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Z-2 Space Suit: A Case Study in Human Spaceflight Public Outreach

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NASA Johnson Space Center's Z-series of planetary space suit prototypes is an iterative development platform with a Mars-forward design philosophy, targeting a Mars surface mission in the mid-2030s. The first space suit assembly, called the Z-1, was delivered in 2012. While meeting the project's stated requirements and objectives, the general public's reception primarily focused on the color scheme, which vaguely invoked similarity to a certain animated cartoon character. The public at large has and continues to be exposed to varying space suit design aesthetics from popular culture and low TRL technology maturation efforts such as mechanical counterpressure. The lesson learned was that while the design aesthetic is not important from an engineering perspective, the perception of the public is important for NASA and human spaceflight in general. For the Z-2 space suit, an integrated public outreach strategy was employed to engage, excite and educate the public on the current technology of space suits and NASA's plans moving forward. The keystone of this strategy was a public vote on three different suit cover layer aesthetics, the winner of which would be used as inspiration in fabrication. Other components included social media, university collaboration, and select media appearances, the cumulative result of which, while intangible in its benefit, was ultimately a positive effect in terms of the image of NASA as well as the dissemination of information vital to dispelling public misconceptions.

Nomenclature

AMA	=	[Reddit] "Ask Me Anything"
JSC	=	Johnson Space Center
NASA	=	National Aeronautics and Space Administration
PAO	=	Public Affairs Office
RFP	=	Request for Proposal
SSA	=	Space Suit Assembly
TRL	=	Technology Readiness Level

I. Introduction

PUBLIC perception is important. Does the public believe that their tax dollars are being well spent? Does the public believe that NASA is capable of meeting its stated goals? Does NASA have the faith of the American public, and faith of the world at large, that they will be the ones to first set foot on Mars? These are all valid and important questions. In the day of seemingly-imminent human access to space by commercial companies, coupled with the stereotype that the private sector can do things faster, better and cheaper than government agencies, there is an increasing segment of society that has developed the theory that it will not be NASA to first set foot on Mars: instead, it will be China, or Europe, or a privately held corporation. In the case of the latter, many believe that commercial, "new space" will place humans on Mars before a state agency does, despite the fact that as of this writing, new space has not yet attempted to fly a human into low earth orbit. While these predictions with respect to Mars obviously remain to be seen, there are myriad reasons why this feeling has developed, and a very complicated 60-year history that has led to this point. Some of these reasons have merit, while others may be more a matter of perception or lack of understanding by the general public at large. Either way, a robust and efficient public outreach strategy is important to not only inspire the public, but also to educate them on what the space community is doing as well as dispel misconceptions that they may have about specific topics or about spaceflight in general. For their part, SpaceX for

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example, has done a great job of not only exciting the public, but also educating them at the same time on the difficulties, realities, and complexity of spaceflight. NASA also has a very comprehensive public outreach component, and employs it well to inspire and educate the public on what NASA is doing, and planning on doing, in space. However, one might argue that a key corollary is the outreach to educate the public on so-called “misconceptions” that might damage the NASA brand or the brand of spaceflight in general.

II. Space Suits as an Outreach Mechanism

I like to think that space suits are a somewhat unique hardware component in human spaceflight from a public perspective. They are, ultimately, fancy clothes for space, and clothes are something that everyone can easily relate to. Children specifically find them to be incredibly relatable from a very young age, which is part of the reason why Johnson Space Center’s Space Suit and Crew Survival Systems Branch conducts so many public outreach events at schools across the country, hoping to inspire the next generation of space explorers or engineers as early as three years old. From the outside, space suits also seem relatively simplistic and easy to understand when compared to a rocket or a water revitalization system, or a radioisotope thermal generator, or even a habitat, rover, or space station. Space suits, being designed around the human body, are naturally reachable from a conceptualization standpoint, which allows even the least technically-oriented people to ask intelligent and insightful questions. For these reasons, the space suit community at large should feel deputized on behalf of the spaceflight community, to leverage these advantages into public outreach work that furthers our cause, and excites the public. To wit, many in the space suit community do engage in public outreach activities; however, over the past decades, most of this has been speaking to schools across the country or conducting interviews or suit demonstrations to showcase what we are working on, and why it’s important in the context of NASA’s aspirations for human exploration of space. While these are all valuable outreach goals, engaging the public on a larger scale should continue to be another.

In 2012, the Z-1 space suit (Figure 1) was delivered to NASA and shown to the world through a series of interviews/television spots and social media engagement. The Z-series of planetary space suit prototypes is an iterative development platform with a Mars-forward design philosophy, targeting a Mars surface mission in the mid-2030s; Z-1 was the first. While Z-1 met relevant requirements and objectives, and provided invaluable information to NASA through testing and evaluation, the general public’s reception primarily focused on the color scheme, which vaguely invoked similarity to Buzz Lightyear, a character from Disney’s *Toy Story*. The various technological improvements of the suit over its predecessors, and the wealth of data accumulated by testing it, was primarily lost on the public as compared to the design aesthetic; this is expected, as the overwhelming majority of people are likely to simply view a few photos, skim the article, perhaps comment on social media, and move on with their day.



Figure 1. Z-1 Planetary Space Suit Prototype

The public at large has and continues to be exposed to varying space suit design aesthetics from popular culture and low TRL technology maturation efforts such as mechanical counterpressure. For the same reason that space suits are more relatable to the public (fancy clothes, simple compared to a rocket or space vehicle), one might argue that this same public is comparatively quick to critique “real” space suit design aesthetics as compared to what they are presented with elsewhere. In other words, the large rotating space vehicle on its way to Mars in a recent science fiction movie is a complex, expensive, difficult to understand concept because not only has one never been built, but it’s not like anything seen in everyday life. Meanwhile, the sleek, form-fitting space suit worn on Mars looks so simple, inexpensive, and not incredibly different from the clothes I wore at the gym this morning. Even more complicated popular culture references, such as the suit Iron Man wears, is seemingly complicated from a fabrication standpoint, but is, at the end of the day, a series of interconnected armor components and a heads-up display – again, relatively easy to conceptualize when you have the human body as a starting point. Now, the takeaway here should not be that the public is misinformed or that they have unrealistic expectations. It’s that, instead of allowing the public’s concept of a space suit design aesthetic to drive the perception of real hardware, that concept can be leveraged to gain the public’s attention, and while doing so, attempt to not only engage and excite, but also to educate; educate on what NASA is doing, why they’re doing it, and how their idea of a space suit design aesthetic fits into reality in the proper context. Ultimately, the lesson learned was that while space suit design aesthetic is not important from an engineering perspective, the perception of the public is important for NASA and human spaceflight in general, and can be leveraged as a means of public outreach.

III. Z-2 Outreach Activity

A. Inception

Given the experience from the Z-1 space suit, for the Z-2, which was completed in 2015, an integrated public outreach strategy was employed to engage, excite and educate the public on the current technology of space suits and NASA’s plans moving forward. This strategy dates back to 2013, when the requirements for the Z-2 were released in a Request for Proposal (RFP). Among the hundreds of other technical requirements which have been discussed in other publications, a relative outlier was included: “The Z-2 space suit cover layer should be aesthetically pleasing.” This requirement was borne out of the public interest seen from the Z-1 cover layer design, as well as some aesthetic deficiencies noted in that design: as might be expected, the cover layer was designed to best meet its requirements, with only superficial thought given to look. Note that this requirement, using “should” language, served as a strong suggestion of sorts, but not a hard requirement, while most other requirements used “shall” language; in other words, the goal to be aesthetically pleasing came second, after all other requirements were met. As a side note, it is interesting to compare this requirement with a requirement that SpaceX included for its launch/entry suit, which used the verbiage “shall look badass”. Obviously, the two requirements meant to serve similar goals, and were released at similar times, but were worded very differently; SpaceX generated an incredible amount of news coverage by simply including this requirement and wording it this way. This underscores how differently new space can engage the public than government, and how they can serve to complement each-other going forward.

In a response to the RFP, ILC Dover engaged the design school at University of Delaware, listing them as a sub-contractor, to aid in designing the cover layer to meet the intent of the requirement. ILC Dover won the Z-2 contract, and early in the design cycle, presented a range of possible options for the cover layer, pulling interesting concepts such as different patterning, materials, lighted elements, colors, fabrics, and combining them with inspirations from popular culture, technology, media and biology. Instead of down-selecting the various concepts to one design, flexibility in the suit fabrication schedule allowed NASA to down-select to a small set of concepts, and then let the public vote on which one would be made.

B. Approach

The three concepts that were chosen were named “Biomimicry”, “Technology”, and “Trends in Society”. True to its name, the Biomimicry design drew from the ocean, an environment with many parallels to the harshness of space: “Mirroring the bioluminescent qualities of aquatic creatures found at incredible depths, and the scaly skin of fish and reptiles found across the globe, this design reflected the qualities that protect some of Earth’s toughest creatures.” The Technology design paid homage to spacesuit achievements of the past while incorporating subtle elements of the future: “By using Luminex wire and light-emitting patches, this design puts a new spin on spacewalking standards such as ways to identify crew members.” Lastly, the Trends in Society design was an attempt to be reflective of what everyday clothes may look like in the not-too-distant future: “This suit uses electroluminescent

wire and a bright color scheme to mimic the appearance of sportswear and the emerging world of wearable technologies.”

These three concepts were presented to the public in the form of a website which went live in January 2014. As of this writing, the website is still available at <https://jscfeatures.jsc.nasa.gov/z2/>. Screenshots of each design’s description and slideshow are shown below in Figures 2-4. On the website, the various milestones of the Z-2 suit were presented (First planetary suit to be vacuum tested, first use of human laser scans and 3D-printed hardware, impact resistant composite structure, integration of the suit-port concept to a hard upper torso). Included for each of the design concepts was a slideshow of renders of the design mapped to a generic rear-entry suit model in various environments (JSC rock pile, Space Center Houston, Neutral Bouyancy Laboratory, Chamber A). Also provided was a rotating 3D model of the design, with the option to view in light or darkness (to see lit-up elements), as well as 2D concept art that was the original basis for the three designs. Lastly, a voting module was presented to the user which allowed them to vote on one of the three designs. A cookie-based ballot stuffing prevention method was employed to minimize the likelihood of abuse.

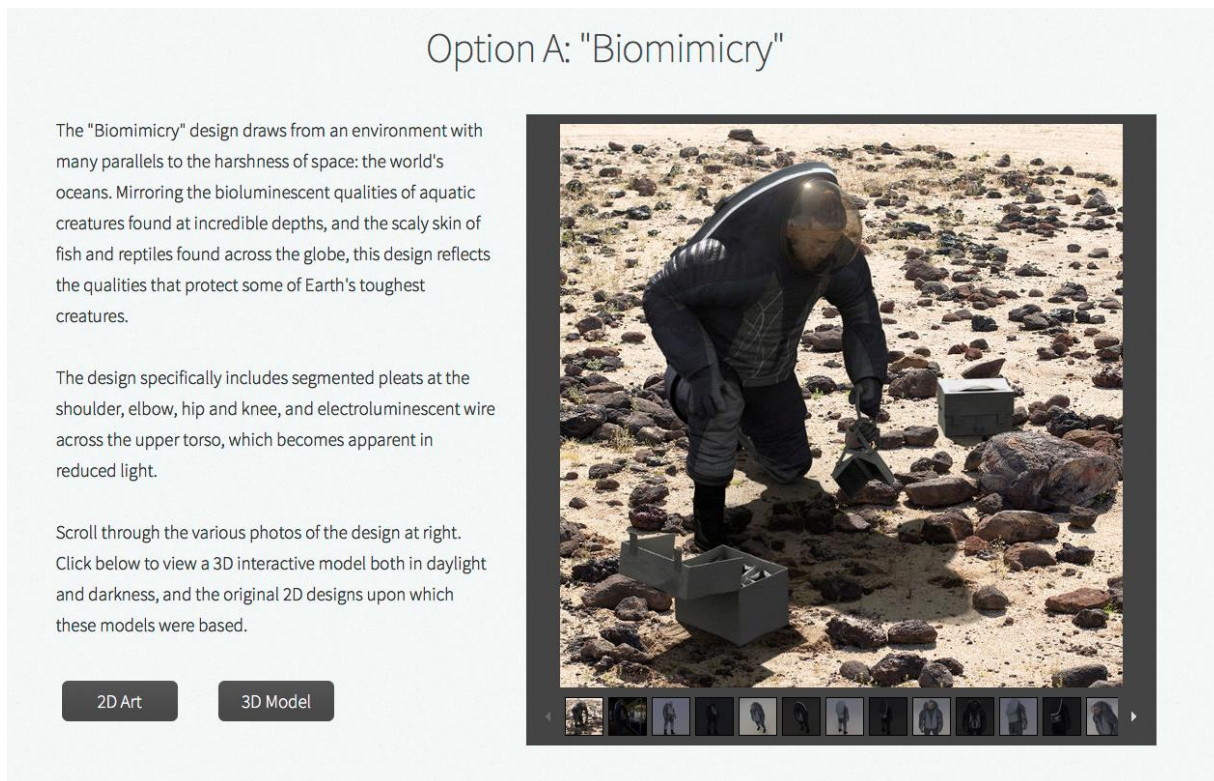



Figure 2. Slideshow module for “Biomimicry” design

Option B: "Technology"



"Technology" pays homage to spacesuit achievements of the past while incorporating subtle elements of the future. By using Luminex wire and light-emitting patches, this design puts a new spin on spacewalking standards such as ways to identify crew members.

The design specifically includes electroluminescent wire and patches across the upper and lower torso, exposed rotating bearings, collapsing pleats for mobility and highlighted movement, and abrasion resistant panels on the lower torso.

Scroll through the various photos at left. Click below to view a 3D interactive model both in daylight and darkness, and the original 2D designs upon which these models were based.

2D Art
3D Model

Figure 3. Slideshow module for "Technology" design

Option C: "Trends in Society"

"Trends in Society" is based off of just that: being reflective of what every day clothes may look like in the not too distant future. This suit uses electroluminescent wire and a bright color scheme to mimic the appearance of sportswear and the emerging world of wearable technologies.

The design specifically includes gore pleats with contrast stitching throughout to highlight mobility, an exposed bearing at the hip, and electroluminescent wire and patches of varying styles across both the upper and lower torso.

Scroll through the various photos of the design at right. Click below to view a 3D interactive model both in daylight and darkness, and the original 2D designs upon which these models were based.

2D Art
3D Model




Figure 4. Slideshow module for "Trends in Society" design

C. Initial Results

The response was immediate and significant. The first lesson learned was that the images and 3D models were too large in size, as within two hours of the site going live and being pushed by NASA’s social media, it went down or was unavailable. This was resolved quickly, with no significant technical issues thereafter. The website spread very quickly across social media, Reddit, and onto technology blogs like Gizmodo within a few hours. This spread to larger media websites such as NBC, CNN, The Huffington Post, and others within 48 hours. In conjunction with this, a Reddit “Ask Me Anything” (AMA) was conducted by the NASA SSA Development team approximately 48 hours after the website was released. At the time it was the first AMA conducted by Johnson Space Center, and while the primary goal was to help publicize the cover layer voting contest and engage in public outreach, a secondary goal was to help correct the various misconceptions about space suits and space suit design that would invariably be raised. The goals seem to have been met: 2,635 people were directed to the voting website from the Reddit AMA. Obviously a considerably small fraction of the total, but valuable nonetheless. In addition, anecdotal review of subsequent discussions on Reddit regarding space suits indicate that while these misconceptions do still exist, there are usually people who correct them, and get upvoted for doing so. In this case, the AMA was successful if for no other reason, the often difficult to communicate design constraints and misconceptions have begun to penetrate into the world of the casual tech, engineering or space reader.

After a few weeks of voting, the Technology concept won with 63% of the vote – however, the bigger point is that during that time, more than 230,000 votes were cast from all over the world. There were in excess of 700,000 unique page views, approximately half of which resulted in views of the detailed 3D models and/or 2D graphic art. An estimation based on news article pageview statistics from the initial spike places the internet impact between 2-3 million people. Users spent, on average, 2 minutes and 4 seconds viewing the website, which is excellent by all accounts. During and slightly preceding the voting period, hundreds of articles were published, both online and in print, covering the design vote from all over the world. Some of the larger media organizations publishing these articles pursued, and were provided when possible, exclusive imagery and/or interviews with engineers. During this time, according to Google Trends, searches for “space suit” approximately tripled, and approximately quadrupled for the search term “NASA space suit” (Figures 5 and 6)

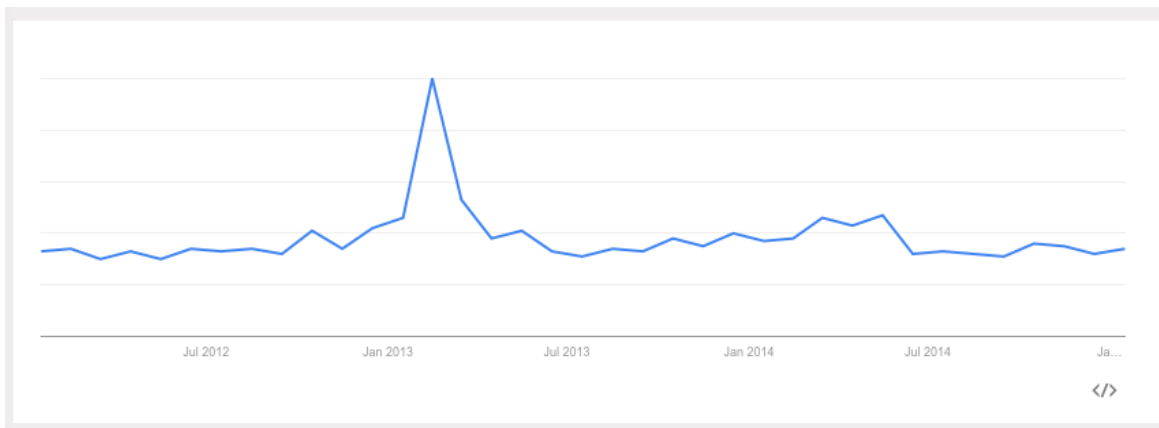


Figure 5. Google Trends graph of term “space suit” from 2012-2015. Shown peak normalized to 100.

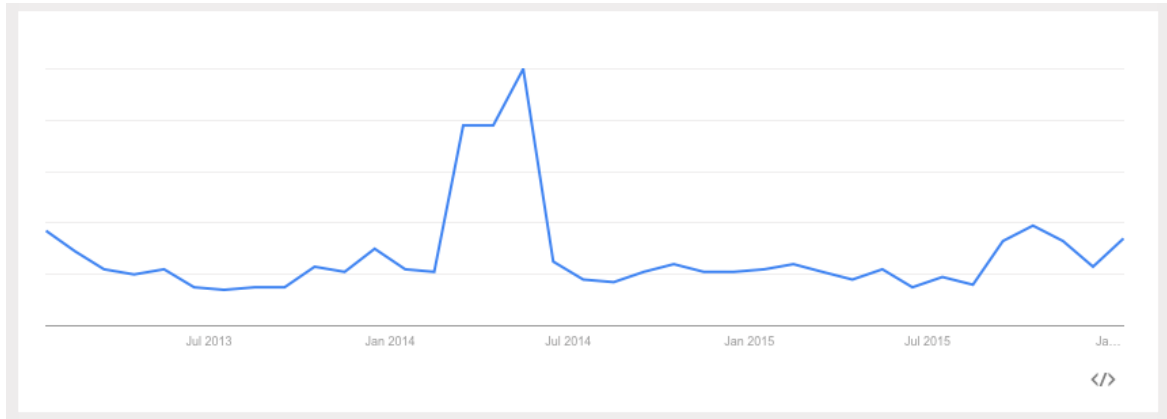


Figure 6. Google Trends graph of term “NASA space suit” from 2012-2015. Peak normalized to 100.

Shortly after the voting period ended, an image announcing the Technology design as the winner was placed on the website, with a pending release date of Fall 2014. Also of interest is the fact that while the Z-1 suit was dubbed the “Buzz Lightyear suit” by the public, the Z-2 Technology design was dubbed the “Tron suit”, and accordingly, the “winner image” used a font giving a nod that that name (Figure 7) This resulted in a second, smaller spike of traffic to the site, with a new round of news and blog articles written announcing the winner of the vote.

The indirect impact in terms of people reached worldwide from the voting campaign is incalculable, but is likely in the tens of millions.



Figure 7. Photo posted to the voting website shortly after the winning design was announced

D. Long Term Results

Delays in fabrication of the Z-2 suit resulted in the first photos of the Z-2 being released on a NASA site in October 2015. Interestingly enough, a cursory search prior to this using Reddit and Google Search was unable to locate even a single instance of someone requesting a status or commenting on the fact that the suit had been scheduled to be delivered in Fall of 2014, yet here it was nearly a year later. Even a month after the first photos of the Z-2 suit were posted on NASA.gov (Figure 8), they had not made a noticeable impact on the web. It took a single Reddit post to eventually garner this impact, which took the form of several blog articles written and multiple posts on Reddit and

social media; however, this was significantly smaller impact than the voting site had, regardless of the fact that this included photos of the real suit (versus a somewhat representative 3D model). This is a somewhat insightful finding, as it indicates a general lack of inertia of public attention that the Z-2 voting initiated. Furthermore, it underscores the importance of communicating the most effective message during the critical impact period, as it may not be possible to hold or regain that attention in the future. (It should be noted that Google Trends indicates that searches for the term “Z-2 space suit” were continuing to occur at a low level in late 2014 and all of 2015, but no direct mentions can be found in forums or articles during this time).



Figure 8. Z-2 Planetary Space Suit Prototype

Casual comparison of subjective comments on the original 3D model from the website, versus the real suit as-built indicates a general preference for the latter, and when a direct comparison was made, they mostly were of the flavor that the real suit “looked better” than the original models suggested. While this is positive, when taken in combination with the fact that most of the outreach impact occurred during the voting period, it could lend itself to the theory that releases to the public such as these are a “one-shot” situation and it may be best to hold one’s cards until the best moment. However, it is also impossible to know what the outreach impact would have been for the Z-2 suit if the cover layer voting contest had never been conducted, and furthermore, a full-fledged PAO campaign has yet to be conducted with the Z-2 as of this writing, which would include additional photos, interviews, etc. Currently, Google searches for “Z-2 space suit” overwhelmingly contain photos of the original models, with no update since the real Z-2 hardware photos were released. The hope is that a more deliberate outreach campaign, once the suit has undergone initial manned testing, will help create an additional bump of awareness and ultimately eclipse that of the original 3D models.

Additional, miscellaneous lessons learned related to this outreach campaign are as follows:

- Attempts to drive traffic back to the voting site by providing new images and an option for people to submit their own space suit designs were mostly unsuccessful, although we did receive several very touching submissions and emails to the incoming mailbox as a result.
- The voting site was primarily a dead-end site, with very few links onto other sites within NASA.gov – although this voting occurred prior to NASA’s “Journey to Mars” campaign, there were at the time several overarching NASA outreach campaigns that could have been linked to, to generate additional interest and awareness. This was a missed opportunity.
- The photos of the actual Z-2 suit, after being posted on a site at NASA.gov, did not seem to garner much traffic, news or social media awareness. It appears that no specific efforts were made to publicize these photos when they were posted, and therefore even a month after posting, not a single reference to them could be found through Google or social media. Approximately 6 weeks after the photos were posted, a Reddit user posted the link, which created a small impact with some news and blog articles as well as multiple Reddit reposts. This lack of publicity was likely due to the fact that a more comprehensive PAO campaign would be conducted at a later date. The impact of this future campaign, as previously noted, is yet to be determined.
- The Reddit AMA was a valuable tool for educating the public on the realities and some misconceptions of space suit design; however, a better job could have been done of publicizing the AMA beforehand, and also waiting much longer to answer questions. Doing so would have resulted in more traffic and questions, but also allow sufficient time for the community to “vote” on which questions were the most interesting or insightful to answer.
- A “Frequently Asked Questions” section at the bottom of the voting page, meant to answer basic questions such as “What will this suit be used for?” or “Will this suit go to space?” was valuable, although many people obviously did not read it based on comments made in internet forums or on news articles. In retrospect, it could have been used as an opportunity to address additional broader questions on space suit design in general, and could have been more predominantly displayed on the website.

IV. Conclusion

This public outreach campaign was very new to us for multiple reasons. Overall, it was very successful, having reached millions, perhaps 10+ million people across the world. We will use the experience gained from this effort in future outreach campaigns in the hopes of exciting the public about human spaceflight and educating them on NASA’s overarching goals. Hopefully, this experience will also aid others who engage in public outreach on behalf of the human spaceflight community or inspire them to pursue new methods of engaging the public in today’s modern society.