Summative Evaluation of the *Sun, Earth, Universe* Exhibition

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Figure 1. A family building their own spacecrafts at the Sun, Earth, Universe exhibition. (Photo by Ethan Kruszka)

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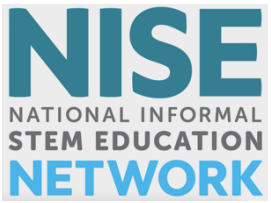

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Executive Summary

The *Sun, Earth, Universe* exhibition was developed by the Space and Earth Informal STEM Education (SEISE) project, which was funded through the generous support of the National Aeronautics and Space Administration (NASA) through cooperative agreements NNX16AC67A and 80NSSC18M0061. The exhibition was designed for public engagement at informal science learning (ISL) sites across the United States in conjunction with ongoing programming, activities, and special events. The exhibition featured a spacecraft building and testing area, a tool bench where visitors could use equipment to detect the invisible, a data visualization puzzle about Venus's topography, a bead tumbler where people could search for a star capable of supporting life-sustaining planets, and several panels with information about the Sun, Earth, and universe. Supplementary resources provided through the SEISE project included tabletop activities on similar topics, as well as professional development workshops and materials for informal science educators.

The summative evaluation of the *Sun, Earth, Universe* exhibition explored its reach and impact on the public. Our evaluation questions included:

1) **Who accessed the *Sun, Earth, Universe* exhibition?**
    a) How many people were reached annually?
    b) How was this distributed among the exhibition's target audiences?

2) **How did the public engage with the exhibition?**
    a) How interesting and engaging was *Sun, Earth, Universe*?
    b) Did visitors feel that they learned something new at the exhibition? How did it increase their understanding of the four Science Mission Directorate (SMD) content areas (astrophysics, planetary science, heliophysics, and Earth science)?
    c) How relevant was the exhibition to visitors' everyday lives?
    d) How did the exhibition support visitors' science and engineering identities?

The SEISE project identified target audiences for the *Sun, Earth, Universe* exhibition as families with children between 6 and 12, school aged children (grades K-5), and underserved audiences (including girls, non-white racial groups, and rural populations). The evaluation team addressed the evaluation questions above through data collection at partner sites across the country hosting the *Sun, Earth, Universe* exhibitions using observations, surveys, and interviews with adult and youth visitors. We also interviewed select gallery staff and volunteers with knowledge about visitor usage of the exhibition at their museum site. Finally, we created reach estimates and descriptions through direct counts of exhibition visitorship and museum self-reports in the exhibition awardee report and SEISE application materials.

Summary of Findings

1. **The *Sun, Earth, Universe* exhibitions will reach an estimated 7 million people per year from general and underserved audiences.**

    An estimated 7 million people will access the 52 copies of the exhibition each year. Sites hosting the exhibition served general and underserved audiences, with almost all (94%) reaching girls and visitors with lower income. Most also served people with disabilities (84%), communities of color (82%), and visitors from rural areas. Adult visitors who participated in the evaluation also represented non-white groups, including 16% who identified as Hispanic or Latino, 8% as Asian, and 5% as Black or African American.

2. **The *Sun, Earth, Universe* exhibition was interesting, engaging, relevant, and educational, providing opportunities to engage in exploring ideas like a scientist or an engineer.**

    a. **Families enjoyed and were interested in the *Sun, Earth, Universe* exhibition, engaging for longer than may be expected for a small footprint exhibition.**
    Almost all adult visitors reported found the exhibition enjoyable (89%, n=375) and interesting (90%). Three-quarters of the youth (73%, n=183) shared that the exhibition was "really fun". Visitors spent an average of 5 minutes, 31 seconds in the exhibition, with a sweep rate index of 109, which is above the industry average. Also, about two thirds of adults (63%) and youth (61%) reported that they were "more interested" or "more curious" in Earth and space topics after visiting the exhibition.

    b. **Most adults felt their groups learned something new at the exhibition and reported statistically significant higher ratings of confidence when asked to share or describe each of the different Science Mission Directorate (SMD) content areas after visiting the exhibition.**

    c. **Earth and space topics were more relevant for adults after visiting the exhibition.**
    A little over half of adults (56%) felt that Earth and space topics were "more relevant" to their life and experiences after visiting the exhibition, while two out of five (43%) indicated that there was "no change". When asked what the exhibition reminded them of, most youth (90%, n=31) shared different connections they had made between their everyday lives and the exhibition.

    d. **Families reported being able to engage in activities at the exhibition that may support positive science and engineering identities.**
    Almost all adults and youth shared they were able to "do something hands-on to learn more" (97% of adults[1]; 99% of youth) "build something" (94% of adults; 93% of youth), and "play and use imagination" (92% of adults; 94% of youth) in the exhibition, while fewer reported being able to "work together" (84% of adults and 66% of youth). Additionally, most adults reported that their groups were able to "look at something closely" (98%), while four out of five were able to "share a discovery" (83%) or "test what was built" (80%). Two thirds shared their groups were able to "solve a problem" (66%) in the exhibition.

[1] Sample size for adults ranged from 356 to 362 for these items and youth sample sizes were 59 or 60, except for "build something" (n= 175 adults; n = 42 youth) and "test what was built" (n=174 adults). These behaviors were only possible for visitors who stopped at the *Design, Build, Test* component and this applied to fewer visitors.

Introduction

Project Overview

The National Informal STEM Education Network (NISE Net) is a community of informal educators and scientists who are dedicated to supporting learning about science, technology, engineering, and math (STEM) across the United States. They work to build the capacity of informal science education institutions and research organizations to work together to raise public awareness, understanding, and engagement with current topics in science.
In 2015, they were awarded funding from the National Aeronautics and Space Administration (NASA) to create educational products and support informal educators' professional development in engaging the public with Earth and space content (through cooperative agreements NNX16AC67A and 80NSSC18M0061). Through this funding, the Space and Earth Informal STEM Education (SEISE) project created numerous professional development workshops (36 between 2016 – December 2019) and additional supports for informal educators, over 1200 activity toolkits for distribution to partners, and 52 copies of the 600 ft² *Sun, Earth, Universe* exhibition (see Map 1). Exhibition copies were awarded to science centers and children's museums, with plans to share them in an additional 100+ locations, including nature centers, libraries, and other museums over the life of the exhibitions.

Map 1. Fifty-two copies of the Sun, Earth, Universe exhibition were distributed to museums across the nation. (Martin et al., 2019; graphic by Darrell Porcello)

Exhibition description

The *Sun, Earth, Universe* exhibition provided a range of interactive opportunities for visitors to engage and learn through a series of components designed for group or individual engagement. Large double-sided graphic panels displayed essential space information and dramatic NASA imagery and were augmented by flip panels showing changes in the Earth, as well as the Sun using different wavelengths of light. Interactive components included a board game where visitors could explore what it would be like to plan and execute an unmanned mission to space, an engineering station where participants could design, build and test a model spacecraft, and an interactive tools table that demonstrated different types of technologies that

reveal invisible forces in the universe. Visitors could also search for our stars that might support life in a bead tumbler or glimpse the relative size of the field of stars that Hubble can view through its lenses. A small table topped with an image of the surface of Mars was available for younger children, supplied with wheeled blocks of different Mars rovers. There was also a wall with magnetic prompts for creating a post-it-note comment board, as well as a variety of content-related books and toys on a shelf, usually placed near two couches that came with the exhibition. Eight stools featuring an image and information about each of the planets in the solar system were also included with the exhibition. See Figure 2 for additional photographs from the exhibition.

Figure 2. Clockwise from top left: Visitors explore the surface of Venus, Visitors use the tool bench to detect the invisible, A visitor looks at changes on the surface of the Sun, A view of the whole exhibit. (Photos by Ethan Kruszka)

The Sun, Earth, Universe exhibition's Big Ideas

The SEISE project team had several guiding ideas that helped them shape the development of the *Sun, Earth, Universe* exhibition. These included goals for experience development and design principles, and the development of a learning framework and content map. Please see Appendices A-C for a more complete description of these guiding ideas.

For the evaluation, it is important to understand how the big ideas in the exhibition (or the "content map") related to the Science Mission Directorate's (SMD) content areas of heliophysics, Earth science, planetary science, and astrophysics. The main points of the content map are presented below, followed by brackets indicating each of the four related SMD content areas. A more detailed content map with content sub-points is included in Appendix C.

- The sun powers Earth and our solar system. [heliophysics]
- Earth is a changing planet of air, water, rock, and life. [Earth science]
- Planetary systems like ours may contain water and life. [planetary science]

- Forces and energy connect everything in the universe. [astrophysics]
- The universe is very large, old, and mysterious. [astrophysics]

Evaluation Questions

The evaluation team used the project goals, design principles, learning framework, content map, and conversations about science identity with the project team to create evaluation questions and instruments that were grounded in the specific realities and goals of the project. The following questions guided our planning for the summative evaluation of the *Sun, Earth, Universe* exhibition.

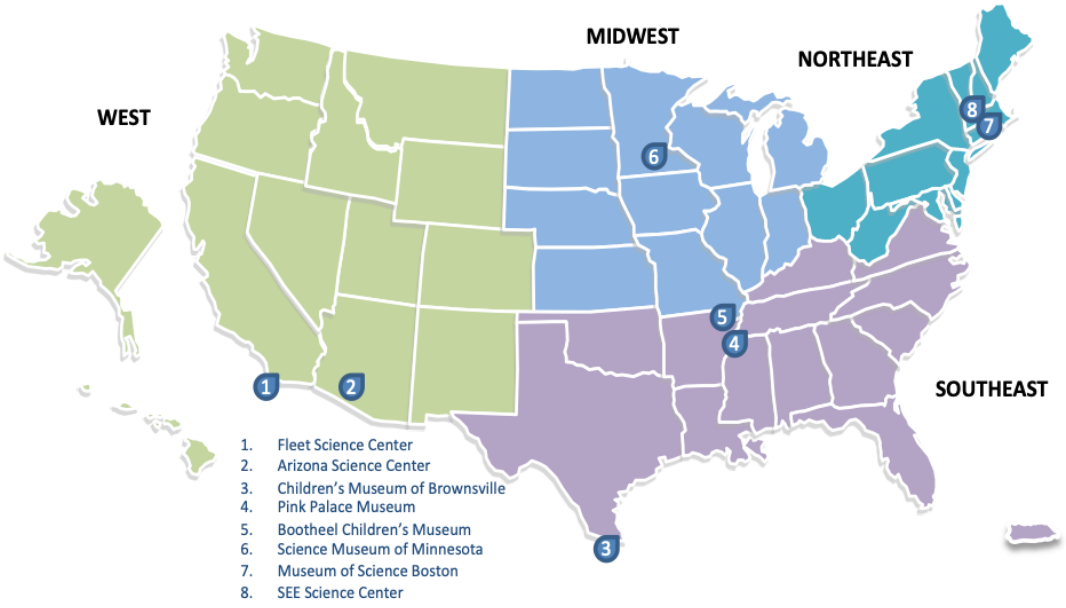
1) **Who accessed the *Sun, Earth, Universe* exhibition?**
    a) How many people were reached annually?
    b) How many people might this exhibition reach by the end of the grant period and beyond?
    c) How was this distributed among the exhibition's target audiences?

2) **How did the public engage with the exhibition?**
    a) How interesting and engaging was *Sun, Earth, Universe*?
    b) Did people learn something at the exhibition? How did it increase their understanding of the four Science Mission Directorate (SMD) content areas (astrophysics, planetary science, heliophysics, and Earth science)?
    c) How relevant was the exhibition to visitors' everyday lives?
    d) How did the exhibition support visitors' science and engineering identities?

Methods

Data Collection Sites

We selected the data collection sites (see Map 2) from a range of museum types, sizes, and regions served by the project in order to collect data from a representative range of museums where the *Sun, Earth, Universe* exhibition was being displayed (see Table 1). Sites self-identified their institution types and annual budget range in application materials, and we used the Association of Science and Technology Centers' (ASTC's) designations to classify location sizes. Museums with annual budgets of up to $1 million were "very small", over $1 million and less than $2.5 million were "small", over $2.5 million and less than $6.5 million were "medium", and $6.5 million or more were "large" (ASTC Sourcebook, 2017). Two sites were located in each region and the project team helped identify two locations where the team was more likely to encounter Spanish language speakers. Sites were located in rural and urban areas and reported annual visitor attendance ranging from 9,291 to 1.3 million people.



Map 2. Data were collected from eight sites where the Sun, Earth, Universe exhibition was displayed.

Table 1. Data collection site overview.

Descriptors	Details	Total Sites
Region	MW	2
	NE	2
	SE	2
	W	2
Museum Type	Science Museums	6
	Children's Museums	2
Organization Size	Very small	3
	Small	-
	Medium	1
	Large	4
Spanish-speaking Audiences	More prevalent	2
	Less prevalent	6

Data Collection Methods & Sampling

Trained evaluators from the Science Museum of Minnesota (SMM) and the Museum of Science in Boston (MOS) collected data at all of the institutions, with the exception of supplementary counting study data that was collected by volunteer or paid staff at participating museums. While surveys and interviews were collected at all eight participating locations, observations were only collected at MOS and SMM. Several collectors identified as Spanish-fluent, and were involved in collections across sites using both Spanish and English instruments that were available for all visitors.

In total, we collected 375 surveys from adults, which were matched with 183 youth interviews, 60 youth surveys, and 103 adult interviews (see Table 2). We also collected 133 observations of youth and adults using the exhibition, 12 interviews with staff and volunteers from 7 partner sites, and 86 data collection description forms.

Table 2. Overview of data collected.

Type of data collected	# Collected
Adult visitor surveys	375
Matched with:	
Adult interviews	103
Youth interviews	183
Youth surveys	60
Visitor observations	133
Youth	84
Adults	47
Staff/Volunteer interviews	12 (from 7 sites)
Counting study collections	74
Data collection description forms	86

Data Collection Description Forms

Each day before, during, and after data collection, evaluators walked through the exhibition area to note the general layout, condition, and presence of each of the exhibition components. The forms were used to note visitor crowding, general things happening that may affect the visitor experience, and the availability of exhibition components and their condition. See Appendix D for the instrument and Appendix E for an overview of which exhibition components were available to visitors throughout the collection.

Visitor Surveys and Interviews

We approached one adult visitor per group leaving the exhibition to fill out a survey, and in some cases, participate in an interview afterwards. If in a group with children, the data collector would also invite the children to participate in a separate interview that was orally administered while the adult was filling out the survey. At the conclusion of the interview, youth who indicated they were 10 or older were also invited to fill out a half-sheet survey. Each instrument is provided in Appendix D.

Interpreting changes in curiosity in Earth in space

In the youth interview, we asked, "After trying the exhibit, how curious are you about Earth and space? Are you more curious, about the same, or less curious about Earth and space?" From our earlier summative evaluation of the Earth and space tabletop activities, we found that groups who had an increase in curiosity or interest in Earth and space attributed this to their enjoyment of the experiences, as well as those experiences' ability to get them thinking about Earth and space in different ways. We decided to reduce data collection burden on visitors by not asking them to interpret their changes in interest for this evaluation, because it is likely that these same mechanisms may explain any increases in interest and curiosity reported by visitors in the *Sun, Earth, Universe* exhibition.

Measuring changes in visitors' understanding of the SMD content areas

In order to specifically address how a visitor's understanding of the four SMD content areas may have changed, we created five action statements for adults to reflect upon. Each action statement was an applied way of talking or sharing about one of the SMD content areas, using examples that were drawn from the topics that families were likely to learn about when visiting the exhibition. In the post survey, adults were asked to rate their confidence talking about each of these ideas before and after trying the activities on a four-point scale. Each of these statements is linked to the content map (see Appendix C) and is inclusive of the experiences that visitors are likely to have in the exhibition. The final action statement is only reflected in the content map and is not drawn directly from the SMD content areas. Our high-level results are shared in the body of the report, while our results for the last action statement, as well as more nuanced results from this item, are found in Appendix E.

The following are the action statements used in the adult survey and interview, with the SMD content area they are linked to in brackets:

- Describe at least one way that the Sun changes over time. [heliophysics = H]
- Share at least one way that scientists are studying other planets. [planetary science = PS]
- Describe at least one way that scientists are looking for life beyond our solar system. [planetary science = PS]
- Give an example of at least one tool that reveals energy or forces at work in the universe. [astrophysics = A]
- Tell a friend at least one way that planet Earth is constantly changing. [Earth science = ES]
- Share at least one way that people are choosing to explore Earth and space. [content map only]

In the main findings of the report, we share mean scores for the pre and post confidence ratings. In these cases, we assigned a point value to each rating, where "not at all confident" was equal to one point, "somewhat confident" was two points, "confident" was three points, and "extremely confident" was four points. This is helpful to keep in mind when interpreting the means of these ranking scores; mean scores below 2 are less confident, scores between 2 and 3 reflect a mid-level confidence, and scores above 3 show higher confidence. We conducted statistical analyses using the Wilcoxon signed-rank test and Cohen's d for understanding the effect size of the exhibition experience.

In the adult interview, we asked a subset of adults what they felt led to their increases in confidence around these different items. We wanted to collect these responses in order to explore if their increases in confidence were linked to meaningful experiences in the exhibition.

Measuring the exhibition's support of science and engineering identities

Research shows that positive identities in STEM can be supported through relatively short, positive experiences being able to engage in STEM practices, which is what this exhibition was seeking to provide (National Research Council, 2009). The evaluation team used a list of behaviors in these instruments to assess the impact of the exhibition on a visitor's science or engineering identity through collecting visitors' reflections on what they had a chance to do in the exhibition, and through an interview question asking if any of their experiences in the exhibition may have made someone in their group feel like they could learn about or do science. While the rest of the interview was designed for the target adult respondent, this question was asked of the adult and the rest of their group. We analyzed each group's response as a single case.

Below is a list of how visitors might engage in an exhibition if they were exploring the world like a scientist or engineer (see Table 3). Many of these behaviors could apply to both scientists and engineers (such as observing phenomena or sharing what was learned with

others), but some felt more specific to engineering experiences; these included creating, testing, and iterating a model. The exhibit team felt that they had designed the exhibition to support the first list of behaviors throughout the exhibition; for example, a visitor may get to do "something hands-on to learn more" at the *Topographic Map of Venus* as they arranged the blocks in the data visualization or at the *Mars Landscape Play Table* as they rolled rovers across the surface of the planet. However, the *Design, Build, Test* component, was the only space where visitors might engage in the specialized engineering behaviors we listed above. At this component, visitors could build a spacecraft from novel interlocking foam and plastic pieces. They had the option of seeking inspiration from other designs on display, as well as testing and making changes to their spacecraft.

Finally, while we asked adults about each of the items below, we gave youth a shortened list as a concession towards visitor experience; we did not want to overwhelm youth with a longer instrument, but wanted to balance this with hearing directly from them, as well. Also, while visitors could reflect on whether they had gotten to do each of the items "a lot", "at least once", or "not at all", we combined responses of "at least" and "a lot" in this analysis.

Table 3. How family actions in the exhibition may be related to the actions of scientists and engineers.

What a scientist or engineer might do	Science/Engineering practices in the whole exhibition
Observe unexplained phenomena	Look at something closely
Try to learn more through imagination or access to others' findings	Play and use their imagination Work together
Learn more through exploring or testing phenomena, by themselves or with others	Do something hands-on to learn more Work together
Note what was learned and share with others	Work together Share a discovery
What an engineer might do	**Engineering practices in the *Design, Build, Test* area**
Test the model to identify characteristics necessary for success	Test what was built Solve a problem
Create a model, Iterate on the initial model	Build something[2]

Observations

Data collectors at MOS and SMM selected an invisible line around the exhibit's entrances and observed the first person (adult or youth) to cross the line into the exhibition, starting a stopwatch and marking which components the visitor stopped at, and in which order they stopped. In addition, if a visitor stopped at the *Design, Build, Test* table, the collector observed how long the individual spent at each area of the component (next to the design booklet that highlighted various spacecraft and the children who had made them, at the building area where materials were available for constructing a spacecraft, or in the test area where visitors could go through an instrument checklist to see if their craft had everything it needed, as well as conduct a spin and/or shake test of their craft) (see Figure 1). The observer also noted if the visitors engaged in these behaviors multiple times. Other information that the collector noted was time of day, the level of crowding in the exhibition, the duration the person spent in the exhibition, the visitor's approximate age, and the approximate number and ages of other group members. The instrument is available in Appendix D and more nuanced findings from the observational data is available in Appendix E.

Gallery Staff and Volunteer Interviews

Data collectors interviewed staff and volunteers at sites where the exhibition had been on the floor for at least a few weeks in order to better understand how partner organizations felt visitors were engaging with the exhibition. We asked questions about how they felt visitors were interacting with the *Sun, Earth, Universe* exhibition compared with other exhibitions and how it fit in with their other offerings. See Appendix D for the instrument.

Counting Study Collection Shifts

We used a counting methodology developed by NISE Net evaluators (Reich & Goss, 2009) in order to develop an estimate for the yearly reach of the exhibition. To create the estimate, we drew on the annual attendance of the exhibition's display locations in the first year

[2] In the observational data, we considered iterating to happen when someone: 1) built something, 2) tested what was built, and 3) made changes to the same design afterwards.

and the percentages of those attendees likely to enter the exhibition based on direct counting observations across data collection sites.

Evaluators and trained staff or volunteers collected direct count data from six sites representing a range of sizes to observe what percentage of people were likely to stop in the exhibition. The number of half hour collection shifts by site ranged from five to seventeen and were spread over mornings, afternoons, and evenings on both weekends and weekdays. We completed 74 counting shifts overall, with an average of 12 counting shifts per site. Then, we compared our direct counts over a given half hour with how many people might be in the museum during that time to come up with a percentage of people likely to see the exhibition at each site. We reviewed the exhibition applications and reached out to the project team to establish both awardee institution size, as well as the most recently reported annual attendance (in most cases, from 2018). In three cases, the awarded copy of the exhibition was planned to be shared with several sites in its first year. For these copies, we averaged the annual attendance of the potential host sites and noted that the sizes of the share sites were generally in the same category as the awardee institutions (see Table 4).

Table 4. Creating the 7 million visitors per year reach estimate.

Size of Sites	Number of copies awarded	Total annual attendance across awardee sites by size	Average % of visitors likely to stop per year	Total estimates for a year
Very small	17	1,000,928	100%	1,000,928
Small	13	1,216,046	80%	972,837
Medium	11	2,568,300	61%	1,566,663
Large	11	6,379,261	55%	3,508,594

Most components were available to visitors during data collection

Almost all of the components with something hands-on to do were available to visitors and in good repair during our data collection (see Table 5). All eight of the planetary stools were displayed with the exhibition at every site, but three of the sites chose not to include both couches in their exhibition. The backs of the larger display panels, where additional content was provided, were available at five or more of the sites.

Table 5. Number of collection sites where component was available to the public (n=8)

Components	Component type	SMD content	# of sites
Design, Build, Test	Interactive	PS, ES, A, H	8
Use Tools to Detect the Invisible	Interactive	PS, ES, A, H	8
Your Mission to Space Board Game	Board Game	PS, ES, A, H	8
Topographic Map of Venus	Panel & Minor Interactive	PS	8
Mars Landscape Play Table	Play Table	PS	8
Earth Flip Cards	Panel & Minor Interactive	ES	8
Sun Flip Cards	Panel & Minor Interactive	H	8
Hubble Telescope Viewer & Search for the Sun Bead Tumbler	Panel & Minor Interactive	A	8
Antarctica Back Panel	Panel	ES	7
Sombrero Galaxy Back Panel	Panel	A	5
Sun Back Panel	Panel	H	5
Enceladus Back Panel	Panel	PS	5

Respondent Demographics

Adult visitor survey and interview respondents were asked several questions about themselves and their group so that we could understand more context about who was supplying data about the exhibition. The majority of adult respondents (81%, n=366) were visiting the exhibition with children. Adults visiting with other adults were about one in five of our respondents (17%), and a handful (2%) were visiting on their own. Two thirds of the adult respondents identified as female (63%, n=357), a third (34%) identified as male, and a handful of respondents indicated that they "preferred not to say" (2%). Two adults selected "another category", with both writing in "non-binary". Finally, though the survey was meant for adults, respondents' ages varied from 13 to 75 (see Table 6). The six respondents who were underage were included in the dataset, because their responses showed that they had understood the survey questions and we wanted to respect their contribution. A majority of respondents were in their forties.

Table 6. Adult survey respondents' ages. (n=354)

Age	% of adult respondents
Under 18	2%
18-19	2%
20-29	18%
30-39	40%
40-49	23%
50-59	7%
60+	7%

Two thirds of adult respondents identified as White (65%), while one third chose another category to describe their race or ethnicity. Close to one in five identified as Hispanic or Latino, one in ten Asian, and one in twenty as Black or African American (see Table 7). Five respondents identified as American Indian or Alaska Native and a handful of participants selected "prefer not to say". Ten people chose "other", writing in "Indian", "Brazil", "East Indian", "French", "Human", "American", "Filipino", and "Mexican" when prompted.

Table 7. Race or ethnicity of adult respondents. (n=376)

	% of adult respondents
White	65%
Hispanic or Latino	16%
Asian	8%
Black or African American	5%
American Indian or Alaska Native	1%
Native Hawaiian or Pacific Islander	-
Other	3%
Prefer not to say	3%

Findings

The *Sun, Earth, Universe* exhibitions will reach an estimated 7 million people per year from general and underserved audiences.

Using our counting methodology detailed above, we generated an estimate and rounded down to the nearest hundred thousand in order to create a more conservative estimate. We estimated that 7 million visitors would be likely to see the exhibition each year.

We also asked sites receiving the exhibitions to report whether they were reaching underserved audiences with their exhibit. Almost all sites (94%) reported that they reached girls and visitors of low-income / lower socio-economic status (see Table 8). Most sites reported reaching disabled visitors (84%), racial and ethnic minorities / communities of color (82%) and rural audiences (80%). Around three quarters of sites reached Spanish-speaking audiences (73%). About three in five sites served at-risk youth (63%), inner city visitors (61%), and other non-native English speakers (57%). Two in five sites reported reaching American Indian or Alaska Native audiences (39%).

Table 8. Sites reported reaching underserved audiences (n=51)

Underserved Audience	% of sites
Girls	94%
Low-income / lower socio-economic status	94%
Disabled	84%
Racial and ethnic minorities / communities of color	82%
Rural	80%
Spanish-speaking audiences	73%
At-risk youth	63%
Inner city	61%
Other non-native English speakers	57%
American Indian / Alaska Native Audiences	39%

Families enjoyed and were interested in the *Sun, Earth, Universe* exhibition, engaging for longer than may be expected for a small footprint exhibition.

Almost all adult visitors reported finding the exhibition enjoyable (89%, n=375) and interesting (90%). A third (34%) found the exhibition "very enjoyable" and about half (55%) gave it an "enjoyable" rating (see Table 9). One in ten respondents (11%) found the exhibition to be "a little enjoyable".

Table 9. "How enjoyable was the exhibit?" (n=375)

	% of adult respondents
Very enjoyable	34%
Enjoyable	55%
A little enjoyable	11%
Not enjoyable	-

A third of adult visitors (33%) reported finding the exhibition "very interesting" while over half (57%) shared that it was "interesting" (see Table 10). One in ten respondents (10%) gave the exhibition a rating of "a little interesting".

Table 10. "How interesting was the exhibit?" (n=375)

	% of adult respondents
Very interesting	33%
Interesting	57%
A little interesting	10%
Not interesting	-

Three-quarters of the youth (73%) interviewed shared that the exhibition was "really fun". Close to a quarter felt it was "a little fun" and a few (3%) rated it "not fun" (see Table 11).

Table 11. "How fun was the exhibit?" (n=183)

	% of youth respondents
Really fun	73%
A little fun	23%
Not fun	3%

Families were more interested in and curious about Earth and space topics after visiting the exhibition

About two thirds of adults (63%, n=372) and youth (61%, n=163) reported that they were "more interested" or "more curious" in Earth and space topics after visiting the exhibition. A little over a third of adults (37%) reflected that they had experienced no change and one adult respondent replied that they were "less interested" (see Table 12).

Table 12. "After visiting the exhibit, how interested are you in Earth & space topics?" (n=372)

	% of adult respondents
More interested	63%
No change in interest	37%
Less interested	1%

Close to two-thirds (61%, n=163) of youth shared that they were "more curious" about Earth and space after trying the activities when interviewed (see Table 13). A third (34%) shared their curiosity was "about the same", and a handful (5%) said that they were "less curious" about Earth and space after visiting the exhibition.

Table 13. "After trying the exhibit, how curious are you about Earth & space?" (n=163)

	% of youth respondents
More curious	61%
About the same	34%
Less curious	5%

Visitors spent a long time in the exhibition, compared with other exhibitions

Visitors spent an average of 5 minutes, 31 seconds in the exhibition. This generated a sweep rate index of 109, indicating that visitors spent more time in this exhibition when compared broadly with others in the field and that it is more likely they engaged in learning-rating behaviors while visiting (Serrell, 1998). Youth spent statistically more time in the exhibition than adults, ranging from 11 to 2189 seconds per observation and an average dwell time of 6 minutes, 21 seconds[3]. Adults spent from 16 to 1380 seconds in the exhibition, for an average of dwell time of 4 minutes, 3 seconds.

Visitors appreciated the hands-on nature of the exhibit

Adults were asked, *"What, if anything, did you enjoy about the exhibit?"* during the interview. Two-thirds (66%, n=102) of the adults enjoyed the interactivity or hands-on nature of the exhibit components, while close to half (46%) enjoyed specific aspects of Earth or space content (see Table 14). Two out of five (37%) enjoyed how the exhibit was good for their group,

[3] T-test, assuming two-tails and even variance predicted that the means of the dwell times between youth and adults were different, with a significance of $p < 0.028$.

many specifically writing that it supported multiple ages (both adults and kids) well. Others enjoyed opportunities to learn something new (16%) and a few (6%) wrote specifically about the beautiful images. One in twenty comments (5%) highlighted other experiences, like "Looking at everything" or learning about astronomy.

Visitors often mentioned specific components when responding to this question. The most frequently talked about component was *Design, Build, Test*, which was mentioned by 23% of respondents. A little more than one in ten adults talked about the *Use Tools to Detect the Invisible* component, and other interactives were mentioned by a handful of respondents. The two most popular components were both hands-on with multiple stations where more than one person from a group could engage at a time. See Table 25 in Appendix E for more details.

Table 14. "What, if anything, did you enjoy about the exhibit?" (n=102[4])

Themes	% of adult respondents
Hands-on components	66%
Earth or space content	46%
Good for my group	37%
Learning opportunities	16%
NASA images	6%
Other	5%

Staff and volunteers at awardee sites noted that visitors enjoyed the hands-on interactives in the exhibition and stayed longer than expected

During interviews, staff and volunteers shared that the exhibition was popular with their visitors, noting that the interactive components *Design, Build, Test [DBT]* and *Use Tools to Detect the Invisible* [TDI] seemed to be an especial draw. Several personnel noted that DBT was "the first thing children gravitated to" and that it was "very popular" because there were "a lot of things you could with your hands". They also noticed that visitors seemed to spend longer in the exhibition than they might expect; one volunteer observed, "I like it. They really spend some time in there, you know?" and this sentiment was echoed by personnel at other sites who said, "I'm impressed so far. People are going in and it seems like they have extended stays in that area," and that there is a "higher traffic flow rate [in *Sun, Earth, Universe*] than in other exhibits in that same area [of the museum]; it seems like a much higher volume [of visitors]."

[4] Percentages add up to more than 100%, because visitors' comments were sometimes coded into more than one category.

Most adults felt their groups learned something new at the exhibition and reported statistically significant higher ratings of confidence when asked to share or describe each of the different Science Mission Directorate (SMD) content areas after visiting the exhibition.

Families learned something new

Most adults (80%, n=373) shared that their group learned something new at the exhibition. A few adults (5%) replied that their groups had not learned something new, and a little over one in ten (16%) reported that they were unsure if their groups had learned something or not. We also asked adults to share what their groups may have learned at the exhibition, and two out of five of these comments (43%) were about the forces at work in the universe and the tools we use to reveal them, which aligns with the SMD content area of astrophysics (see Table 15). About a quarter (27%) of the ideas that were top of mind for people had to do with the search for life or understanding more about other planets (planetary science). About one in ten people shared changes in the Earth (Earth science, 12%) or ideas about our Sun (Heliophysics, 10%).

Table 15. "What are 1 or 2 things that you or your group learned about?" (n=232)

SMD content area	Response examples	% of adult responses
Astrophysics (A)	*"Magnetic fields."* *"Goldilocks planets have the conditions to potentially support life. And Hubble images are a tiny fraction of the sky."* *"Ultraviolet light shows hidden things."* *"I have always been curious about the scientific instrumentation carried on board the various spacecraft which have explored the planets of our solar system. The exhibit covering the sensors of UV, IR, and magnetic fields. Very interesting."*	43%
Planetary Science (PS)	*"The number of planets that could potentially host life."* *"How the planet and solar system affect the world around us."* *"How Venus looks topographically."* *"The amount of star systems containing possible habitable planets is far greater than I thought."* *"Varias cosas del Sistema solar, muy interesante." [Various things about the solar system that were very interesting.]*	27%
Earth Science (ES)	*"Changes to our planet."* *"The effects that Earth experiences from space."* *"Changes in sea ice."*	12%
Heliophysics (H)	*"Sobre las tormentas solares." [About the solar flares.]* *"Solar storms."* *"The Sun changes magnetic fields every eleven years."*	10%

Visitors were significantly more confident talking about all four SMD content areas

Adults were significantly more confident sharing, telling, or describing aspects of Earth and space in all of the four SMD content areas (Earth science, heliophysics, planetary science, and astrophysics) after visiting the exhibition (see Table 16). The greatest increases (and effect sizes) were seen in visitors' comfort with heliophysics; feeling confident "describing at least one way that the Sun changes over time". On average, visitors did not feel confident talking about the Sun's changes before entering the exhibition; their pre-confidence mean score was under 2, indicating the average rating was between "not at all confident" and "somewhat confident". However, after visiting the exhibition, visitors provided an average ranking of 2.57, meaning that their average post-confidence rating was between "somewhat confident" and "confident". When interviewed about what led to these increases, visitors shared that they flipped through the cards in the exhibition that showed how the Sun changes or talked about Sun facts of which they had been reminded.

Table 16. Statistically significant increases in adults' levels of confidence with SMD content after visiting the* Sun, Earth, Universe *exhibition.

SMD content area	Item[5]	Post Confidence[6]	Mean Confidence, pre	Mean Confidence, post	Effect size[7]
H	Describe at least one way that the Sun changes over time.	69%	1.87	2.57	0.78
A	Give an example of at least one tool that reveals energy or forces at work in the universe.	68%	2.37	2.88	0.74
PS	Share at least one way that scientists are studying other planets.	73%	2.47	2.94	0.72
PS	Describe at least one way that scientists are looking for life beyond our solar system.	71%	2.48	2.92	0.66
ES	Tell a friend at least one way that planet Earth is constantly changing.	76%	2.79	3.07	0.47

[5] Sample sizes for each item ranged from 345 to 351 adults and included only those who gave both a before and after rating.

[6] POST confidence reflects all visitors who gave top two ratings of confidence on a four-point scale, and reported like other NISE Net projects that use similar post retrospective questions.

[7] All changes in confidence were statistically significant at $p<0.0005$, using a Wilcoxon signed-rank test.

Most of the visitors we spoke with (88%, n=33) were able to share about something they learned or were reminded about that helped them feel more confident talking about Earth and space topics (see Table 17).

Table 17. A selection of responses from visitors who shared what they learned that helped them feel more confident about Earth and space topics. (n=29)

SMD content area	Item	Response examples
H	Describe at least one way that the Sun changes over time.	*"The Sun is a star and not a planet - I knew that a long time ago but forgot, exhibit reminded me."* *"I flipped through and learned about infrared changes and x-rays."*
A	Give an example of at least one tool that reveals energy or forces at work in the universe.	*"The one with the tiles that shows the U.V. light revealing and using that in being able to condense that down for my kids on how they do it. To show it to them."*
PS	Share at least one way that scientists are studying other planets.	*"It took a big jump there, because of the more obvious examples like the telescope and observations, but actually using radiation and the different spectrums on it to observe how other planets are changing."* *"That's building the satellite and how they send back information from space. They're man-made on Earth but people don't have to go to study the planets."*
PS	Describe at least one way that scientists are looking for life beyond our solar system.	*"The beads were a great visual representation of the information we're receiving about the possibility of life out there."*
ES	Tell a friend at least one way that planet Earth is constantly changing.	*"I knew about the Earth. Now I know more that the Earth was changing from the times and pictures of the aerial view."* *"I didn't realize. I read about the possibility of man-made ideas, that it was happening in the United Arab Emirates. And the change in the ice islands. Seeing the pictures; a visualization of the change. Then the urbanization changes over thirty years."*

Earth and space topics were more relevant for families after trying the activities.

A little over half of adults (56%, n=372) felt that Earth and space topics were "more relevant" to their life and experiences after visiting the exhibition, while two out of five (43%) indicated that there was "no change" and 1% marked that the topics were "less relevant" (see Table 18).

Table 18. Adults' reflections on changes in relevance of Earth and space content after visiting the exhibition. (n=372)

	% of adult respondents
More relevant	56%
No change	43%
Less relevant	1%

Adult visitors shared personal connections with the exhibition

In the interview, we asked, "What in your daily life connects to something you saw in the exhibit?" Most often, visitors shared moments of personal connection (53%); times when they had wondered about something that was touched on in the exhibition or moments from their life when they've been with their families or spending time where they live (see Table 19).
A quarter (25%) included responses where visitors shared content from the exhibition they found meaningful, but didn't go on to say how it mattered in their lives. A handful shared bigger ideas that felt grand in scope – feelings of being small in a vast universe (5%). Two responses suggested that everything in their daily lives connected to the exhibition, but didn't provide details. Another 15% found it difficult to think of anything from their experiences that connected with something they saw in the exhibition.

Table 19. "What in your daily life connects to something you saw in the exhibit?" (n=101)

Themes	Response examples	% of adult respondents
Personal connections	*"The Hubble telescope. I always wanted to know how much it could see."* *"Raising and entertaining young kids with games and trying to add-in education."* *"Just seeing the stars. Where we live we can see stars."*	53%
Earth or space content	*"The changes of Earth over time."* *"Energy or climate. How easy it is to look for ways or solving ways to find things."* *"Humans live on Earth and are composed of elements, like planets."*	25%
Big ideas	*"Humans are irrelevant in the grand scheme of the universe."* *"Knowing that we're so small in such a large universe with so many forms of life. It's very humbling and needed."*	5%
Everything in general	*"Everything. Because we use everything."* *"Probably everything."*	2%
Nothing, Not Sure	*"I don't know."* *"Not really."*	15%

Youth shared that the exhibit reminded them of experiences they had had in school

We asked youth 10 and older to fill in the blank for the statement, "This reminded me of…" About a third (32%) gave examples from school, with classes or projects that they had done there (see Table 20). About a quarter of the youth shared topics that they had learned about around Earth or space (23%, n=31). Six youth (19%) shared more personal connections with the exhibition; that it reminded them of something they had done with another person, a movie they had watched, or something that they were hoping to do professionally when they grew up. One in ten youth wrote that it reminded them of other museum experiences (10%) or shared about something outside of the other categories (10%), and three youth indicated that it did not remind them of anything.

Table 20. "This reminded me of…" (n=31)

Themes	Response examples	% of youth respondents
School experiences	*"Science class."* *"School projects and activities."* *"Labs that I did in school, and tests and experiments."*	32%
Earth or space content	*"Learning about space and how they test the spaceships."* *"Space."* *"Los satellites artificiales." [Man-made satellites.]*	23%
Personal connections	*"Spending time with my dad. We like to build, watch documentaries, and do things together."* *"What I want to be when I grow up; an aerospace engineer."*	19%
Museum experiences	*"Nothing, because I have never been in a museum this hands-on."* *"Space museum in D.C."* *"The Cell Lab, because you can do other things to build, work together, and play."*	10%
Other	*"Engineering challenges."* *"A pinhole camera?"*	10%
Did not remind them of anything	*"Nothing."* *"I don't know."*	10%

Families reported being able to engage in activities at the exhibition that may support positive science and engineering identities.

The exhibition supported visitors engaging like scientists and engineers

Almost all youth (99%) and adults (97%) reflected that their groups got to "do something hands-on to learn more" at the exhibition, which is related to what a scientist or engineer may do to learn more about phenomena (see Table 21). Similarly, most adults (92%) and youth (94%) reported being able to "play and use [their] imagination" in the exhibition. Two thirds (66%) of youth reported being able to "work together" in the exhibition, and about four out of five adults reported being able to do so (84%). For items that we only asked adults, almost all of them indicated their group had the opportunity to "look at something closely" (98%) and about nine out of ten indicated their groups "shared a discovery" (86%).

Table 21. Visitors were able to engage with the exhibition like an engineer or scientist.

What a scientist or engineer might do	Science/Engineering practices in the exhibition	% adults (n=375)	% youth (n=60)
Learn more through exploring or testing phenomena	Do something hands-on to learn more	97%	99%
Try to learn more through imagination	Play and use imagination[8]	92%	94%
Learning or sharing with others	Work together[9]	84%	66%
Observe phenomena	Look at something closely[10]	98%	NA
Share what was learned with others	Share a discovery	86%	NA

Visitors engaged in engineering activities at the exhibition

About half of the adults we sampled (47%, n=375) had visited the *Design, Build, Test* component with their group. Almost all of these adults reflected that their groups "built something" (94%) at the component, as did the youth that we asked (86%) (see Table 22). Four out of five adults (80%) reflected that their groups "tested what was built" and seven out of ten indicated that their groups had "solved a problem" (71%).

Table 22. Visitors were able to build, test, and problem-solve in the exhibition, like an engineer might do.

What an engineer might do	Science/Engineering practices in the exhibition	% adults (n=176)	% youth (n=59)
Create a model, Iterate on the initial model	Build something	94%	86%
	Test what was built	80%	NA

[8] n=328 adult responses.
[9] n=302 adult responses.
[10] n=362 adult responses.

Test the model to identify characteristics necessary for success	Solve a problem	71%	NA

Visitors shared ways that the exhibition had given them positive experiences with science or engineering

The majority of visitors (87%) shared that the exhibition provided opportunities to learn about or do science, with most of the remainder indicating that they did not feel like an exhibition *could* do this for them because they either already came in with a strong science affiliation (7%) or were "too old" (2%). One person indicated that they weren't sure if the exhibition did this or not and four provided short responses that the exhibition did not do this, but refrained from giving detail.

A selection of responses highlighting the aspects of the exhibition that supported visitors feeling like they could learn about or do science is included below. They provide examples that range from specific content in the exhibition, to the way that it engaged people in a hands-on way, to the way that it supports learners of different ages and spectrums, to the way that ideas in the exhibition were explained in an accessible way, making visitors' groups feel like that they were someone able to learn about or do science.

A selection of responses to "Did any of your experiences in the whole exhibit make you, or someone in your group, feel like someone who could learn about or do science? Can you tell me a little more?" (n=101)

- *"I think definitely. Because of the whole experience, to build and test it out, it builds confidence to learn more. Some think science and the solar system is a big thing. It's too hard. Through this, they can get a hold on it and say, 'Hey, I can learn about this.'" "The game for my kids. The questions were a great way for my seven-year-old to think more about the play that was going on."*
- *"Yes, the building activity made me feel like that."*
- *"Absolutely! It encourages basic engineering skills."*
- *"Written descriptions are accessible for kids and adults."*
- *"My daughter wants to be a scientist, and playing enhanced that."*
- *"Yes. A lot of it is planted and structured, so I can't come up with my own experiments, which is helpful, because I have autism and it helps me concentrate."*
- *"Absolutely. When you go through the motions, your capacity to understand science is increased, and you can explain it to other people."*
- *"Definitely. Feels like science is for everyone, not just people who go to MIT."*

Conclusion

The *Sun, Earth, Universe* exhibition engaged millions of general and underserved audiences across the country in quality informal education experiences that were relevant, enjoyable, informative and supportive of developing science and engineering identities. Visitor comments provided more context for understanding why the exhibition was effective - fun, hands-on interactives were key to creating the right "space" for exploration. The tone and language were also important, as shown through visitor comments about supporting science and engineering identities. We noticed that several people shared that the way ideas were explained in the exhibition was so clear and easy to understand that they felt like someone able to learn about science. Handling science content as technically focused and abstract as space exploration for a wide age group can be an incredible challenge, but the findings indicate that this team met that challenge and created engaging and accessible experiences for the whole family.

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Appendices

A. National Informal STEM Education Network Design Principles

The project team used NISE Net design principles to support the creation of the exhibition. These included five big ideas that the exhibition needed to be or do in order to be successful (see below).

NISE NATIONAL INFORMAL STEM EDUCATION NETWORK

Design principles

ENGAGING

Offer enjoyable and accessible experiences for multiple and diverse audiences, including underserved audiences
Promote social interaction among groups of learners
Provide layered and interrelated experiences that allow learners to explore in various ways and at various depths

AUTHENTIC

Engage in science skills, practices, and ways of thinking
Incorporate NASA assets, including science content and data, space and airborne platforms, and scientific and technical personnel
Encourage interaction between learners and subject matter experts

CURRENT

Feature celestial and mission events
Address the latest discoveries
Focus on dynamic processes

RELEVANT

Make connections to learners' everyday lives
Present Earth and space science as activities that multiple and diverse groups of people participate in (as students, citizens, and scientists)
Promote reflection about the social dimensions of science and technology
Connect to other ways learners can engage in STEM (including other experiences in museums, K-12 science education standards)

ACCESSIBLE

Repeat and reinforce key concepts
Provide multiple entry points and multiple ways of engagement
Offer physical and sensory access to all aspects of the experience
Produce equitable English and Spanish versions

B. Space and Earth in STEM Informal Environments Learning Framework

The SEISE project also created a learning framework to help articulate the kinds of learning experiences that they wanted to support for visitors. Inspired by the six strands of science learning developed by the National Research Council (2009), this document described key ideas, questions, and ways of experiencing content that would help visitors to learn, engage, and grow in informal science environments like those served by the SEISE project (see below).

Learning framework

1. **Experience Earth and space PHENOMENA and explore scientific discoveries**
    a. **Experiencing the joy of active learning, including play, discovery, invention, and experimentation**
        i. Learning is a continuum, which connects and builds on past and future experiences.
        ii. Learners can work alone or in groups to discover new knowledge and build skills.
        iii. Both novices and experts can be excited by seeing or understanding something for the first time.
        iv. Learners can recognize and overcome common misconceptions about our planet Earth and the solar system.

    b. **Experiencing real phenomena, celestial events, and compelling imagery**
        i. We can directly observe and experience many phenomena related to Earth and space science.
        ii. The study of celestial events can spur curiosity and contribute to our personal and collective knowledge.
        iii. The universe can be very beautiful.

    c. **Exploring and understanding our place in the universe**
        i. The universe is very large and can be difficult to conceptualize.
        ii. The universe is always changing: galaxies are colliding, stars are forming and dying, and the Earth and solar system are hurtling through space.
        iii. Space has many dangerous environments that can be harmful to both humans and robotic instruments.

    d. **Investigating the big questions that drive Earth and space research**
        i. How did life on Earth start, and are we alone in the universe?
        ii. How did the universe begin, and how were our galaxy, solar system, and planet formed?
        iii. What protects life on Earth and how do humans change these conditions?

2. **Use the scientific PROCESS and reflect on science as a way of knowing**
    a. **Engineering and scientific research is an iterative design process**
        i. Planning and executing a NASA mission is a long process with many steps.
        ii. Missions do not always go as planned and sometimes have unanticipated results, but all missions provide valuable information that provide data and inform future missions.
        iii. Grand challenges in Earth and space research are often broken down into simpler problems to be tackled one at a time.
        iv. While quantitative methods and critical thinking are important in solving

problems, ingenuity and imagination are also helpful in advancing us to the next stage of knowing.

b. Using a variety of tools and approaches to make discoveries

i. NASA science teams collect important data using satellites and other instruments to look out into space as well as back at Earth.
ii. We need many different kinds of information and perspectives to answer the big questions that drive space and Earth science research, which means we need both diverse teams and tools.
iii. People use scientific tools, such as robot explorers and remote-controlled instruments, as extensions of their senses to observe and collect data about Earth and space.

c. Understanding the power and limitations of data sets

i. Data about Earth and space can be analyzed in different ways to support multiple theories.
ii. Data are interpreted and weighed as evidence against theories in Earth and space science. Whether or not data support previous ideas, they increase our understanding of big scientific questions and led to new ideas to investigate.
iii. Data can also be misinterpreted and presented incorrectly. When we hear stories and see images about Earth and space, it can sometimes be difficult to judge their accuracy.

d. Making and using models to communicate and further our understanding

i. We need models to show invisible forces present in fields: electrical, gravity, and magnetic.
ii. Models can be changed over time as we gain new data and our understanding improves: they may be refined, improved or rejected. Examples include changing models of the solar system over time and the debate over the ninth planet in our Solar System.

e. Using our imagination and ingenuity to explore the universe

i. Imagination, play, and practical ingenuity can all lead to creative solutions for big challenges in space and Earth science exploration.
ii. Play can lead to innovative new methods and tools to explore Earth and space.
iii. Narrative, science fiction, and visions of the future can inspire us to ask new questions and motivate us to take on grand challenges.
iv. Dreaming about space and exploring new frontiers have motivated many scientists to become who they are today.

3. PARTICIPATE in the scientific community and identify as a science learner

a. Working together in groups to accomplish goals and tackle challenges

i. NASA missions involve many different types of people and communities working together over a long period of time.
ii. Mission teams must cooperate, communicate, and take advantage of their diversity of experience, expertise, and perspectives.
iii. Missions require many different tools, instruments, and methods--all designed to work together.
iv. Major discoveries in Earth and space science can take years and years of work by many different people, including scientists and citizens.

b. Recognizing the relevance of Earth and space science

i. There are many connections between Earth and space science to our everyday lives.
ii. We can build on existing knowledge and find future opportunities to learn about Earth and space science.
iii. Diverse cultures and communities have their own ways of observing nature and passing down knowledge about Earth and space, which influence the perceived relevance of Earth and space science.

c. Considering the social dimensions of Earth and space science

i. As individuals and as a society, we make decisions about what kinds of science to pursue and fund.
ii. Some scientific questions can be pursued by individuals with relatively little resources. Other questions require commitment of many people and resources.
iii. Our individual and cultural values influence the science and technologies we develop, and the ways we use them.

d. Identifying as someone who learns about and sometimes participates in current research

i. There are many opportunities to learn about Earth and space science, at home, in school, and in the community.
ii. We can all participate in Earth and space science as citizen scientists, by recording data from our home planet.
iii. Citizen scientists are contributing data to ongoing space and Earth science research projects.

C. Content Map for the *Sun, Earth, Universe* exhibition

The Sun powers Earth and our solar system.

The Sun radiates a massive amount of energy across the entire electromagnetic spectrum and through a shifting stream of charged particles.

- Energy and particles from the Sun
- The Sun and life on Earth
- The Sun and the solar system

Planetary systems like ours may contain water and life.

The solar system contains many planets, moons, and smaller objects; some may have water or support life similar to objects in other planetary systems.

- Solar system beginnings
- Solar system objects
- Water and life in the solar system
- Exoplanets

Earth is a changing planet of air, water, rock, and life.

Earth is dynamic system with a changing climate due to interactions between air, water, rock, and solar input, in addition to human activities.

- Earth is a water planet
- Earth is a rocky planet
- Diverse lifeforms of Earth
- Human influence on Earth

The universe is very large, old, and mysterious.

In 14 billion years, the universe has gone from a small, hot ball a few millimeters across to a huge expanse of galaxies, stars, and planetary systems almost 50 billion light years across, and still expanding today.

- The big bang and other models
- Life cycles of stars
- Light from the universe

Our society chooses to explore Earth and space.

- Our values influence questions
- Inspiration for new technology
- Better decisions about our home
- Teamwork and specialized tools

Forces and energy connect everything in the universe.

- Electromagnetic spectrum
- Gravity
- Magnetism

v2/23/18

D. Data Collection Instruments

Figure 3. Adult Survey

Exhibit Survey Loc:_____ Date:_____ #_____ DC:____

Thank you for being in our study!

Your response helps us understand how this exhibit works for people. This survey is anonymous and voluntary, meaning you can stop at any time. While we may use this information in additional studies or share it with other researchers, we will not be able to link any individual responses back to you.

1) How interesting was the exhibit?

☐ Not interesting ☐ A little interesting ☐ Interesting ☐ Very interesting

2) How enjoyable was the exhibit?

☐ Not enjoyable ☐ A little enjoyable ☐ Enjoyable ☐ Very enjoyable

3) Did you or your group learn anything new at the exhibit?

☐ Yes ☐ No ☐ Unsure

3b) If yes, what are 1 or 2 things that you or your group learned about?

4) After visiting the exhibit, how interested are you in Earth & space topics?

☐ LESS interested ☐ No change ☐ MORE interested

5) After visiting the exhibit, how relevant do you feel these Earth & space topics are to your life and experiences?

☐ LESS relevant ☐ No change ☐ MORE relevant

NEXT

6) **BEFORE visiting this exhibit, how would you rate your confidence in your ability to do each of these? (Please circle ONLY ONE choice per row.)**

Opportunity	Level of Confidence			
Share at least one way that scientists are studying other planets.	Not at all confident	Somewhat confident	Confident	Extremely confident
Describe at least one way that the Sun changes over time.	Not at all confident	Somewhat confident	Confident	Extremely confident
Tell a friend at least one way that planet Earth is constantly changing.	Not at all confident	Somewhat confident	Confident	Extremely confident
Give an example of at least one tool that reveals energy or forces at work in the universe.	Not at all confident	Somewhat confident	Confident	Extremely confident
Describe at least one way that scientists are looking for life beyond our solar system.	Not at all confident	Somewhat confident	Confident	Extremely confident
Share at least one way that people are choosing to explore Earth & space.	Not at all confident	Somewhat confident	Confident	Extremely confident

7) **Now AFTER visiting this exhibit, how would you rate your confidence in your ability to do each of these? (Please circle ONLY ONE choice per row.)**

Opportunity	Level of Confidence			
Share at least one way that scientists are studying other planets.	Not at all confident	Somewhat confident	Confident	Extremely confident
Describe at least one way that the Sun changes over time.	Not at all confident	Somewhat confident	Confident	Extremely confident
Tell a friend at least one way that planet Earth is constantly changing.	Not at all confident	Somewhat confident	Confident	Extremely confident
Give an example of at least one tool that reveals energy or forces at work in the universe.	Not at all confident	Somewhat confident	Confident	Extremely confident
Describe at least one way that scientists are looking for life beyond our solar system.	Not at all confident	Somewhat confident	Confident	Extremely confident
Share at least one way that people are choosing to explore Earth & space.	Not at all confident	Somewhat confident	Confident	Extremely confident

NEXT

8) At the exhibit, how much did you or your group get to do each of the following?

	Not at all	At least once	More than once	I'm not sure
Do something hands-on to learn more.	☐	☐	☐	☐
Look at something closely.	☐	☐	☐	☐
Play and use imagination.	☐	☐	☐	☐
Build something.	☐	☐	☐	☐
Test what was built.	☐	☐	☐	☐
Solve a problem.	☐	☐	☐	☐
Work together.	☐	☐	☐	☐
Share a discovery.	☐	☐	☐	☐

We want to know more about who we are hearing from to better understand how the exhibit is serving multiple audiences.

9) Who are you visiting with today?

☐ With children ☐ Only with other adults ☐ By myself

10) Your age:_____

11) Ages of the other people in your group today:_____

12) What is your gender?

☐ Male ☐ Female ☐ Prefer not to say ☐ Another Category: Please specify _____

13) With which racial or ethnic group(s) do you identify? (Check all that apply.)

☐ American Indian or Alaskan Native ☐ Asian ☐ Black or African American ☐ Hispanic or Latino

☐ Native Hawaiian or Pacific Islander ☐ White ☐ Other:_____ ☐ Prefer not to say

Thank you!

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Figure 4. Adult Interview

There were two versions of the adult interview; the only difference being the focus of question four. We have included both versions of question four here, right after the other.

Exhibit Interview v1 Loc:_____ Date:_____ AS #_____ DC:_____

1) What, if anything, did you enjoy about this exhibit?

2) If someone asked you what this exhibit was about, what would you say?

3) What in your daily life connects to something you saw in this exhibit?

4) [Skip and check NA if there were no increases in confidence.] ☐ **NA**

In the survey you just did, we asked some questions about how confident you felt sharing about some ideas included in the exhibition. [*Show them survey responses].* **It looks like you felt more confident with these** [one, two...five] **items *after* trying the exhibit.**

Could you pick one to tell me a little more about what led to that feeling?

☐ **Other planets** ☐ **Sun** ☐ **Earth** ☐ **Tool** ☐ **Explore** ☐ **Life beyond**

1

4) [Skip and check NA if all items were checked "not at all".] ☐ **NA**

In the survey you just did, we asked how much you or your group got to do some things in the exhibit. [*Show them survey responses].* **It looks like you felt that your group got to do these** [one, two... eight] **activities while trying the exhibit.**

Could you pick one to tell me a little more about how you or your group were able to do that in the exhibit?

☐ **Hands On**	☐ **Build**	☐ **Work Together**
☐ **Look Closely**	☐ **Test**	☐ **Share Discovery**
☐ **Play/Imagination**	☐ **Solve Problem**	

1

5) [Skip and check NA if visitor indicated that they did not stop at DBT.] ☐ **NA**

Could you tell me about what you or your group did in this area? [Gesture to DBT only.]

6) Did any of your experiences in the whole exhibit make you, or someone in your group, feel like someone who could learn about or do science? Can you tell me a little more?

Target adult responses	Child responses (if any)

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Figure 5. Youth Interview

Youth Interview

Loc:_____ Date:_____ AS #:_____ #_____ DC:____

A) How fun was the exhibit? Was it "really fun?", "a little fun?", or "not fun"? [Show face scale handout.]

Youth 1: ☐ Not fun ☐ A little fun ☐ Really fun

Youth 2: ☐ Not fun ☐ A little fun ☐ Really fun ☐ NA

Youth 3: ☐ Not fun ☐ A little fun ☐ Really fun ☐ NA

B) And how old are you?

Youth 1: _____

Youth 2:_____ ☐ NA

Youth 3:_____ ☐ NA

C) What did you get to do or try in this exhibit?

Youth 1:

Youth 2:

☐ NA

Youth 3:

☐ NA

D) After trying the exhibit, how curious are you about Earth & space? Are you "more curious?", "about the same?", or "less curious" about Earth & space?

Youth 1: ☐ Less ☐ About the same ☐ More ☐ No response

Youth 2: ☐ Less ☐ About the same ☐ More ☐ No response ☐ NA

Youth 3: ☐ Less ☐ About the same ☐ More ☐ No response ☐ NA

Thank you! I have two questions for everyone who is ten or older to fill out on their own.

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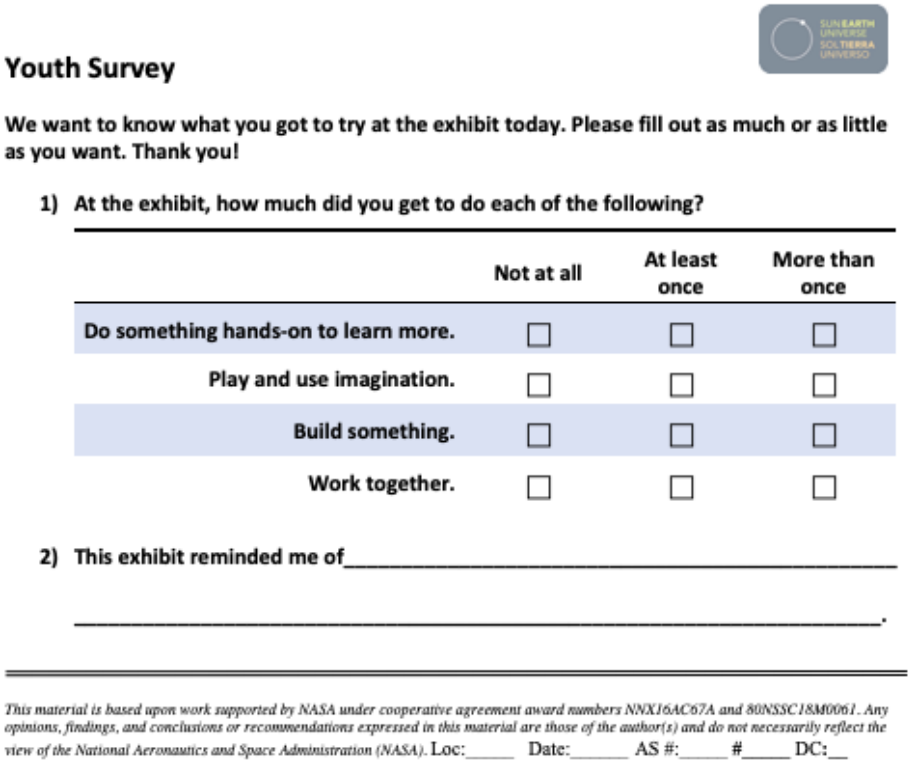
Figure 6. Youth Survey
This survey was for youth who identified as 10 or older during the interview.



Youth Survey

We want to know what you got to try at the exhibit today. Please fill out as much or as little as you want. Thank you!

1) At the exhibit, how much did you get to do each of the following?

	Not at all	At least once	More than once
Do something hands-on to learn more.	☐	☐	☐
Play and use imagination.	☐	☐	☐
Build something.	☐	☐	☐
Work together.	☐	☐	☐

2) This exhibit reminded me of_____

_____.

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Figure 7. Observation

Data Collector: _____ Date: _____ #: _____

1) Time of Day: open-12 12-5 after 5 **Crowding:** L M H

2) Enter time (m/s): _____ Leave time (m/s): _____ Duration? (m/s): _____

3) Approximate Age: _____ Approximate Ages of Group Members: _____ Refuse Q? __

Component	Order	Time Notes	Activity	
Design				Build ☐ ☐ ☐
Build				Test ☐ ☐ ☐
Test				Change ☐ ☐☐
Sun panel (Back)				
Sun flip card activity & panel		**NOTES:**		
Tiles Interactive & Panel				
Earth flip card activity & panel				
Antarctica panel (Back)				
Venus blocks & **Saturn** Panel				
Enceladus panel (Back)				
Universe bead tumbler, Hubble & panel				
Sombrero Galaxy panel (Back)				
Mars' surface block table				
Game: Mission to Space				
Couch				
Books, Post-its				

Figure 8. Staff or Volunteer Interview

Sun, Earth, Universe informal interview with site staff or volunteers

Hello, my name is ____ and I'm looking at how visitors use the Sun, Earth, Universe exhibition over the next __ days. Now, I'll be speaking directly with visitors to get their input, but I'm also curious what your impressions of the exhibition have been, since you seem to spend time in this gallery. Do you mind chatting with me for a few minutes?

1) **What is your role at the museum?**

2) **How long have you been at the museum?**

3) **About how much time do you usually spend in this area?**

4) **And what are you doing when you're in this gallery?**

5) **What have you noticed about how visitors use this exhibit?**

6) **Were you here before the Sun, Earth, Universe exhibition was installed?**

7) **What did you notice about how visitors tended to use that exhibition?**

8) **Is there anything else you'd like to let me know about how this exhibit has or has not supported visitor engagement?**

9) **Could we have your email address, in case we wanted to follow up with you later about your opinions?**

Figure 9. Data Description Form

There was an additional form used for every day after the first day at a site. It had fewer questions than the instrument below (questions 3, 4, and 5 were omitted).

Data Collection Description Form_Day 1

1) Walk through exhibition area before collecting.

2) Note the...

Location:_____ **Date:**_____ **Day of Week:**_____

Current Time:_____ **Museum opens & closes at:**_____

Data Collectors:_____

Circle your name in the list above.

CROWDING at Beginning of Collection: L M H

3) Describe the general layout. (Clustered or spread out? What floor of the museum? By entrances/exits? By what other exhibits?)

4) Draw exhibit being sure to label a) where DBT is, b) where 2 couches are, c) where stools are, d) what exhibits are nearby, e) where visitors are likely to enter or exit, f) where you'll probably stand to collect data, and g) any important nearby museum features (like bathrooms, stairs, etc...).

5) Take a picture of layout.

6) Are there any components that are damaged, worn, missing parts, or inaccessible to visitors in some way?

Component	Available for visitors? Y/N	Please describe if non-normal in any way.
Design, Build, Test	All three stations?	
	Building pieces available?	

1

Data Collection Description Form_Day 1

Component	Available for visitors? Y/N	Please describe if non-normal in any way.
SUN	Sun back panel?	
	Flip card activity side?	
TOOL BENCH	4 tiles?	
	Each station works?	
EARTH	Antarctica back panel?	
	Flip card activity side?	
UNIVERSE	Bead tumbler side?	
UNIVERSE	Sombrero Galaxy back panel?	
VENUS	Data visualization blocks – all 5 colors? Any wear and tear?	
	Enceladus back panel?	
SURFACE OF MARS	Are all four blocks present? Anything additional?	
MISSION TO SPACE	All four player pieces available?	
	In good repair?	
BOOK/POST-IT PANEL	How many info cards present? #_____	
	Please describe books and other materials in area ->	
COUCHES	2 couches present in immediate exhibition area?	

Data Collection Description Form_Day 1

Component	Available for visitors? Y/N	Please describe if non-normal in any way.
STOOLS	All eight stools available? (one for each planet in solar system – no Pluto)	

7) MID COLLECTION PAUSE:

CROWDING during Middle of Collection: L M H

8) END OF COLLECTION:

Time Ending Collection:_____

CROWDING at End of Collection: L M H

How do you think crowding changed throughout the day?

How, if at all, did you change your approach to data collection throughout the day?

9) Anything else that should be noted that may affect visitors' experiences?

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E. Supplemental Findings

This additional analysis may be of interest to stakeholders who wonder more about visitor behavior in the exhibition, visitors' favorite components, and how visitors' confidence shifted around the different big ideas.

Visitors stopped at interactive components more often than large panel displays

Most visitors we observed (57%, n=131) stopped at the *Design, Build, Test* component where participants could create and test their own spacecraft (see Table 23). Half of the visitors (51%) stopped at the bead tumbler interactive, where people could search for the one star we know of that supports life in the universe (our Sun), while also getting a sense the ratio of stars that may have life-supporting planets in the universe. *Using Tools to Detect the Invisible* was also stopped at frequently; almost half (45%) of the visitors we observed used the component to reveal hidden images or text in small tiles at the workbench. A quarter of visitors tended to stop at the *Topographic Map of Venus* (28%) and the *Your Mission to Space* board game (21%). Flip card interactives, the seating and reading area, and back panels were visited less frequently.

Table 23. Percentage of visitors who stopped at each component. (n=131[11])

Components	Component type	% of visitors who stopped
Design, Build, Test	**Interactive**	57%
Universe Graphic, Hubble Telescope Viewer, & Search for the Sun Bead Tumbler	**Panel & Minor Interactive**	51%
Use Tools to Detect the Invisible	**Interactive**	45%
Solar System Graphic & Topographic Map of Venus	**Panel & Minor Interactive**	28%
Your Mission to Space Board Game	**Board Game**	24%
Sun Panel & Flip Cards	**Panel & Minor Interactive**	21%
Earth Panel & Flip Cards	**Panel & Minor Interactive**	15%
Mars Landscape Play Table	**Play Table**	11%
Sun Graphic Panel (n=91)	**Panel**	10%
Reading & Seating Area	**Info & Resources**	8%
Universe Graphic Panel	**Panel**	2%
Earth Graphic Panel (n=91)	**Panel**	-
Solar System Graphic Panel (n=91)	**Panel**	-

[11] Three panels were only available to visitors at SMM during our observations. For these, our sample size 91 instead of 131.

Table 24. Percentage of visitors who stopped at each component first. (n=131[12])

Components	Component Type	% of Visitors
Design, Build, Test	**Interactive**	27%
Universe Graphic, Hubble Telescope Viewer, & Search for the Sun Bead Tumbler	**Panel & Minor Interactive**	15%
Use Tools to Detect the Invisible	**Interactive**	15%
Sun Panel & Flip Cards	**Panel & Minor Interactive**	14%
Solar System Graphic & Topographic Map of Venus	**Panel & Minor Interactive**	10%
Sun Graphic Panel (n=91)	**Panel**	7%
Your Mission to Space Board Game	**Board Game**	6%
Earth Panel & Flip Cards	**Panel & Minor Interactive**	4%
Mars Landscape Play Table	**Play Table**	2%
Universe Graphic Panel	**Panel**	2%
Earth Graphic Panel (n=91)	**Panel**	1%
Reading & Seating Area	**Info & Resources**	1%
Solar System Graphic Panel (n=91)	**Panel**	-

Visitors enjoyed the* Design, Build, Test *component

When we asked visitors, "What, if anything, did you enjoy about the exhibit?" a quarter of respondents (23%) mentioned *Design, Build, Test* and one in seven (14%) shared something about the *Use Tools to Detect the Invisible* component (see Table 25). Other components were shared by a handful of respondents and were also interactive in nature.

Table 25. Components mentioned by respondents. (n=102)

	% of adult respondents
Design, Build, Test	23%
Use Tools to Detect the Invisible	14%
Earth or Sun Flip Cards	6%
Search for the Sun Bead Tumbler	5%
Your Mission to Space Board Game	5%
Topographic Map of Venus	5%
Hubble Telescope Viewer	3%

[12] Three panels were only available to visitors at SMM during our observations. For these, our sample size 91 instead of 131.

Changes in confidence speaking or sharing about SMD content areas
In the body of the report, we shared statistical details about visitors' increased confidence in talking about Earth and space content after visiting the exhibition. Descriptive statistics are provided below in Tables 26-31 for each item and its responses. Tables are arranged from items with the largest to smallest changes.

Table 26. "Share at least one way that scientists are studying other planets."

	% Before (n=351)	% After (n=351)	Difference
Extremely Confident	13%	24%	+11%
Confident	35%	49%	+14%
Somewhat confident	39%	25%	-14%
Not at all confident	13%	2%	-11%

Table 27. "Describe at least one way that the Sun changes over time."

	% Before (n=350)	% After (n=350)	Difference
Extremely Confident	11%	23%	+12%
Confident	32%	46%	+14%
Somewhat confident	34%	26%	-7%
Not at all confident	23%	4%	-19%

Table 28. "Tell a friend at least one way that planet Earth is constantly changing."

	% Before (n=345)	% After (n=345)	Difference
Extremely Confident	23%	33%	+10%
Confident	40%	43%	+3%
Somewhat confident	29%	22%	-7%
Not at all confident	8%	2%	-6%

Table 29. "Give an example of at least one tool that reveals energy or forces at work in the universe."

	% Before (n=347)	% After (n=347)	Difference

Extremely Confident	15%	24%	+9%
Confident	29%	44%	+16%
Somewhat confident	35%	27%	-7%
Not at all confident	22%	5%	-17%

Table 30. "Describe at least one way that scientists are looking for life beyond our solar system."

	% Before (n=347)	% After (n=347)	Difference
Extremely Confident	15%	23%	+8%
Confident	33%	48%	+15%
Somewhat confident	37%	26%	-11%
Not at all confident	15%	3%	-12%

Table 31. "Share at least one way that people are choosing to explore Earth & space."

	% Before (n=346)	% After (n=346)	Difference
Extremely Confident	18%	29%	+11%
Confident	40%	47%	+8%
Somewhat confident	33%	23%	-10%
Not at all confident	9%	1%	-8%