
- Have you heard about Curiosity?
 - What about Spirit & Opportunity?
 - What is Curiosity looking for?
 - What kind of life?
 - Do you think there is water on Mars right now?
- Why does it take so long to communicate with Curiosity? How far away is Mars?
- If someone is into subject – Why?
- If someone isn't into subject – Why not? What would make it more interesting?

Engineering/Robotics

- Why do we use robots/rover to explore Mars?
- How do rovers work on Mars?
 - How do they communicate?
 - How do they move?
 - How autonomous are they? (Do they control themselves? Does someone else control them? How? How much does someone else control them?)
 - How are they powered?
- What kinds of limitations do you think the rovers have? (What limitations do the scientists have working with them?)
- How many people do you think are involved in planning the rover's daily activities?
 - What are their roles? Titles?
 - How do you become someone who works with a Mars rover?
 - How do they make decisions?
- What do you know about how scientists tell the rover what to do? (programming)
 - How do they send the messages to the rover?
 - Tell me more about how programming a rover works
- How easy is it to program a rover? Is it something you can do one time and it's done? For the engineers who are controlling/programming it, how do they do it? How do they make it work? What are their steps?

Appendix B: Characteristics of Sample

This document describes the characteristics of the participants in the open-ended interviews.

Table 1: Characteristics of Sample

Respondent ID	Observed Gender	Age	Observed Ethnicity
1	Female	14	African-American
2	Male	22	White
3	Female	15	White
4	Male	10	White
5	Female	17	White
6	Male	30	White
7	Male	48	White
8	Female	58	White
9	Male	36	White
10	Female	42	White
11	Female	7	White
12	Female	22	White
13	Male	65	White
14	Male	9	White
15	Male	13	African-American
16	Female	11	White
17	Female	21	White
18	Female	30	African-American
19	Male	10	White
20	Male	10	White



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