

Journey to Space

Summative Evaluation Report

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Introduction

The Science Museum of Minnesota (SMM) engaged Rockman et al (REA) to conduct a summative evaluation of the museum's *Journey to Space (Space)* exhibit. *Space* is a large-scale traveling exhibition that simulates a journey to the International Space Station (ISS), allows visitors to explore the physical properties of low gravity environments, and introduces some of the engineering and technology that makes it possible to live and work in space. This exhibit is a collaborative project led by SMM, the California Science Center and the three other members of the Science Museum Exhibit Collaborative.

The goals of the exhibit are to encourage museum visitors to: 1) immerse themselves in the sights and sound that astronauts experience traveling to, and living in, space; 2) engage as problem solvers with some of the unique engineering challenges that must be solved to support living and working in space; and 3) experience life aboard the ISS interpreted through the voices of engineers, scientists, and astronauts.

The purpose of this mixed method summative evaluation study was to gather information on visitors' interest in and perception of the exhibit; visitors' interest in and understanding of space science and research; the appeal of the exhibit across different audiences and contexts; and any impacts on visitor attitudes and understanding of the exhibit-specific content and technology.

Two REA staff, with the assistance of SMM evaluation staff, conducted the summative evaluation at SMM from July 6 – 17, 2015.

Evaluation methods included:

- Pre and post visitor surveys
- Visitor intercepts within the exhibit
- Post exhibit visitor interviews
- Pre and post exhibit paper activity

REA staff with assistance from SMM, developed survey items, intercept and interview questions, and protocols for the group activity.

Executive Summary

The exhibit attendees were a fairly self-selecting audience. Most of those interviewed had a keen interest in space travel going into the exhibit. An equally large percentage held very positive attitudes about continuing to fund space exploration and research. The Science Museum of Minnesota selected the exhibition topic in part because it tested very highly among museum visitors and potential visitors. For this reason, it is not surprising that the vast majority of those attending Space were already positively engaged about the topic.

Attendees' attitudes and knowledge about space were shaped by numerous factors, including one's place of employment (e.g., space, engineering and aviation fields), fields of study (e.g. engineering, physics, astronomy other science fields), and by media and popular culture (books, films, TV, etc.). More than half of survey respondents stated that they used science in their work. The most frequently cited ways of using science 'at work' was through school or teaching.

A majority of visitors attending the exhibit were adults with children in groups of three or more. These were primarily family groups, many including multi-generational members (grandparents, parents, children/grandchildren). A majority of respondents had come to SMM exclusively to see the Space Exhibit. Most of the respondents were not museum members, with more than half (70%) either not having visited the museum at all over the previous two years or at least 1-2 times during that same period. The exhibit was clearly a major draw for those who had not been to SMM in the recent past.

Many visitors were intrigued by the mystery and excitement of space travel. They expressed an intense curiosity about exploring 'new frontiers' and learning about other planets in the solar system. Many older visitors' (50 and older) perceptions about space travel were strongly influenced by memories of the first manned moon expedition in 1969. Many of these same visitors had little knowledge of subsequent or future manned or unmanned space missions.

Very few visitors admitted to any attitudinal or knowledge change about space exploration as a result of attending the exhibit. Since most were very positive about space to begin with, the exhibit served to reinforce existing attitudes. Many came away with a greater appreciation for the amount and types of preparation necessary for space travel, in addition to a greater awareness of the kinds of risks astronauts face. The exhibit enabled visitors to see astronauts as individuals, whose personal lives and relationships were impacted by long periods away from family and friends.

Visitors found the ISS simulator to be the most interesting part of the exhibit. They particularly enjoyed the simulated sensation of being weightless in space. Being in the ISS simulator provided visitors with a valuable context of how astronauts live in space. Their sense of physical disorientation while in the simulator gave visitors empathy for the astronauts' experience. Visitors spoke in general terms about their knowledge of the ISS. Most everyone referred to the mission's focus on research and experimentation, though very few could recall any specific experiments that had been conducted on the space station.

Visitors were fascinated to learn how astronauts conducted daily health, exercise and hygiene activities in zero gravity. Visitors were also drawn to many of the exhibit's hands-on elements such as the robot arm. Being able to manipulate objects in the manner of astronauts made the exhibit more real and accessible for visitors. Visitors were very gratified to have had greater insight into the personal stories of astronauts. Many remarked that the human and emotional strands of the exhibit were both very powerful and meaningful.

Visitors spoke in very emotional terms when describing the risks and challenges of travel to Mars. They wondered about the psychological consequences of traveling on a mission of such long duration, in addition to being away from friends and family. Visitors emphasized the bravery and sacrifice of astronauts who embark on long missions to space. Visitors cited 'distance' as the primary distinction between traveling to the ISS vs. traveling to Mars.

Concern about emotional and/or psychological issues was most evident in visitors' perception of the most critical barriers to continued space travel. Loneliness, separation, personal safety, and physiologic adaptation to weightless environments were some of the more acute barriers cited. This focus reinforced many visitors' somewhat visceral reaction to many of the exhibits' most prominent themes. Others expressed concern over lack of continued federal funding, and the question of long-term sustainability of materials. Pre-exhibit survey respondents cited gravity as the greatest barrier to overcome, while post-exhibit survey respondents cited funding as the greatest barrier.

With respect to interesting technology and engineering, visitors were most impressed with the design and complexity of the ISS simulator. A good number of visitors were also intrigued with the ion thruster, and the amount of energy it was able to produce. Many reported they were surprised at the rapid evolution of space suit design. This response may have been triggered as a result of seeing the more lightweight suits astronauts wear while exercising while aboard the ISS and, perhaps, confusing them with the bulkier suits worn to go outside the space station. Visitors were also fascinated by the many examples of sustainable materials development and engineering. Visitors remarked on the

innovativeness of applying 3-D printing technology aboard the ISS, and envisioned the subsequent benefits of these applications back on Earth.

Words visitors used to describe the exhibit and space travel reflected a heightened curiosity of exploration (adventurous, discovery, fascinating, amazing), or a cautious trepidation of embarking on the unknown (frightening, mysterious, dark, cold).

Methods

Pre- and post- visitor surveys were administered at the entrance and exit of the Space exhibition area. All visitors over thirteen years of age were invited to complete the survey and were offered an SMM pencil or temporary tattoo as an incentive for doing so. A total of 879 pre-surveys and 880 post-surveys were collected.

Visitor intercepts took place at the exit of the ISS simulation. Visitors were approached as they exited the simulation and were offered a pencil for their time. The intercepts lasted approximately three to four minutes and responses were recorded in writing by the researchers. Sixteen intercepts were conducted in total.

Post-exhibit interviews were conducted with selected visitors as they exited the Space exhibit. Each interview lasted approximately 5-10 minutes. 50 interviews were conducted in total. Potential interviewees were selected as to represent a range of visitors from family groups to young adults. All interviewees were asked to sign an Interview Consent Form, which outlined the purpose and procedures of the study. All interviews were digitally recorded with the full knowledge and consent of the participants. These digital audio recordings were used strictly for transcription purposes, and were erased following transcription. No names of any of the visitors participating in the intercepts are used in this report. Visitors received a \$10 SMM gift card as incentive for their participation.

For the pre- and post- group activity, groups of two to five visitors were recruited either as they approached the exhibit (for the pre- activity) or as they exited the exhibition (for the post- activity). Participants in the groups had to be thirteen years of age or older, and groups with younger children were not approached (as asking them to take part in an activity not appropriate for the entire group would be distracting and might detract from their museum experience). Potential participants were told the activity should not take more than twenty minutes and that the group would receive a \$25 museum gift card in exchange for their time. Ten groups consisting of 35 total participants completed the pre- activity and eight groups consisting of 22 individuals completed the post- activity.

Full interview summary

Demographics

Interviewees ranged in age from 13 – 75 years. Approximately 20% of the interviewees were from *13 – 19 years old*; 25% from *20 – 29 years old*; 12% from *30 - 39 years old*; 14% from *40 - 49 years old*; 10% from *50 – 59 years old*; 15% from *60 – 69 years old*; and 4% were *70 or older*.

Sixty-eight percent of those interviewed were part of a family group, while 32% came with friends. Family groups included parents and children, grandparents and grandchildren, and married couples.

Reason for coming to SMM

Nearly everyone interviewed (98%) stated that they came to SMM for the sole purpose of seeing the *Space* exhibit. An equal number had heard about *Space* before coming to the museum either through the media, on billboards or recommendations from a friend or family member.

Interestingly, many adults (parents and grandparents) told us that they came to the *Space* exhibit specifically on the requests of their children or grandchildren. During the interview process, there was a good deal of intergenerational comment, insight and conversation amongst those families who participated.

Attitudes about space and space exploration

We asked interviewees what their attitudes were about space and space exploration before they visited the exhibit. The vast majority had very positive attitudes about space.

Many visitors' interests in space and science were shaped in large part by professional or academic pursuits. A number of interviewees had formal space and aviation backgrounds, while some teens referenced their high school studies in astronomy, physics, and the like, as the source of their interest. Others were drawn to the topic through popular film, TV and web series dealing with space and science fiction. Some families had visited space themed attractions such as Cape Kennedy in Florida, the Johnson Space Center in Houston, and the US Space and Rocket Center in Huntsville, Alabama. Some

parents spoke of attending space camps in their youth, or sending their own children to similar types of camps.

We took astronomy in high school, so it was very interesting especially to him, and he's the one who wanted to come to see it. He's usually the one who doesn't want to come to events with me. (Girlfriend talking about her boyfriend).

Other interviewees talked their own personal interest in science, and how a universal theme of the mystery of space and the joy of exploration drew them to the exhibit.

A hobby of mine has always been astronomy. I have my own telescope. As a kid growing up with an interest in space was very mysterious. It's kind of the next adventure, frontier. I have always been fascinated by it. I think the show kind of has the same thoughts so to come back here it felt like a kid again; all that wonder and enjoyment. It was pretty cool.

Older adults spoke wistfully about watching the first manned space launch in 1969. For many, this expedition was the framing event of their knowledge of or interest in space and space travel. Some remarked that they knew little about the US space program other than their memories of that first space walk, and a limited number of subsequent expeditions to the moon.

I grew up in the 60s. Space travel then was very exciting. We watched it on television. The night we landed on the moon we had a moon landing party in our backyard. Since then, I've kind of lost track. I'm aware of what's going on, but not like then. When those reporters were on television and telling us what was going on, it was just so exciting. Now it kind of like 'yeah we're in space' so it's different now.

In general, most interviewees had very positive attitudes about space exploration. Many believed that the benefits and knowledge derived from space travel and research more than justified the billions of dollars invested by the US government and the private sector. A number of interviewees expressed a very palpable excitement about continued exploration of space, and the potential of new findings and discoveries. This sentiment was consistent across all age groups.

I'm very excited about space travel. I love the data gathering, in particular the pictures of flyovers of earth. It is just awesome.

I think they (US government) should spend more money on it. I think the whole thing is just fascinating.

Since most of those interviewed were very positive about space exploration going into the exhibit, there was very little expressed change in anyone's attitudes about space after visiting the exhibit. Most individuals' attitudes about space were either heightened or reinforced. There was, however, one level of change that many visitors experienced after seeing the exhibit: a greater appreciation of the more human elements of space travel, and the levels of technology and design required to keep astronauts safe during long and potentially dangerous periods in space. Many visitors expressed that the exhibit provided them with a clearer understanding of the types of risks and sacrifice involved when astronauts embarked on expeditions to the ISS, and other regions of space. These visitors began to see astronauts as individuals, whose family and friends would most certainly be impacted by their absence, and concerned for their safety.

I'm more respectful now of the people giving up their time and potential lives to explore beyond.

I've always been interested in space, but now I have a great understanding for the experiential side of things.

For many of the older adults, the exhibit brought back the excitement they experience watching the first manned expedition to the moon.

Seeing this exhibit makes space travel more real to me again.

Most interesting elements of exhibit

There were many different facets of the exhibit that interviewees found most interesting. Many interviewees ranked the ISS simulator as their favorite part of the exhibit. They enjoyed the simulated feeling of weightlessness and disorientation, equating it to a very powerful type of hands on experiential learning that allowed them to feel, in part, the types of things that astronauts encounter while in space. This sentiment is consistent with visitor responses about being drawn to the more personal and human side of space travel.

We really liked the laboratory (ISS) exhibit, where we got to feel a little bit what it's like to be inside the laboratory with it moving.

Being in the simulator and understanding how your perception is going to be off when you're in space is really neat.

In the same vein, visitors also enjoyed watching the video presentations of how astronauts eat, sleep and exercise in space. It reinforced the interest visitors had in better understanding the day-to-day life and challenges of astronauts in a gravity free environment. These demonstrations provided a powerful human element to the visitor experience.

Most interesting thing I think were the big videos showing how people live and play around in space. They're really impressive.

Visitors enjoyed working the robot arm and being able to interact with real objects. A few specifically commented on how these components helped them to better understand and experience how astronauts experience life in space. Parents and grandparents in particular felt that their children and/or grandchildren were especially drawn to these types of hand-on activities, making the exhibit, and the concept of space travel, more real and accessible to them.

I had my grandchildren and some special needs children here with me today. They all loved working the robot arms especially the special needs kids. It really helped all of them to understand the kinds of things astronauts have to do, and how they live in space.

Visitors were intrigued learning about plans for human colonization on other planets. While many acknowledged the risks involved, individuals felt that there would be much to learn by creating colonies on the moon, Mars and elsewhere, such as adding to our understanding of the Cosmos, and expanding biodiversity by bringing plant and life forms to new environments.

A majority of older adults spoke of their excitement at seeing the gloves Neil Armstrong used. For them, the gloves were a kind of contextual introduction to other elements of the exhibit, connecting their personal past (viewing of the first moon landing) to the new realities and complexities of space travel.

Other favorite elements of the exhibit included learning about 3D printer technology, space suit design and functionality, and how astronauts go the bathroom in space. One older couple was particularly intrigued watching how astronauts move about in gravity, comparing that to their own experiences when skydiving.

Travel to ISS and Mars

We asked visitors what types of considerations astronauts would have to deliberate when embarking for trips to the ISS and Mars.

Visitors were very thoughtful and contemplative when responding to this question. Reflecting earlier comments about an interest in the ‘human’ side of space exploration, visitors believed that astronauts would need to carefully consider the physical, personal and emotional risks associated with prolonged and possibly indefinite absences to unknown and harsh environments. They wondered about the level of psychological preparation necessary to cope to being away from family and friends, as well as ways to adjust to cohabitating with ‘strangers’ in closed quarters for months or perhaps years at a time.

In addition to physical training, there are so many social and psychological components they (the astronauts) must have to deal with. To be gone for so long, and be mentally and emotionally strong enough to endure that kind of challenge, the excitement alone isn't going to help you get through that experience.

It is a life commitment to me. Do I really want to? This is it. I'm done. It is not like moving to New York where you could move back again. And it is not like even another country because it so unknown. The psychological preparation would be massive for that.

To adapt to that length of time away from your family would be incredible. I could not do it myself.

The difficult of being disconnected is probably the biggest thing I could think of.

You are talking about being away from your family and you're with the same 4 to 6 people for a long time. Can you put up with that?

In a similar vein, interviewees felt that astronauts would need to carefully consider their own personal safety. Many interviewees were inspired by an astronaut's seeming willingness to potentially sacrifice their life. They wondered what would be necessary to psychologically prepare for that type of possibility?

They have to think about their life being at risk. I think it would be really hard.

You've got to worry about the radiation. You've got to worry about the space debris itself hitting your ship. There are a lot of safety considerations.

Other suggested considerations for prolonged travel included personal hygiene, exercise, nutrition and adapting to a weightless environment.

International Space Station (ISS)

We asked visitors to describe the purpose of the ISS, and the kinds of activities astronauts are involved in.

While the ISS exhibit component was designed to focus on the engineering and technology that allows humans to live and work in space, every interviewee mentioned something about research and/or experimentation, though very few were able to expand on their responses with any specificity.

Those who did elaborate talked about astronauts conducting different types of medical research aboard the ISS, in particular to better understand the impact of prolonged periods in space on the human body. Others described experiments with different types of plants and animals.

They do a lot of scientific experiments they know that can also be used back here on earth. They use it as a chance to, at least my understanding, to be able to do further exploration of having humans in space for long-term, better understand the effect on humans and what we need to be able to do to figure it all out.

A few interviewees recalled reading or hearing about experiments conducted on the ISS to determine how flames react in space. Others spoke about the more personal day-to-day activities astronauts participated in (e.g. moving about in weightlessness, eating 'floating' food, exercising, playing cards). Some wondered whether the ISS astronauts ever got bored, and if so, what they could do to counteract it.

One visitor commented on the element of international cooperation.

The number one thing that I like and learned about the Space Station is how people from different countries get along.

Barriers

We asked interviewees to list or describe some of the barriers to space travel and exploration.

A majority of the responses reflected visitor interest and concern about some of the more qualitative or personal side of space travel. These observations touched on emotional and psychological issues that astronauts might be forced to confront. The theme of personal sacrifice came up again and again. Not only were astronauts leaving loved ones for prolonged and often indefinite periods of time, they were also voluntarily putting their lives at risk.

Interviewees believed that loneliness, separation, personal safety, and the body's need to adapt to unfamiliar environments were some of the greatest roadblocks or barriers to expanded space exploration. Interviewees posited that the cumulative emotional and physical toll on an astronaut's mind and body could be difficult to overcome.

The impact on the body would be a barrier. I know that there is a lot of bone and muscle deterioration in your body. Mentally there are also issues of course. The one barrier ultimately is that we can't travel any faster than light at this point. You will be gone so long that when you return to earth so at some point you are going to give up your life on earth with whoever it is.

In the low gravity or no gravity environment, it's tough on our bodies. We don't function real well, and we get older, and a lot of things deplete. When you look at what happens just to cells themselves, a lot of weightlessness is not good. There are aspects of osteoporosis, bone problems, muscular problems.

Safety has got to be a priority. It's the safety of every single person. We have lost a lot of people both astronauts and not in the space exploration process. I understand that's all part of it but it has to be a priority in my book.

Another frequently cited barrier to continued space exploration was the expense of supporting these missions. A number of interviewees were concerned about the rapidly decreasing government funding of NASA. A few suggested that often it was not clear what benefits were derived from investments in space travel. Not all of the interviewees knew that the Space Shuttle program had ended,

I'm surprised at the difference back in 1958 when they gave a tremendous amount to space exploration. It has really seemed to dwindle off in the past couple of years.

I wonder who's going to pay for it, and how we balance between investments in space programs in general, compared to fixing roads and bridges. I think that's a tough challenge.

A few of the interviewees believed that sustainability of materials was a critical barrier to be addressed. These individuals wondered about the environmental challenges of space travel. Some were concerned with increased space debris residual waste and polluting substances, others with the level of nutrients and liquids needed to sustain human life in space over time. In sum, there was recognition that over-consumption of energy of all kinds during space missions could have a potentially negative impact on humans and the systems designed to support and sustain them.

Definitely sustainability would be huge. I was talking with my girlfriend about how much water you would need to bring with you if you can recycle everything. You still absorb water and use water and sweat and that kind of stuff. So what kind of materials would actually be required if you could save as much as possible. How much would you actually need to sustain you?

We have to think about the technology needed for actually traveling through space at a speed that you're going to. It will decades to get to another planet, or to the moon, or whatever else. We need to figure out a way to use resources that are sustainable, for instance how to use solar power, or whatever you can to, because batteries only last so long.

One interviewee brought up the question of territorial rights in space. As space colonization expedition expands, possibly led by multinational teams of travelers, how or would individual countries lay claim to these new settlements?

I think the big issue is who would own space? Would each new colony be a territory of a country or part of nation as is? Would we be starting another kind of space race?

Technology and Engineering

We asked visitors to describe the most interesting piece of technology or engineering design they discovered in the exhibit.

The ISS simulator ranked highest for a number of visitors. Visitors were most impressed with the complexity of the simulator's interior, and the way in which, while in the exhibit, they were able to experience motion and feeling as if in space.

I think the actual space station is really impressive. The fact that they are able to get this big thing up in space and filled it and have enough space for people to do things up there and live up there for long periods of time is really incredible engineering.

A large number of visitors also made note of the ion engine or thruster display. Visitors remarked on the surprising amount of thrust generated by the engine itself, the ingenuity of the concept, and the efficiency of the technology behind its design.

The ion drive I thought was pretty cool. It was kind of cool to see it in action and see how with such a small amount of mass you can get a fairly significant amount of propulsion.

I like the ion thrusters. I definitely do think as far as current technology that would be the way to go. Not a violent explosion but something that also helps your body too so you're not experiencing 5G's all the time. You just get a little push all the time. You get to go a lot faster that way.

For one visitor, the ion engine display dramatically changed his way of thinking about rocket propulsion:

That (ion engine) was really, really interesting especially when you think of spaceships going off of the rocket and the big explosion it takes to put them in orbit. But to realize the more effective way of traveling is I think they describe it as a putt putt putt rather than a big explosion that kind of sunk in with me. That was kind of mind blowing that they're coming up with more efficient ways of space travel and that they may be going away from our iconic idea of big explosion.

Visitors were very impressed with the current generation of space suit design. Older visitors in particular remembered how bulky and unwieldy suits were for some of the earliest space missions. A number of visitors commented on how well the newer spacesuits addressed the importance for improved mobility and to help astronauts better meet the demands of a specific mission's work and living requirements.

When you look at the spacesuit you could see what's inside it. They have to be cool, they have to be heated, and make sure the bladders aren't going to burst. That's right because if something doesn't work in a spacesuit the person inside it is no longer productive. The technology that was needed in that to me was totally amazing.

Visitors enjoyed learning how engineers designed and/or created materials and equipment to be more sustainable in space. A number of visitors cited the recycling of bathroom waste as an example of creative and sustainable engineering.

Visitors were also impressed with the use of 3-D printing on the ISS. Many were fascinated at the range of tools and other objects that astronauts could manufacture while in space. Others noted the economic, financial and environmental efficiencies and benefits derived from this new mode of production.

The 3-D printer impressed me because once they are done with the tool that's been produced they can recycle and reuse that material to make something else. This is such a great sheer eco-friendly concept on the national space station. We can apply that to things here on earth. It would probably help give us more time to produce all the stuff we need to get into space without damaging the earth any further.

Visitors enjoyed being able to manipulate objects with the space glove and robotic arm. These hands-on activities helped visitors better appreciate the unique physical demands of working in space. Younger visitors in particular were awed by the many activities being conducted by robots.

A majority of visitors were very impressed with the way food was manufactured, packaged and consumed for space travel. Visitors readily compared their own food experiences with those they witnessed in the space exhibit. This very personal and tangible contextualization of a shared experience heightened the visitors' interest and curiosity on this topic.

The food in space was pretty neat. I love it when they had their drinks and they would swallow the balls and have little things inside them like M&Ms or flowers or whatever. I thought that was an interesting way to eat. Some of the food looked pretty, well the cake looked kind of gross. They said it tasted good but I guess when you're in space you can't expect it to be like going to your grandma's house. So I guess you have to get past some of that stigma of what it (the food) looks like.

Words associated with space

We asked visitors to come with four words that they associate with space or space travel.

Words, in order of those frequently used were:

- Adventurous
- Fascinating
- Amazing
- Fun
- Expensive
- Frightening
- Discovery
- Beauty
- Inspiring
- Mysterious
- Dark
- Cold
- Sustainability

Visitor Intercepts

Visitors were approached as they exited the International Space Station simulator and asked if they would be willing to answer a few brief questions about the simulation and the Space exhibit as a whole. A total of sixteen intercepts were conducted.

General Impressions

Visitors were asked about their general impressions of the exhibit. Researchers found that the ISS simulator impressed visitors. With the exception of one interviewee, all were able to articulate why this simulation would be included in the exhibition. Visitors emphasized that the simulation provided an opportunity for them to see and feel what it is like to be on the space station.

Visitors to the simulator appreciated how this experience provided them with a better sense of what life is like for astronauts on the ISS from weightlessness to the kinds of work they do on a daily basis. The feeling of physical disorientation while in the simulator, made visitors think about how being in space can effect a person's body and the way they physically feel. Seeing the different areas of the lab and hearing an astronaut talk about work they do helped to solidify visitors' understanding of the research currently taking place on the International Space Station. Because since most people will never have the chance to visit the ISS, be in space, or experience weightlessness, the exhibit provided them with a perspective on today's astronaut experience that they would not otherwise have.

Well done! Nice variety of information. I liked how it moved and gave the real impression of being there.

Positive, Interesting! I've been to the space exhibit in Houston several times and this seems to be a better/newer version on it. We felt float-y, the illusion they were aiming for worked well.

Understanding

In addition to appreciating the experience of the simulation itself, the exhibit helped visitors to think about the type of research and other activities that takes place there. While some visitors, before entering the exhibit, may have been able to articulate that research takes place on the ISS, after experiencing the simulation, nearly all of them cited that conducting research is one of the most important reasons for the ISS's existence.

When asked to describe the purpose of the ISS, most visitors cited research, but some were more forthcoming. One said:

The (purpose of the) space station is also to learn about the human body and plants and other things—by putting them in a different environment we are forced to think outside the box...and we realize other things through seeing how they change in space.

Another visitor said:

It's a first step to more and deeper exploration of space. It's an active workshop in space to keep learning through experience. The only way to learn about space travel is data. Data is what is teaching us about how things work and react in a whole different environment.

Most surprising

To complete the intercept, visitors were asked what they found was the most surprising thing they learned from the Space exhibit. The range of responses was wide and indicated the depth of content in the exhibit.

Six of the sixteen visitors who were intercepted reported they were most surprised to learn that without air circulation astronauts would suffocate on their own breath on the space station. This realization provided visitors with a greater appreciation for the danger of life in space. Multiple visitors also expressed surprise about scientific interest in Mars and the fact that there are efforts being made towards colonization of the planet.

Visitors were surprised and pleased to learn of the advances being made in space exploration. Some thought the space program had stagnated with the reduction in NASA funding:

The space program kind of died down after landing on the moon and everything that happened with the Russians, but it's nice to know that the space program is once again important and going somewhere new.

Lastly, visitors said they left the exhibit with a renewed appreciation for the value of investment and research in space:

I don't know if I learned it here or elsewhere but we haven't been to the moon after having landed there 45 years ago. Maybe it's more difficult than we thought. So this research is important.

Researchers continued to approach every appropriate group until one was found that agreed to participate.

As the goal was to compare those who had been through the exhibit with those who had not yet experienced it, the same protocol was used for pre- and post-activities. After having the study described to them, all participants were asked to sign consent forms.

The activity began with a warm up. Participants were asked to reflect on how they would prepare for a camping trip. A camping trip was used to help participants start thinking about a familiar kind of trip planning, something they were likely to be more familiar with than space travel.

They were given the following instructions:

If you were planning to go on a camping trip, what would you do to prepare? What would you bring with you? Using a blue pen, please write those things down on the paper in front of you.

Participants were given up to four minutes to write their lists and then were asked to go around and share what they had written. At that point, they were asked to change to a red pen if they wanted to add any items or preparatory activities they would need for a successful camping trip. Once all participants had gone through their lists, they were asked to use the green pen to circle any items of the list without which they would not go camping; those items were their must-haves.

Upon completing the camping exercise, participants were asked to turn the page over to the “space” side and were given the same instructions, but rather than planning for a camping trip, they were asked to plan for a trip to space.

After going through the activity, reflecting on what they would need to have or prepare for a trip to space, participants were asked to take a couple of minutes to write down the words that came to mind when they thought about space and then share them with each other.

Ten groups consisting of 35 total participants completed the pre- activity and eight groups consisting of 22 individuals completed the post- activity.

Themes

Predominant themes that emerged during the activity fell into the following categories:

- Survival
 - Need for oxygen
 - Food
 - Oxygen
 - Water
 - Protection
- Preparation
 - Education and training
 - Fitness
 - Wrapping up loose ends at home
- Quality of life in space
 - Emotional and social issues
 - Entertainment
 - Loneliness
 - Things to do
- Connection with home/Earth
 - Communication with earth
 - Items from home

General Findings

While there was some expectation there would be measurable differences in knowledge and attitudes between those who completed the pre- and post-activity, as with the pre- and post- questionnaires, results indicated that there were no measurable differences in either category. The five most frequently cited terms (food, space, water, oxygen, suit) remained the same from pre- to post-. In addition to these terms, responses in the post- appeared to be more concrete in that some individuals specifically addressed issues of hardware, dangers of space travel, and emotional/social conditions. (See Appendix A)

Both pre- and post- groups were informed about space and engaged with the topic. Since visitors to the exhibit were a self-selecting group, who not only opted to come to SMM, but also paid an up-charge to attend the Space exhibition, it makes sense that they would be interested in or informed about the subject. While most visitors were not experts in space exploration, they knew enough to understand that living in space for an extended period of time would require the support and knowledge of experts in the field.

Since groups consisted of individuals who came to the museum together, it did not come as a surprise that within a group, individuals often listed similar needs for a trip to space. For example, within one group, one individual felt it was necessary to “get things right with family,” while another felt it was important to have a will and funeral arrangement in place.

Individuals in both the pre- and post- groups were very clear that in order to successfully travel to space they would need basic supplies to ensure their survival. These items included food, water, oxygen, a source of power, and protection from the hazards of space, including radiation. While some visitors listed clothes, no one specifically mentioned protection from cold. Most assumed they would have support in procuring specialized supplies including a vehicle and other necessary technology. Another preparation related concern; was having a plan in place to return to Earth.

Visitors knew enough to understand that preparing for a journey to space would require extensive training before leaving Earth. This training was not limited to, but included, getting in shape, learning to manage and maintain the vessel in which they would be living, and addressing unfinished business on Earth. Multiple individuals also talked about getting to know the people they would be traveling or living with and the importance of learning to live and work collaboratively in a limited space.

Quality of life in space was of great concern to visitors. Understanding they would be disconnected from the people and comforts of home, participants listed many items that would remind them of home, keep them occupied, or would connect them with others, and generally, would help them to deal with

the loneliness and isolation they might feel. These items included games and books to help pass the time; cameras and journals to document the journey; communication tools to connect with those back home; and exercise equipment to stay healthy and fit. Whether it was because they cared about those who would be living and working with them or because they were worried about their own personal hygiene, many people listed specific toiletry items such as deodorant, soap, toothbrush, toothpaste, and toilet paper.

Understanding of dangers and significance of space travel

Throughout the activity, it was clear that visitors understood the dangers and significance of space travel. They grasped that living on the International Space Station or on some other vessel in space would mean a completely different way of living. Knowing they would need a reliable source of oxygen, water, food, and energy was high on their list of needs.

Visitors also understood some of the ramifications of living in a low- or no-gravity environment and emphasized the need for exercise. Some even indicated they would bring anti-nausea medications with them.

Those who participated in the activity knew living in space would require sacrifice. Without the comforts of home, having access to toilet paper and a way to dispose of human waste becomes increasingly important. They grasped that they would not see their loved ones for a long time, or ever again. To that end, some visitors said they would need friends or family with them if they were to venture into space.

A well-informed, self-selecting audience

As mentioned earlier, the people who visit the Science Museum of Minnesota are a self-selecting group. Admission to the museum itself is inexpensive. Those who are members have made an investment in the museum and are likely to visit more than once a year. Those who are not members pay \$13 per adult for admission to the museum, in addition to an upcharge for visiting the Space exhibit. This latter group includes visitors who are most likely interested in science and space, or are with someone who is. Because these visitors have chosen to come to the museum and the exhibit, it stands to reason they are knowledgeable in advance about science.

Another factor that may have influenced people's knowledge was the adjoining NASA exhibition: Destination Space, which was included with a basic museum admission and did not require an additional ticket and the Omnitheater film: Journey to Space. If pre-activity participants saw a film (many mentioned they had) or visited the other exhibit before coming to see Space, they may have learned and thought about life in space before completing the group activity.

What we did see were people who were excited to learn about space, how people live, and the engineering required to support life while in space. Those who participated in the activity left saying the exercise was fun and helped them to think about the subject they had come to the museum to learn about; the \$25 gift card probably did not hurt either.

Pre- and Post- Surveys

Pre- and post- visitor surveys were administered at the entrance and exit of the Space exhibition area. All visitors over thirteen years of age were invited to complete the survey and were offered an SMM pencil or temporary tattoo as an incentive for doing so. A total of 879 pre-surveys and 880 post-surveys were collected.

Demographics for Survey Respondents

Breakdowns by age were fairly similar from before the exhibit to afterwards. The average age reported for all attendees (pre and post) was 38. Due to modifications of the pre and post survey items (which were later omitted), a smaller sample of less than 100 respondents were asked to list the oldest and youngest person in their group at the exhibit (See Figure 2). If groups consisted of more than two members they were asked to list the ages of up to six attendees. The average age of additional group members before and after the exhibit was 25 (See Figure 3). Additionally, there were no changes in ethnic distribution from pre to post - most respondents identified as White (See Figure 4). Slightly more women (pre N=503; post N=458) than men (pre N=370; post N=405) attended the exhibit (See Figure 5). Also due to modifications to survey items during data collection, a sample of less than 60 were asked to state their zip code. Sixty-four respondents listed over 45 zip codes, mostly from the central Minnesota area.

Figure 1. Breakdown by Age (by percentage) in Aggregate (pre and post) (N=1,759)

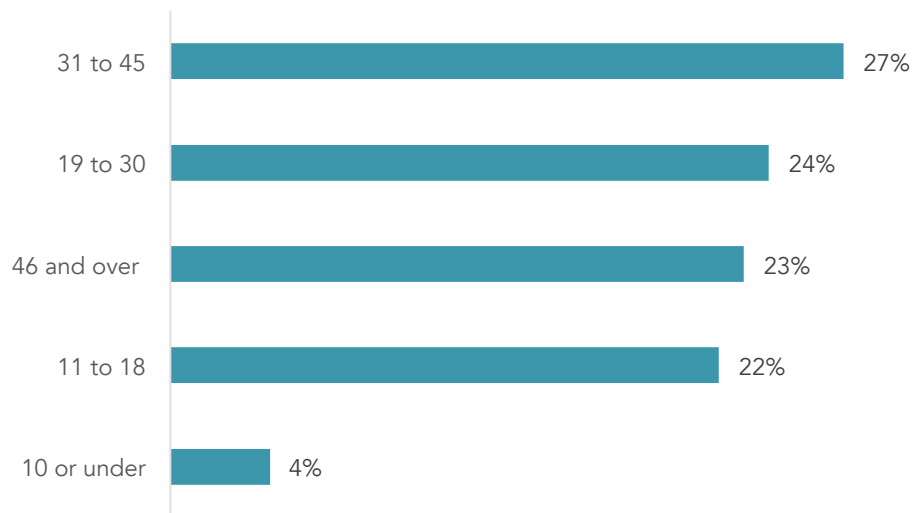


Figure 2. Oldest and Youngest Group Members (by mean age) in Aggregate (pre and post)

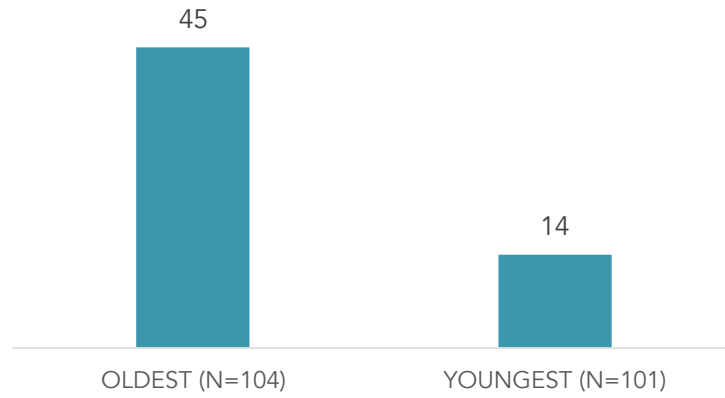


Figure 3. Age of Additional Group Members (by mean age); Aggregate (pre and post)

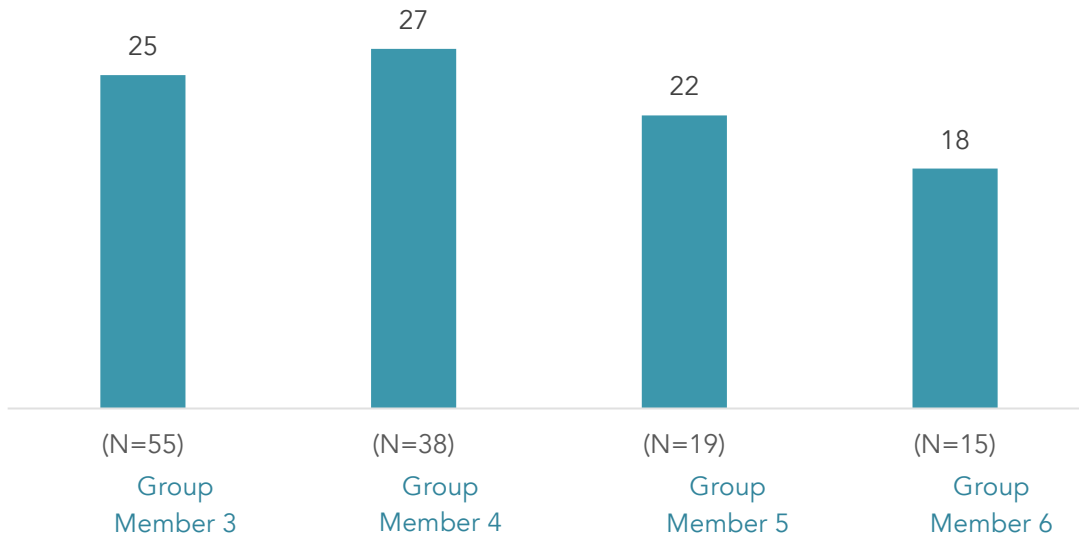
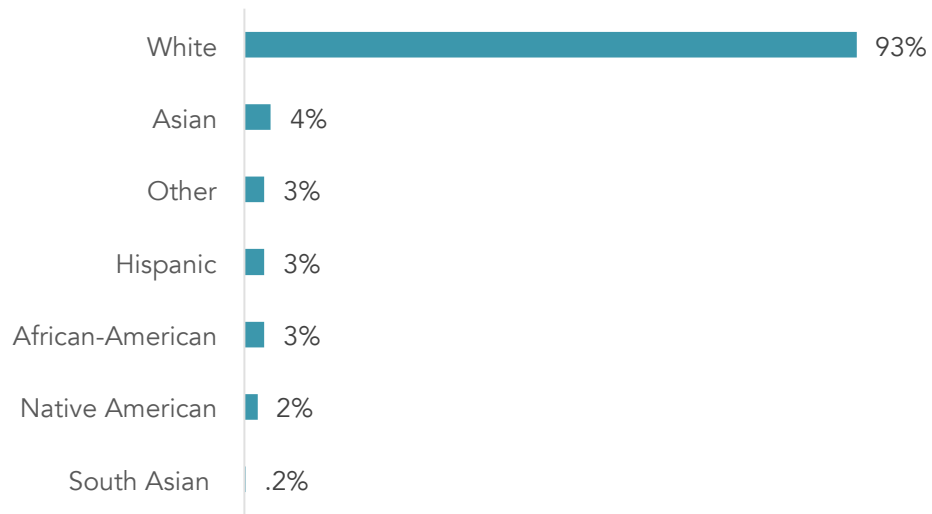
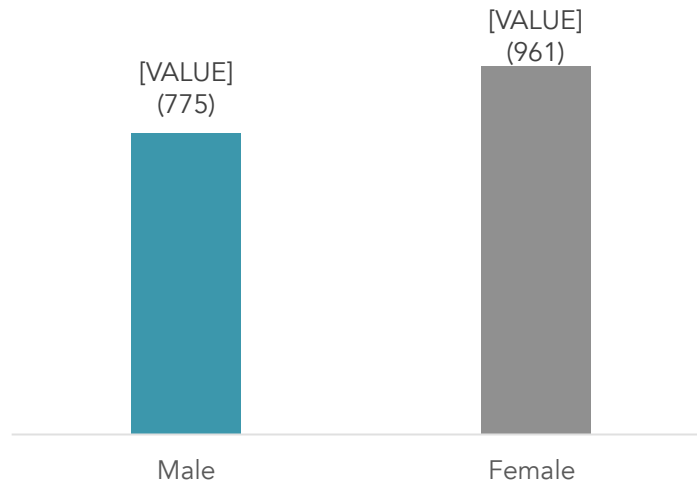


Figure 4. Ethnic Distribution (by percentage) in Aggregate (pre and post) (N=1,752)



(Note: Respondents were asked to "check all that apply." Totals per interval may exceed 100%)

Figure 5. Gender Distribution in Aggregate (by percentage and frequency) (N=1,737)



Additional Participants Characteristics

Most respondents who completed surveys attended the museum with adults and children, both before and after the exhibit (62% and 60% respectively); very few respondents attended the exhibit by themselves (See Figure 6). The average group size for each cohort of respondents (pre-exhibit and post-exhibit) was three. The majority of respondents and their family members were not members of the museum at the time of survey completion (both pre and post; 62% and 60% respectively), with an average of 37% reported being members of the museum. More than half of survey respondents (70%) either had not visited the museum at all in the past two years or had managed to at least 1-2 times (See Figure 8).

Figure 6. Who did you come with today? (by percentage) (N=1,742)

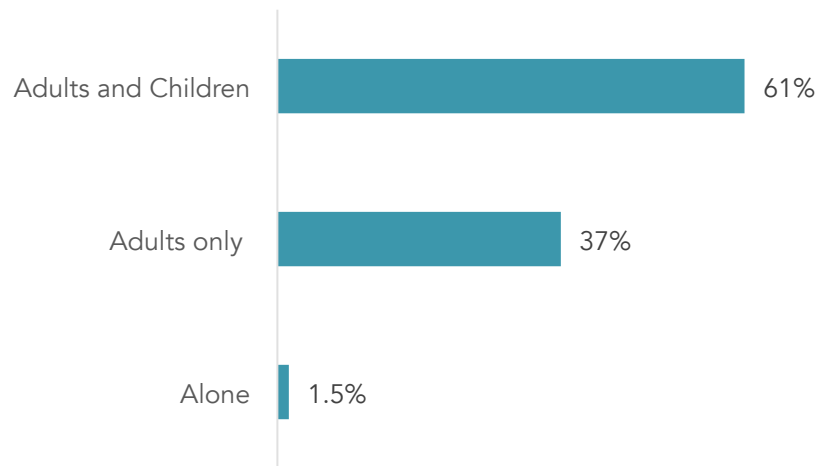


Figure 7. Museum Membership Status – Are you or your family a member of this museum? (by percentage) (N=1,677)

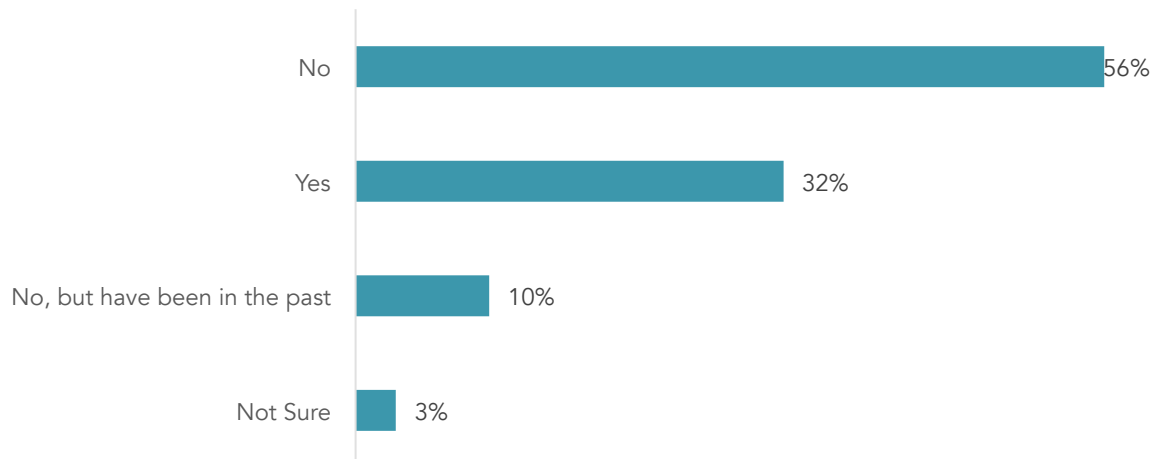


Figure 8. Prior Museum Visits – Before today, how many times have you visited the museum in the past 2 years? (by frequency) (N=1,672)

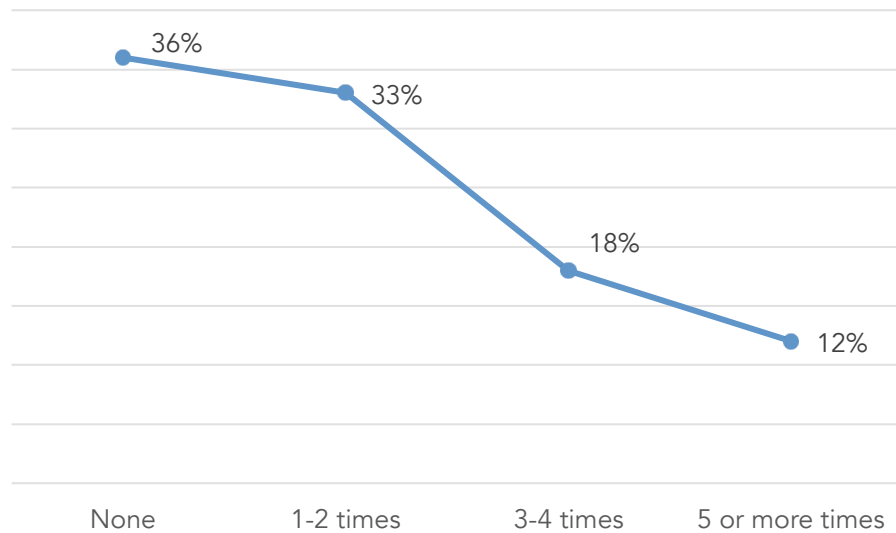
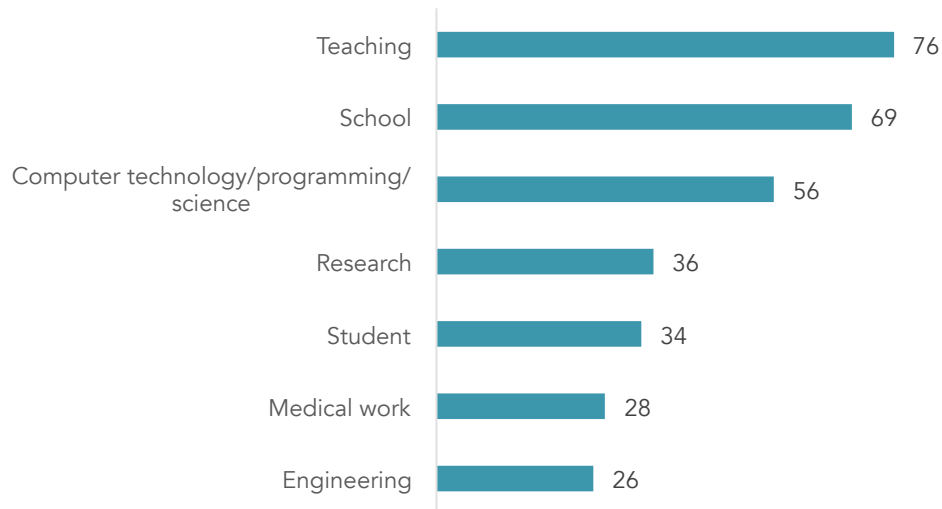


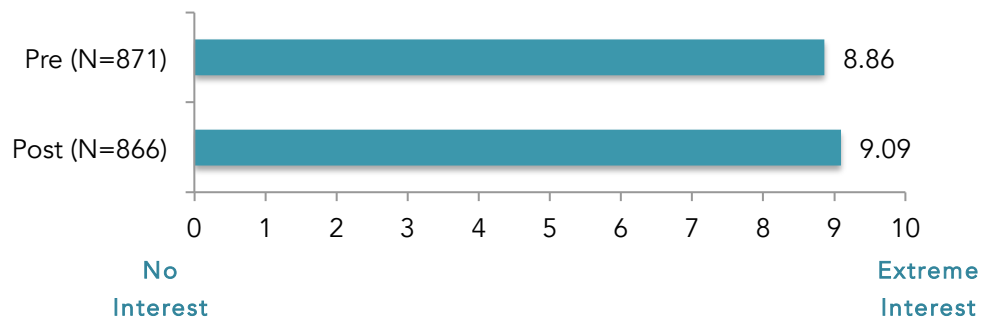
Figure 9. How do you use science in your work? (by frequency)



Key Findings

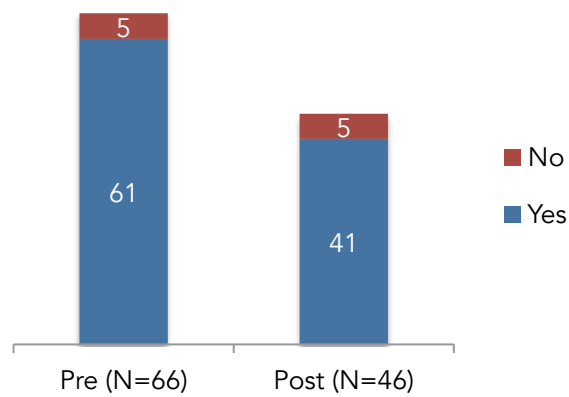
- **No change in interest in science.** Respondents' interest in science before and after the exhibit showed no change overall, with just a mean increase of just .23 points (See Figure 9).

Figure 10. Interest in Science (by average mean)



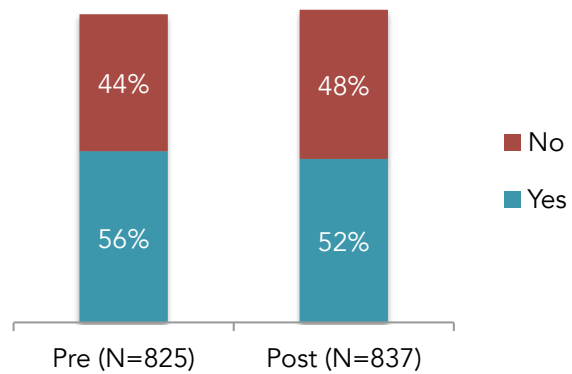
- **Visitors came to see Space.** Survey respondents overwhelmingly reported that they came to see space at the museum (See Figure 10).

Figure 11. Did you come to the Science Museum to see Space?



- **Half of respondents use science in their work.** Slightly more than half of respondents reported using science in their work (See Figure 11). The most frequently cited ways of using science at work were at school (both teachers and students) and with their teaching (See Figure 12).

Figure 12. Do you use science in your work?



- **Space Science content knowledge showed no change from pre to post with the exception of two items.** When comparing the percentages of statements recorded as “true” or “false” from pre to post. All statements showed relatively no change from pre to post (See Table 1).

Table 1. Space Science Knowledge (“Please answer these questions to the best of your ability”)

Statement	PRE (N=844)		POST (N=841)	
	True (PRE)	False (PRE)	True (POST)	False (POST)
I would like to go to Mars.	43%	57%	48%	52%
There are people who live on the International Space Station.	89%	11%	90%	10%
Space is a hostile and dangerous environment.	81%	19%	84%	16%
Technology is not sophisticated enough to allow people to live on the International Space Station for extended periods of time.	26%	74%	20%	80%
If I travel to Mars, I will be able to return to earth.	60%	40%	58%	42%
I think the International Space Station is an important tool that can be used to learn about our world.	97%	3%	98%	2%
We should be working towards a human mission to Mars.	86%	14%	88%	12%
People do important work on the International Space Station.	98%	2%	98%	2%
In the International Space Station they serve meals on plates.	10%	90%	7%	93%
Without a spacesuit, a human could survive for up to ten minutes in space.	17%	83%	10%	90%
Engineering plays an important role in our ability to explore space.	98%	2%	98%	2%
Astronauts have time to play while on the International Space Station.	87%	13%	89%	11%

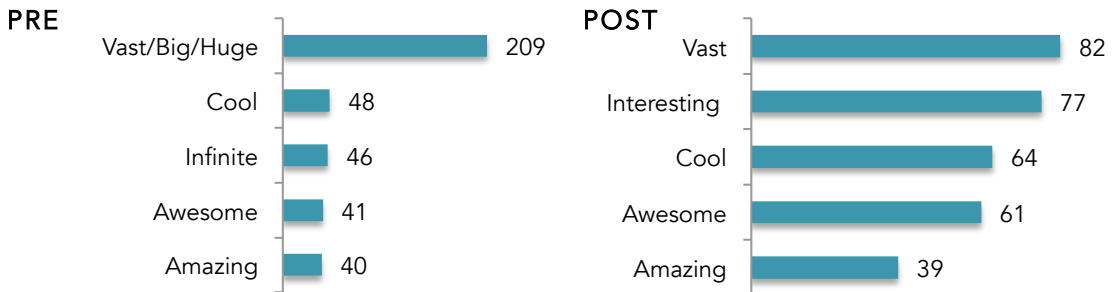
Note: 1=True; 2=False

- **What makes Mars different from going to the International Space Station? DISTANCE.** Survey respondents overwhelmingly listed distance, location, or “Mars being further away” as the primary distinction between traveling to Mars and the ISS.
 - **PRE:** Distance/location/being further away mentioned 132 times.
 - **POST:** Distance/location/being further away mentioned 171 times.

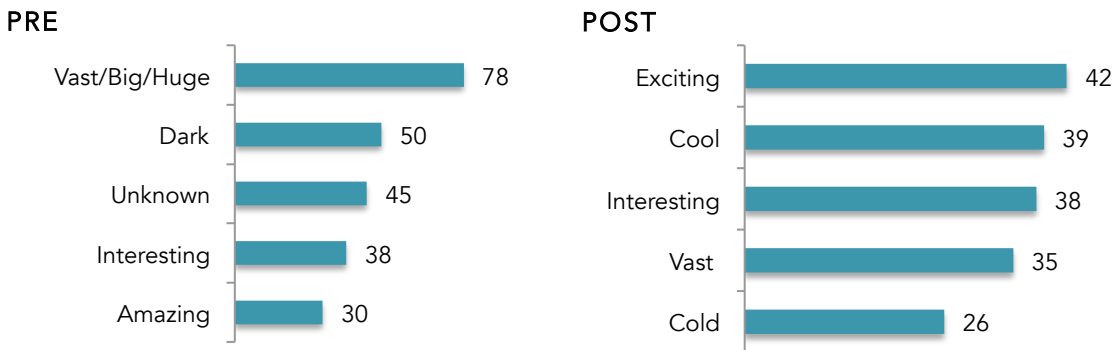
- **There is a consistency of top 4 words respondents used to describe the ISS.** The most frequently cited words listed to describe the ISS included: Vast, Interesting, Cool, Amazing, Cold, Mysterious, Unknown, Exciting, Scary and Infinite (See Figure 13).

Figure 13. Top 4 words respondents would use to describe the International Space Station (by most frequently cited)

WORD 1

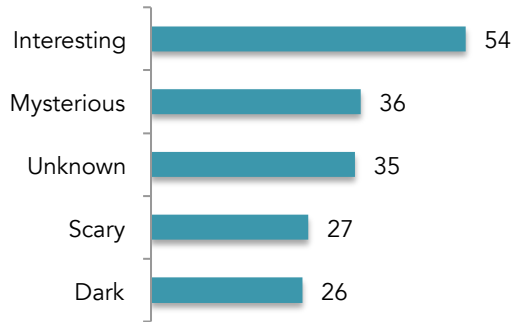


WORD 2

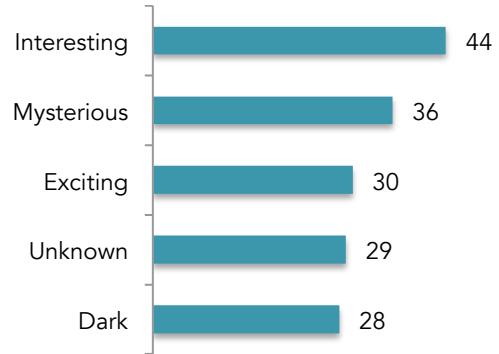


WORD 3

PRE

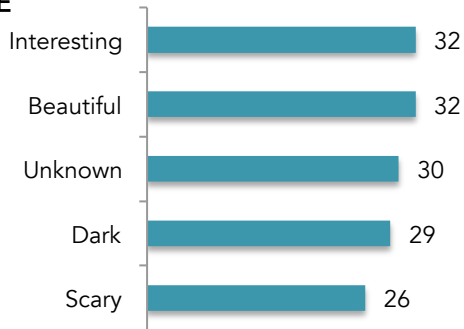


POST

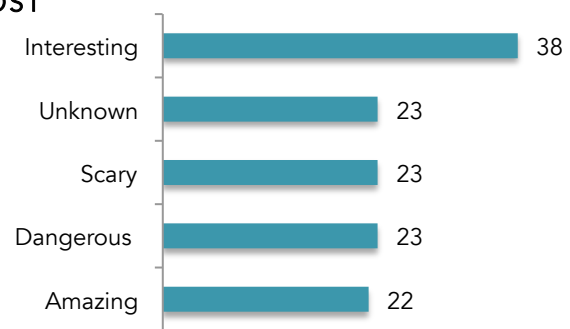


WORD 4

PRE



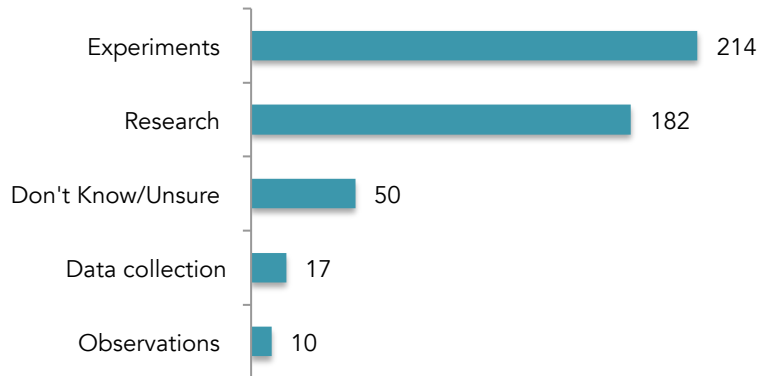
POST



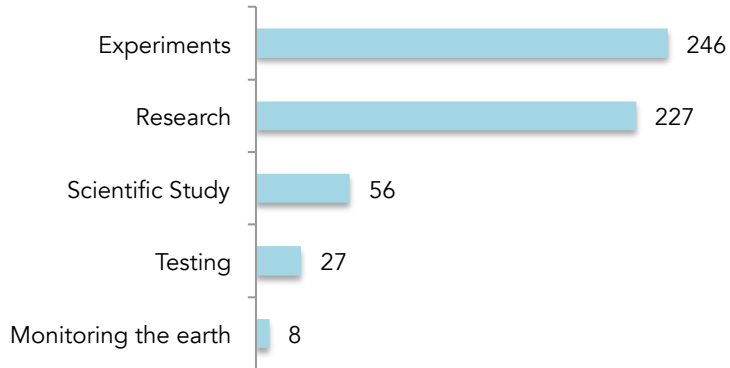
- **Research and Experiments are the two primary activities that take place on the ISS according to respondents.** Most respondents listed experiments, research, or other terms related to conducting research as the main activities on the ISS.

Figure 14. What happens on the International Space Station? (by most frequently cited)

PRE



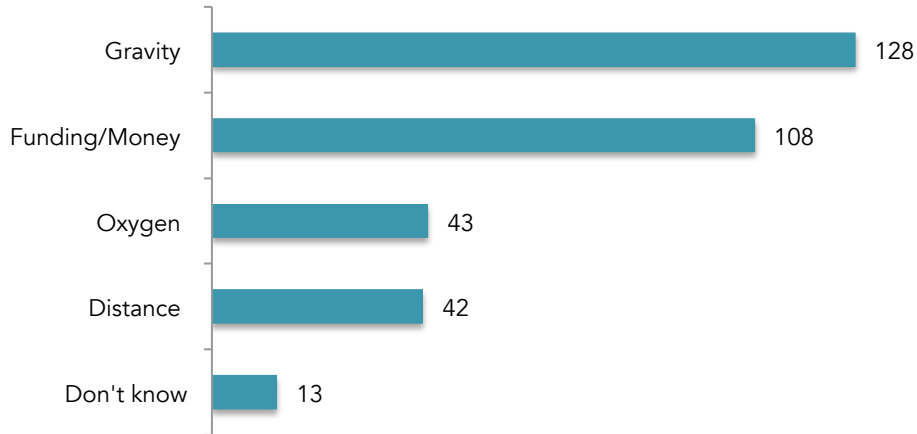
POST



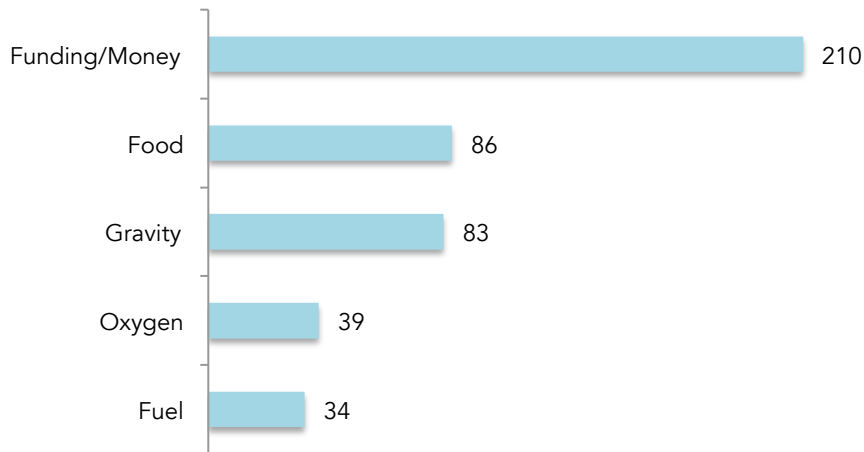
- **The most frequently cited barriers that must be overcome in order to travel to space, the moon and other planets – Gravity (listed before the exhibit) and Funding/Money (listed after the exhibit).** Gravity and funding were the most cited barriers to overcome *prior* to viewing the exhibit. Following the exhibit, attendees listed funding as the main barrier to overcome in order to travel to space, the moon, and other planets. The change from gravity to funding indicates that as a result of visiting the exhibit, museum attendees learned that the engineering and technology required for space travel exist, but that the cost is great. Without monetary investments, space exploration becomes increasingly difficult.

Figure 15. What barriers have to be overcome in order to travel to space, the moon, and other planets (by most frequently cited)?

PRE

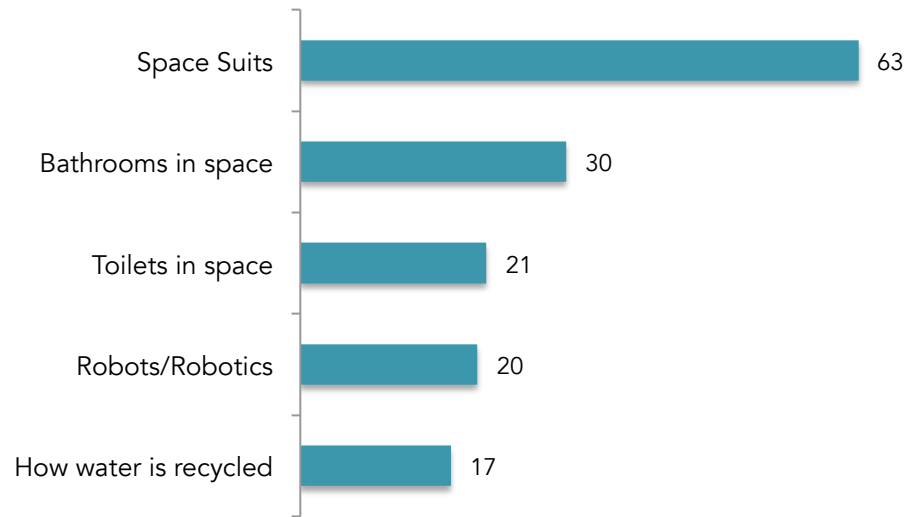


POST



- **Space suits were the most interesting things learned from the Space exhibit.** When asked what the most interesting learned from the exhibit, which was included on just the post survey, the most cited feature mentioned was learning about space suits, followed by how bathrooms and toilets work in space, respectively. These exhibit components may have been of particular interest because they provided a level of detail visitors probably did not know before visiting the exhibit. The space suit showed the various layers required to protect a human from the elements of space, while the bathroom demonstrated a way of going to the toilet that we are unfamiliar with on Earth.

Figure 16. What is the most interesting thing you learned in the Space exhibit (by most frequently cited)?



Conclusions

Our summative evaluation results confirm that visitors of all ages both enjoyed and greatly benefited from their experience at the Space exhibit. The exhibit served to validate and heighten the positive view of space travel that many of the visitors had before entering the exhibit. The exhibit's innovative ISS simulation and other hands-on elements provided visitors an opportunity to experience first-hand the many tasks and challenges of an astronaut's life while in space.

The exhibit served as the impetus for cross-generational mentoring, education and storytelling. During data collection, we observed spirited dialogue between visitors of different ages (and generations) about the many facets of space travel. We listened as grandparents recounted their exhilaration at watching the first manned flight to the moon, while their grandchildren spoke excitedly about the 'cool technology' used for travel to the ISS and beyond. The exhibit's open and appealing design, interactivity and media encouraged family groups to bridge the decades and participate in shared learning experiences.

Findings that Space was well received by visitors is corroborated by the tracking and timing study done by the Science Museum of Minnesota that found a visitor Sweep Rate of 166 square feet per minute and a diligence rate of 55%, meaning 55% of visitors stopped at more than half of the exhibition elements. While there are relatively few exhibits of similar size, type, and content with published timing and tracking data available for comparison, among large science exhibits, Sweep Rate indices between 300 and 550 are common, as are Diligent Visitor percentages below 30%. In that regard, the Space exhibit is performing exceptionally well. Given a Sweep Rate indices of less than 300 square feet per minute and visitor Diligence value of greater than 51, the exhibit fits into a small category of exhibits Serrell describes as "exceptionally thoroughly used".

Visitors came away with a deeper appreciation of the many individual risks and sacrifices made by astronauts. The exhibit's focus on the day-day lives of astronauts, away for extended periods from friends and family, triggered a very powerful empathetic response amongst visitors. After leaving the exhibit, visitors expressed concern about astronaut safety, their physical condition, and the potential psychological effects of isolation and loneliness. This element made the idea of space travel less abstract, providing more of a personal, human context.

The exhibit provided visitors with the opportunity to reflect on how their lives would be different if they were to spend an extended period of time in space. Basic activities of daily life look much different in space than on Earth and

visitors were intrigued by these differences, such as using the toilet, showering, eating, sleeping, and exercising. Having the chance to see how astronauts live did more than provide a human context for life on the ISS, it also gave visitors the chance to think about what it would be like if they, themselves, were to go to space, what they would have to give up, and what they would have to change about the way they live.

Visitors were impressed with the range and sophistication of technology designed to support space travel. The opportunity to touch many of the exhibit objects heightened visitor appreciation of how aerospace engineering and design could be both functional and innovative. Visitors came away with a greater appreciation of how experiments conducted in space (e.g. aboard the ISS) inform the design and development of a wide range of scientific and consumer products and sustainable systems, as well as provide data for improving human health and quality of life. As a result, visitors more easily connected the concept and practice of sustainability in space and on Earth.

While researchers had hoped to see a significant difference in the pre- post-questionnaire, knowledge between those who had visited the exhibit and those who had not was not great. What researchers did see was that the exhibit gave visitors and visitor groups the opportunity to reflect on the many technological advances that have been made, what these advances mean in terms of how astronauts currently live in space, and the possibility for those of us not highly trained astronauts to, perhaps, one day visit or live in space.

Appendix A

Word count distributions for pre- and post- group activity

Pre- activity

Total word count: 680 words

Primary Keywords (no common words): 619 words (91.3%)

Common Words Count: 61 words (8.97%)

Primary Keywords	Frequency	Common Words	Frequency
food	33	to	20
water	31	of	11
space	27	and	6
oxygen	22	get	5
suit	21	or	2
equipment	14	with	2
camera	13	tp	2
fuel	12	is	2
clothes	11	for	1
aid	11	do	1
first	11	me	1
exercise	10	go	1
communication	7	the	1
radio	7	tv	1
air	6	how	1
waste	6	a	1
something	6	there	1
training	6	uv	1
paper	6	into	1
toilet	5		
medicine	5		
emergency	4		
tools	4		
rocket	4		
radiation	4		
cards	4		
knowledge	4		
blanket	4		
shelter	4		
plan	4		
computer	4		
parts	4		

spacesuit	4
co2	4
entertainment	4
ship	3
pillow	3
research	3
take	3
astronaut	3
return	3
supplies	3
duct	3
kit	3
personal	3
movies	3
books	3
filtration	3
book	3
classes	3
hygiene	3
sealant	3
protection	3
tape	3
clothing	3
ropes	3
advil	3
family	3
replacement	3
shuttle	3
knife	3
photos	3
system	2
solar	2
lots	2
boots	2
working	2
favorite	2
tethers	2
toothbrush	2
crew	2
team	2
yourself	2
proper	2
earth	2
sun	2

things	2
spaceship	2
bible	2
batteries	2
journal	2
manual	2
vaccines	2
tanks	2
experienced	2
energy	2
sleep	2
souvenirs	2
music	2
place	2
body	2
clean	2
mylar	2
maps	2
medical	2
communications	2
repair	2
blankets	2
electricity	2
backpack	2
departure	1
hygenic	1
come	1
tool	1
map	1
underwear	1
flashlights	1
make	1
backup	1
items	1
toothpaste	1
player	1
stay	1
form	1
means	1
dehydrated	1
insurance	1
transportation	1
cleaner	1
recycle	1

purity	1
mission	1
device	1
comfy	1
cleaning	1
liquits	1
ziplock	1
calculation	1
sure	1
person	1
life	1
critical	1
scrubbers	1
facilities	1
freeze	1
disposal	1
elevator	1
production	1
two	1
mp3	1
spacecraft	1
sleeping	1
area	1
support	1
heavy	1
another	1
bungee	1
experience	1
soap	1
walk	1
writing	1
travel	1
materials	1
check	1
record	1
procedures	1
shield	1
nasa	1
craft	1
moonboots	1
somewhere	1
help	1
supply	1
cots	1

occupy	1
kindle	1
time	1
ready	1
cords	1
filtration	1
dramamine	1
ps4	1
funding	1
control	1
block	1
zip	1
returning	1
freezedried	1
friend	1
computers	1
systems	1
telecom	1
reclamation	1
headcover	1
care	1
reading	1
prepclasses	1
propulsion	1
manuals	1
drive	1
suits	1
beforehanf	1
fellow	1
gear	1
games	1
prepackaged	1
health	1
dried	1
basic	1
arrival	1
medication	1
bathroom	1
management	1
capsule	1
wipes	1
resist	1
notebook	1
video	1

pencil	1
lock	1
calculator	1
magazine	1
wrm	1
bags	1
walking	1
deodorant	1
helmet	1
perfume	1
everything	1
spare	1
pens	1
reserve	1
markers	1
moon	1
pencils	1
hold	1
coloring	1
foods	1
stuff	1
planelts	1
deck	1
battery	1
shoes	1
properly	1
towel	1
pen	1

Post- activity

Total word count: 444 words

Primary Keywords (no common words): 374 words (84.23%)

Common Words Count: 70 words (15.77%)

Primary Keywords	Frequency	Common Words	Frequency
food	23	and	15
space	15	to	10
water	15	of	7
oxygen	13	will	3
suit	10	other	3
camera	8	be	2

training	7	for	2
entertainment	7	tv	2
communication	7	have	2
clothes	6	at	2
sleeping	5	with	2
clothing	5	from	2
aid	5	a	2
family	4	there	1
things	4	2	1
supplies	4	able	1
first	4	not	1
emergency	4	can	1
toilet	3	say	1
kit	3	get	1
energy	3	as	1
exercise	3	that	1
source	3	some	1
equipment	3	in	1
transportation	3	my	1
solar	3	do	1
books	3	all	1
bathroom	3	or	1
pictures	3	how	1
friends	3		
power	3		
ship	3		
tools	3		
purifier	3		
stuff	3		
elements	2		
phone	2		
goodbye	2		
medication	2		
device	2		
radio	2		
support	2		
bag	2		
paper	2		
dehydrated	2		
cleaning	2		
education	2		
protection	2		
right	2		
keep	2		

people	2
craft	2
loved	2
toiletries	2
panels	2
fuel	2
knowledge	2
computers	2
ones	2
proper	2
work	2
supply	1
viramins	1
crisis	1
computer	1
station	1
astronomical	1
sun	1
shoes	1
duct	1
filter	1
feel	1
help	1
sharpie	1
lots	1
friend	1
pad	1
living	1
body	1
soccer	1
eater	1
shower	1
poop	1
filters	1
area	1
packages	1
calm	1
cooking	1
going	1
vacuum	1
sickness	1
room	1
compass	1
hygiene	1

cooperate	1
center	1
shampoo	1
canned	1
legal	1
doctor	1
electricity	1
glasses	1
brush	1
home	1
deodorant	1
telescopes	1
bible	1
resourceful	1
photos	1
toothbrush	1
i'm	1
done	1
pod	1
pillow	1
way	1
busy	1
waste	1
air	1
tape	1
launch	1
sort	1
soap	1
funeral	1
cleansing	1
repair	1
shuttle	1
spacecraft	1
screen	1
blanket	1
active	1
talk	1
various	1
mind	1
protective	1
towel	1
devices	1
sucked	1
ships	1

gameboy	1
armor	1
viewing	1
etc	1
bedding	1
gear	1
something	1
charger	1
composure	1
container	1
alone	1
outside	1
prepare	1
movement	1
different	1
rifle	1
provided	1
sterilization	1
book	1
fix	1
frame	1
shelter	1
vitamins	1
transportation	1
maps	1
enough	1
football	1
health	1
medicine	1
repairs	1
motion	1
pee	1
back	1
site	1
survival	1
listen	1
location	1
including	1
tent	1
travel	1
house	1
hair	1
place	1
team	1

live	1
pens	1
recording	1
heat	1