OpenSpace Annual Progress Report – Year Seven

NASA Science Mission Directorate Science Activation Program
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I. Administrative

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II. Accomplishments

The American Museum of Natural History (AMNH) is pleased to submit this seventh annual report on the accomplishments to date of *OpenSpace: An Engine for Dynamic Visualization of Earth and Space Science for Informal Education and Beyond*, referred to below as the OpenSpace project. The overarching goal of the OpenSpace project is to build and support the use of a pipeline for transmitting visualized science content from across NASA SMD divisions to Informal Science Institutions (ISIs) and the general public. Central to achieving this goal is the development of an open source software, known as OpenSpace, and the promotion of the software's use in informal settings through the establishment of a network of ISI partners.

During the project's seventh year, AMNH made significant progress toward these objectives through ongoing code development, content visualization, and community outreach. Our Year Seven activities are described in greater detail below.

Software Development

The OpenSpace software has continued to progress in Year Seven through cooperative development at AMNH, Linköping University and Norrköping Visualization Center C,[1] New York University Tandon School of Engineering, and the University of Utah Scientific Computing

[1] The activities at Linköping University are not funded by this grant, but are supported by the Knut & Alice Wallenberg Foundation in Sweden, the Swedish e-Science Research Centre, and the Stena Foundation.

and Imaging (SCI) Institute. Faculty, software engineers, and graduate research associates at each of these locations have continued to work collaboratively to enhance the overall software by developing effective code and algorithms to handle data intensive tasks, integrating new data sets from NASA and other sources, and improving the user interface.

During this period, one significant update of OpenSpace software was published; Beta-11 (v0.18.0) was released on May 6, 2022. This update, which improved the software's stability and usability and added new content and features, was informed by feedback from our ISI partners and other OpenSpace users.

Major new features and computational improvements include:

- SkyBrowser: Through collaboration with the American Astronomical Society's (AAS) WorldWide Telescope, a new integration allows users to view high-resolution astronomical images in OpenSpace. The location of a selected image is shown within the Digital Universe. SkyBrowser can be used in combination with mission visualizations, such as the James Webb Space Telescope, Chandra, Hubble, and Spitzer, to display observations targeted by those spacecraft.
- Fly-To: Using Fly-To, users can automatically fly between different objects by clicking an airplane icon in the navigation menu. This simplifies piloting for live presentations.
- Actions: This makes it easier for users to customize and activate complex tasks with the click of a button, supporting more sophisticated presentations.
- Event System: Specific events are automatically triggered depending on the state in OpenSpace, such as automatically fading an object's trail when approaching the object. This enhances the production values of live presentations.

Content Development

The creation of new content continues to be driven by the needs of our users and fueled by collaborations with NASA agencies and infrastructure as well as outside scientists and institutions, as detailed below.

OpenSpace currently has 17 prepackaged profiles.[2] Ongoing content development included the addition of two new profiles and enhancements to multiple existing profiles.

<u>New Profiles</u>

Bastille Day 2000: This new profile incorporates data from one of the most violent solar storms in recorded history that occurred on July 14-16, 2000. The Bastille Day 2000 profile traces the flight path of the magnetized plasma particles ejected from the Sun and their impact on Earth's magnetic field. The profile was created through a collaboration with NASA Goddard CCMC.

[2] For a list and short description of each of the 17 profiles – previously referred to as "scenes" – developed over the course of the grant's seven years of funding, see *Appendix A*.

Solar Storm 2012: The Solar Storm 2012 profile integrates data from the massive CME that occurred on July 23, 2012. The profile was created through a collaboration with NASA Goddard CCMC.

Enhanced Content for Existing Profiles

New Assets

- Image sequences available from NOAA's Science-on-a-Sphere
- NASA Treks Moon, Mars, and Mercury layers
- Starlink satellites and other active satellites
- Model-based representations of Mars moons Phobos and Deimos
- Notable landmark models for use as scale references

James Webb Space Telescope (JWST)

- Added a new animated model of the telescope
- Updated the timing information to match the actual launch date of December 25, 2021
- Updated the telescope's trail from launch to orbit around Lagrange Point 2
- Added a webpage to control the orientation of JWST[3]

Interface Improvements

- Updated Launcher panels for Simple Graphics Custom Toolkit (SGCT) configurations
- Added Launcher panels for JPL Horizons interface, which simplifies the process of bringing in data from NASA JPL
- Added the ability to enable and disable the Exoplanet and SkyBrowser components for individual profiles
- Included links to tutorial pages in the menu

Additionally, developers created a patch website to routinely share small bug fixes with users.[4]

Stakeholder Meetings

Throughout the seventh year, key meetings were held among OpenSpace stakeholders.

Developer Meetings

Project developers and managers from AMNH, Linköping University, New York University, and University of Utah met virtually on February 14 and 15. The meeting was devoted to reviewing development goals for the latest release and beyond. The agenda for this meeting is included in *VIII. Attached Information.* This group also met virtually on October 11 to prioritize software development objectives that will inform the next OpenSpace software release.

[3] http://ui.openspaceproject.com/jwst_scripts/index.html.
[4] http://hub.openspaceproject.com/patch/.

Informal Science Institution (ISI) Network

Our annual ISI Network meeting was held in person at AMNH on July 14 and 15. Representatives from the six ISI Partner Network institutions along with project evaluators and developers attended the meeting. This was an opportunity to reconnect the Network in person for the first time in three years and learn about each institution's achievements and needs. The meeting allowed the Network to share software use cases (some of which were unexpected and highly creative applications of the software) and share feedback directly with developers. The agenda for this meeting is included in *IX. Appendix C.*

The OpenSpace ISI Network poses outside AMNH's Rose Center for Earth and Space.

OpenSpace Trainings

In Year Seven, we have continued monthly training sessions for our ISI Network Partners led by Software Integration Engineer Micah Acinapura. These "Micah Monthlies" have become a valuable resource to share software updates with users and gather live feedback.

After the release of OpenSpace version 0.18.0, developers hosted four training sessions to share new updates with users. Ten established users attended these virtual sessions.

Additionally, a training webinar was hosted on June 30 in collaboration with the Museum & Informal Education Alliance and Solar System Ambassadors. The webinar introduced over 50 planetarians and informal science educators to case studies of OpenSpace use ranging from dome shows to interactive exhibitions. Those in attendance received a demonstration of recent software updates including the James Webb Space Telescope profile and heliophysics content.

Developers also continued to meet one-on-one and in small groups with new and existing users to address their individual installation and training needs.

Year Seven ISI Partner Network Activities

Activities in Year Six were nearly 100% virtual, but in Year Seven, as the pandemic conditions changed, many institutions slowed their online programming as they prepared to implement on-site programming. Interestingly, though fewer programs were offered this year, there was a greater diversity in OpenSpace uses and program types, and enormous enthusiasm for continuing

to implement OpenSpace in their institutions across our ISI Partner Network. This network includes the ISIs who are funded by the SciAct grant.

Adler Planetarium

After a prolonged closure due to the COVID-19 pandemic, the Adler Planetarium reopened to the public in March 2022. While transitioning back to in-person programs, the Adler continued to share and develop content for digital online outreach. Five online videos featuring OpenSpace have been highlighted on Adler's social media channels and attracted a total of approximately **21,000** views on YouTube.

During the summer, two teen interns worked with OpenSpace as part of the Adler's Teen Programs team. Led by the planetarium's Director of Theaters & Digital Experience, the interns developed visuals with OpenSpace including a short show on the launch of JWST. The internships culminated with an in-person presentation for staff, family, and the public within the Space Visualization Lab.

In Year Seven, a suite of objects including a full-scale model of the Mars Perseverance rover and Ingenuity rotorcraft from NASA JPL, along with the Adler's permanent display of a model of the 2004 Mars Exploration Rovers, engaged visitors about new discoveries on Mars. As part of this display, a new online program was offered on August 24, 2022 for the Adler's "Sky Observers Hangout" sessions. Content for the session was developed in collaboration with NASA JPL, which included OpenSpace visuals developed to illustrate Mars geology.

The Adler Planetarium also hired a new staff position to support visualization for outreach and research applications. This staff position will lead implementation of OpenSpace in the dome theaters and within the Space Visualization Lab in Year Eight.

American Museum of Natural History (AMNH)

In Year Seven, OpenSpace was used in a range of activities to reach over **242,000 people on-site and online**. AMNH transitioned from primarily virtual programming in Year Six to primarily onsite programming in Year Seven.

The Museum celebrated the launch of the James Webb Space Telescope with a virtual program on YouTube reaching 298 live viewers and a total 240,384 people online.[5]

"Astronomy Live" programs returned to the Hayden Planetarium to explore topics related to Earth and space science in OpenSpace software. In April, "Astronomy Live: Our Dynamic Universe" was part of the American Astronomical Society's (AAS) 53rd Annual Meeting of the Division on Dynamical Astronomy. The program brought subject matter experts together with

[5] https://www.youtube.com/watch?v=mb4rEUUurT4

the general public to explore star-forming regions, young clusters, and streams of old stars in OpenSpace with Dr. Jackie Faherty. "Astronomy Live: Insights from the James Webb Space Telescope" shared recent images from JWST using the new SkyBrowser feature. These programs were attended by **757 on-site visitors.**

OpenSpace was also used in two on-site mass meditation programs with The Big Quiet, an organization that brings meditation and breathwork to world renowned venues. OpenSpace was used to provide participants an opportunity to see the earth the way astronauts do from space, an awe-inspiring experience known as the overview effect. The event reached an additional **800 on-site visitors**.

In addition to public programs, OpenSpace was used in internships, pre-service teacher preparation, and other Education programs:

Youth Interns: The Museum continued its relationship with the Bergen Academy for Technology and Computer Science with three high school interns under the direction of co-I Carter Emmart during the academic year. These interns contributed to improving and expanding visualizations in the software by writing and implementing code for six missions: NEAR Shoemaker, Voyager 1 and 2, Galileo, Hayabusa, Cassini, and Parker Solar Probe missions. The interns troubleshot errors, adjusted the orientation of objects and images, and confirmed the positioning of images when mapped on 3D objects like the moon. Co-I Emmart also worked with two high school interns in the Museum's Lang program.[6]

Education Programming: OpenSpace was also used in two one-week sessions of the Museum's Digital Universe Flight School where 35 rising 9th and 10th graders learned to pilot the software and presented live to friends and family in the Cullman Hall of the Universe. Over 150 elementary school students were also engaged in two dome presentations where OpenSpace was used to investigate the terrains of different planetary bodies. Educators also used OpenSpace for a presentation in the Museum's Big Bang Theater for 25 students (the first time OpenSpace was projected in this unique spherical venue).

Pre-service teacher preparation: OpenSpace continues to be used in the Museum's Masters of Arts in Teaching Earth Science Residency (MAT-ESRP) program for its cohort of 15 pre-service teachers working in high-needs schools in the New York City area as a tool for learning and teaching about space science concepts in 7^{th}-12^{th} grade classrooms. OpenSpace was both used by professors during instruction and by pre-service teachers as part of their science practicum research project contextualizing analysis of NASA TESS data.

[6] For more information on intern activities, see the evaluation report included in the *Appendix B*.

Outreach: Finally, project staff and the growing group of OpenSpace pilots at AMNH organized 14 training sessions, demonstrations, and conference presentations, which are further detailed below.

California Academy of Sciences (Cal Academy)

In Year Seven, California Academy of Sciences further developed on-site programs using OpenSpace.

The Morrison Planetarium continued its daily "Tour of the Universe," a live program flown entirely in OpenSpace. The "Tour of the Universe" was also incorporated into Cal Academy's weekly NightLife program, which invites adults over 21 to the museum to explore after hours. With 348 shows, these programs reached **47,094 visitors on-site**.

Cal Academy also utilized OpenSpace in other spaces onsite. In November 2021, a live flight of OpenSpace was added to the planetarium's main feature, "Living Worlds." In all, the 965 show reached **145,747 visitors on-site**. OpenSpace was also used throughout the Benjamin Dean lecture series where top researchers present their science for the public. These lectures reached an additional **520 visitors on-site**.

For its virtual programming, Cal Academy continued the weekly simulcast of its in-person planetarium program streamed on YouTube and Facebook. The "Tour of the Universe" simulcast resulted in 42 virtual programs and reached an additional **1,108 live viewers**. In total, Cal Academy reached **64,316 people online** and **193,761** people on-site in Year Seven.

Finally in Year Seven, Cal Academy's Hohfeld Hall premiered "Landscapes of the Solar System," a new 15-minute program flown in OpenSpace. Hosted by planetarium staff, the show highlights landscapes on Earth, such as the Himalayas and the Grand Canyon, then compares terrains to other planets. We look forward to sharing more about this new OpenSpace program during Year Eight.

Denver Museum of Nature & Science (DMNS)

In Year Seven, Denver Museum of Nature & Science began the slow transition from all virtual programming in Year Six to more in-person learning in the physical museum. Still, in spring 2021, DMNS' Virtual Programs division, educators, and scientists introduced the *Digital Earth Academy* targeting elementary and middle school students. This program was based on DMNS' successful "Scientists In Action" model, which consists of free, live virtual broadcasts hosted by scientists who interact with students globally on a broad range of scientific topics and disciplines during an hourlong program. These live broadcasts utilized OpenSpace to fly over topic specific terrain, interspersed with polls, science activities that can be done at home or in the classroom (e.g., experiments showing the effects of different acids in the "World of Extremes" program),

and short video vignettes highlighting science ideas related to the theme of the program (e.g., showing what hydrochloric acid can do to teeth in "World of Extremes"). Themes this past year included titles like "Ice," "Fires," "Weather," "Biodiversity," "From Stonehenge to Skyscrapers" (on human-made structures visible from space), and "Volcanoes." DMNS reached approximately 2,270 people live and recordings of programs have been viewed an additional 420 times. DMNS also offered a virtual *Digital Earth* program ("Changing Colorado: Fire & Water") for adult audiences in November. Through these virtual programs this past year, DMNS reached over **2,838 people online.**

Crew 4 astronauts Watkins and Lindgren onboard the ISS during live Q&A

DMNS participated in a NASA Expedition 67 Downlink with Crew 4 astronauts Kjell Lindgren and Jessica Watkins onboard the International Space Station. Before the live Q&A and freefall demonstrations from orbit, co-I Yu gave a presentation about the ISS utilizing OpenSpace to 1,941 students and teachers online, 100 visitors viewing at DMNS, and 427 additional online views, for a total of **2,468 people**.

On August 18, 2022 and continuing a tradition going back 13 years, DMNS' Gates Planetarium hosted its first on-site *Digital Earth* program since the start of the pandemic. The presentation was co-developed and presented by a DMNS archaeologist, and used suborbital flights with OpenSpace over the regions around the Nile River to show the landscape and geophysical context of ancient Egyptian civilizations, while dozens of 360° panoramic imagery of archaeological sites immersed audiences in what it's like to be on the ground exploring these locations.


Digital Earth program on Egyptian civilizations presented at DMNS' Gates Planetarium

DMNS also started a collaboration with the National Park Service to develop a Digital Earth Caves program. DMNS worked with an external contractor to obtain photogrammetric surveys of locations within Carlsbad Caverns in New Mexico, which were then converted into photorealistic digital 3D models. The open-source nature of OpenSpace software allows the models to be loaded and interactively explored. The digital assets (including many 360° panoramic images from inside and outside the caverns) are complete and have been tested in OpenSpace, The first live, in-person program is scheduled for early 2023.

Houston Museum of Natural Sciences (HMNS)

In Year Seven, HMNS unveiled its new **OpenSpace Lab** which is outfitted with monitors displaying pre-rendered simulations and live OpenSpace interactive demonstrations. The lab is a multipurpose space that can be both open to public visitors or hosted by interns who take requests from the visiting public ranging from traveling to the edge of the universe, to exploring Mars, to zooming into the visitor's own backyard. The lab, which includes 14 new touchscreen computers, doubles the area of the Frensley Hall of Astronomy and provides additional teaching space for programming and summer Space Camps. The lab features a variety of games and content created with OpenSpace, including a selection of 10 OpenSpace tours and informational videos. Astronomy interns also developed a number of interactive games such as "Sonification," "Show What You Know," and "Tic Tac Toe," which integrate OpenSpace visualizations with informational questions and simple game mechanics. Simple interfaces ensure that visitors immediately know how to engage with the software and play the game. Questions are related to Mars, the Moon, eclipses, and Earth's geography. More interactive software is in development. The OpenSpace Lab has reached approximately **23,000 visitors on-site**.

In Year Seven, HMNS hosted 21 high school summer astronomy interns. These interns worked in the OpenSpace Lab to complete a variety of projects. Eight interns created scenes in OpenSpace for the "Totality Over Texas" planetarium program, which will open in March 2023. Intern segments composed approximately 30% of the show. Additionally, interns created an evening planetarium rock show using visualizations in OpenSpace.[7]

North Carolina Museum of Natural Science (NCMNS)

In Year Seven, NCMNS utilized OpenSpace visualizations for public programs, multiple conference and school presentations, and exhibition content. In all, NCMNS reached over **183,217 people on-site** and **1,093 online.**

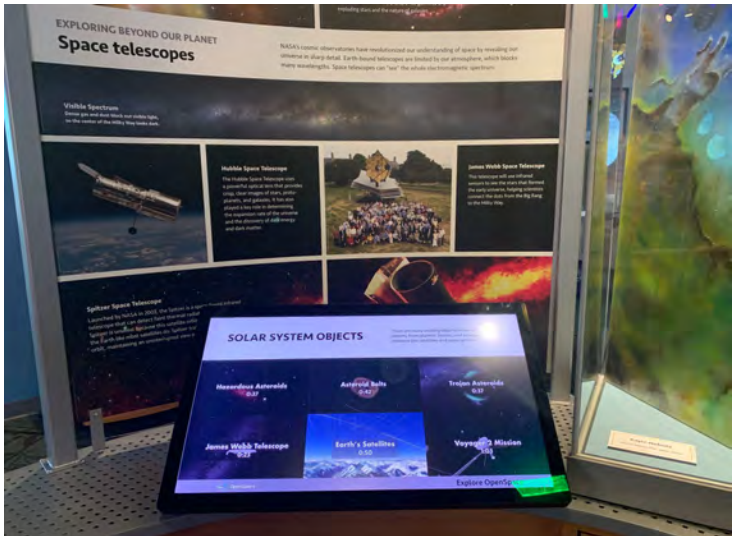
The museum's annual Astronomy Days was again held virtually this year. The weekend of programming included two OpenSpace presentations: "Plants in the Habitable Zone: A Journey to the Past, Present, and Future of Life in Space" presented by Co-I Dr. Rachel Smith and "NASA's James Webb Space Telescope: How, What and Why" presented by AMNH Co-I Emmart. Co-I Smith also presented "Exploring Carbon Chemistry Around Massive Stars" for the Astronomy Club of Asheville. Throughout Year Seven, NCMNS' virtual programs reached over 250 live viewers.

Co-I Dr. Rachel Smith presented numerous in-person programs utilizing OpenSpace throughout Year Seven. Several programs targeted adults such as those presented at Astronomy on Tap in Durham, NC and Bayport Sunday Speaker Series, a condo community in Longboat Key, Florida.

[7] More information on HMNS intern activities are included in the evaluation report included in the *Appendix*.

Additional presentations included “The Search for Life Beyond Earth” for the Tarheel Gem and Mineral Club of Raleigh and “Exploring Mysteries of Planet Formation” for the North Carolina SciTech Expo. These programs reached over 320 people.

Exhibits: In December 2021, four touch-screen kiosks featuring six curated videos were installed at NCMNS’ meteorite and astronomy-themed exhibits. The thematic, user-driven video kiosks exhibit a selection of on-demand OpenSpace videos that highlight various planetary, solar system, galactic and extragalactic themes. Visitors can select any video that appeals to them, and each is shown for approximately 30-40 seconds.



Touch-screen kiosk with OpenSpace video renderings at NCMNS


Four young visitors explore OpenSpace in an interactive at NCMNS

Astronomy & Astrophysics Research Lab: Adjacent to the above exhibits is a public-facing Astronomy & Astrophysics Research Lab. In Year Seven, the lab received a makeover complete with new high-resolution displays.[8] Large-screen tiles on the lab’s walls take visitors on a journey from Earth to the edge of the known universe, making various stops to investigate planetary surfaces and celestial bodies, all using OpenSpace. The lab is used by undergraduate interns to create visualizations in OpenSpace. Co-I Dr. Rachel Smith also welcomed visiting Cary Academy high school students to explore the lab.

Dr. Smith is a strong promoter of OpenSpace, and has supported its adoption at multiple institutions. Additional uses of OpenSpace in conference presentations and by partner institutions, the Museum of Life and Science and A Time for Science, are described in the section below.

[8] Full lab updates are available in the NCMNS press release: https://naturalsciences.org/calendar/news/new-look-the-astronomy-and-astrophysics-research-lab/.

Additional Year Seven Community, Academic, and ISI Activities

We've been in touch with 80 additional OpenSpace users (outside the funded partnership) with diverse purposes for their interest in the software (please see the OpenSpace Network Survey Report). Below we describe a diverse set of these additional uses. New users are denoted with an asterisk.

A Time for Science: A Time for Science, a partner institution with NCMNS, continued to operate its arcade style interactive OpenSpace exhibit in Year Seven. The museum also used OpenSpace for its daily planetarium shows during its "Space is the Place" summer camp in June and July for children grades Kindergarten–5th. Students were given a tour of the universe and learned more about the constellations.

Appalachian State University (Boone, NC): NCMNS Co-I Smith has continued to use OpenSpace in her Appalachian State University coursework, integrating it into undergraduate courses "Astrobiology: Exploring Life in the Universe" and upper level astrophysics course "Star Formation." Fellow App State professor and director of the Dark Sky Observatory Dr. Dan Caton also used OpenSpace in his fall introductory astronomy course and for in-person and virtual observing nights. Undergraduate students act as the OpenSpace pilots for these programs. In all, OpenSpace was experienced by over 160 people online at App State.

*Ars Electronica Center (Linz, Austria): New user Ars Electronica is a science and technology center focused on demonstrating and developing new technologies to show how digitization impacts society. In Year Seven, Ars Electronica installed OpenSpace in its Deep Space 8K Theater, a fully immersive visualization experience using state of the art laser projectors. Visitors to the Deep Space 8K program can explore some of the largest crater landscapes and highest mountains in the solar system, from the Grand Canyon to Olympus Mons and beyond.

Visitors experience OpenSpace in the Ars Electronica Deep Space 8K Theatre Credit: Ars Electronica/ Robert Bauernhansl.

B612 Foundation (Mill Valley, CA): Building upon its interest in OpenSpace from Year Six, the B612 Foundation and its core program, the Asteroid Institute, began using OpenSpace in Year Seven to visualize the trajectories of asteroids over time. By continuously adding new observed measurements to the open-source software, the B612 Foundation is able to contextualize asteroid trajectories and data to better assess threats to Earth. A video rendered in OpenSpace showing the first 104 main-belt asteroids discovered by the Asteroid Discovery, Analysis, and Mapping (ADAM) platform was viewed over 11,400 times online.

City College of New York Planetarium (New York, NY): CCNY Planetarium Director James Hedberg has continued to be a "superuser" of and contributor to OpenSpace. In Year Seven, Dr. Hedberg continued to make short educational videos to share on Instagram and other social media channels using OpenSpace to illustrate concepts. Views, comments, and likes on these videos continued to skyrocket this year, with one video featuring a year on Earth in 30 seconds to the tune of "Don't Stop Me Now" by Queen being viewed over 15.5 million times and received 829,000 likes to date. In total, these videos had a reach of over 38.2 million to date. The CCNY Planetarium also hosted several in-person programs on Jupiter's moons. These programs were written and narrated by an undergraduate Science Learning and Public Engagement student Tiana Lewis. Dr. Hedberg also utilizes OpenSpace frequently in his undergraduate physics classes.

Fernbank Science Center (Atlanta, GA): In Year Seven, the Fernbank Science Center continued its weekly virtual planetarium program, "FSC At Home Planetarium" hosted by planetary geologist R. Scott Harris. The 21 videos featuring OpenSpace were viewed over 3,400 times online.

*Jewish Museum Milwaukee (Milwaukee, WI): As part of the newly opened "Jews in Space" exhibition, The Elumenati collaborated with OpenSpace developers to create custom content in a GeoDome Portal environment. Using a touch-screen kiosk, visitors can maneuver around planetary bodies and the International Space Station, which appear on the dome, while videos of Jewish astronauts describe their experiences. This unique use of OpenSpace was developed collaboratively in under two months.

Michigan Science Center (Detroit, MI): The Michigan Science Center continued its use of OpenSpace in its virtual and in person public programs. In Year Seven, the Michigan Science Center premiered a new daily planetarium show "Other Worlds: There's No Place Like Earth," which reached 8,277 in-person. Additionally, online content was viewed 182 times to date.

*Midland University Lueninghoener Planetarium (Fremont, NE): "Superuser" Dr. Ken Murphy of Southwest Minnesota State University helped introduce OpenSpace to the Midland University Lueninghoener Planetarium this year. In July, Dr. Murphy led a program on the

newly released images from JWST where he piloted OpenSpace. The in-person program was attended by 100 people.

Audience awaits JWST presentation by Dr. Ken Murphy at the Midland University Lueninghoener Planetarium

*Mochileros Astronómicos: Bryant Gonzalez Vasquez founded Mochileros Astronómicos as a way to spread his appreciation for space and science to communities in South America with limited access to informal education resources. Vasquez found OpenSpace online and started using the software for both his virtual and onsite programs in Year Seven. During his program, “Experiencia Planetaria” (“The Planetarium Experience”), Vasquez pilots OpenSpace for “Un Viaje por el Universo (A Trip to the Universe),” where he starts from Earth and flies out beyond the Milky Way and to the edge of the known Universe. This program has been presented over 30 times in multiple cities across Argentina, Bolivia, Uruguay, and Paraguay, reaching over 500 people. The virtual program “Hagamos ZOOM a las Imágenes del JWST” (“Let's ZOOM to the Images of the JWST”), which was streamed on YouTube, reached 597 viewers. Additionally, the Mochileros Astronómicos Instagram page has featured 8 videos rendered with OpenSpace that have been viewed 8,116 times to date.

Museum of Life and Science (Durham, NC): The Museum of Life and Science, a partner institution of NCMNS, has collaborated with Co-I Dr. Rachel Smith to highlight OpenSpace. A pre-rendered video using OpenSpace to investigate lunar surfaces is permanently on display at the Museum. In Year Seven, over 96,600 people were reached.

Norrköping Visualization Center C (Linköping, Sweden): In Year Seven, the Visualization Center C continued its dome show of "Vast 3D: A Cosmic Journey Through Space and Time," which was created using OpenSpace. This movie is part of the WISDOME effort funded by the Knut and Alice Wallenberg foundation that will expand the use of OpenSpace to four additional dome planetariums in Umeå, Stockholm, Gothenburg, and Malmö, Sweden. Additionally, a playful interactive exhibit using OpenSpace allows visitors to board a spaceship and explore. The exhibition is aimed at preschool-younger school aged children, but continues to be popular among guests of all ages.

Spacecraft-style interactive to explore OpenSpace at the Norrköping Visualization Center C

*Phillip and Patricia Frost Museum of Science (Miami, FL): After reconnecting with the OpenSpace team at the Association of Science and Technology Centers (ASTC) Conference in September, Dr. Doug Roberts, vice president for science education and director of the Frost Planetarium began installing OpenSpace in his planetarium. Through collaboration from SSIA Technologies' technicians, the OpenSpace team was able to seamlessly integrate OpenSpace onto the Museum's system. We plan to host training sessions for Frost Planetarium presenters in Year Eight.

*Secret Science Club (Brooklyn, NY): The Secret Science Club is a science lecture, arts, and performance series, based at the Bell House in Brooklyn. The Club hosted Dr. Jackie Faherty

and Co-I Carter Emmart for a program describing the science shown in JWST's first images. The program was attended by over 300 people.

Southwest Minnesota State University (Marshall, MN): Under the direction of Dr. Ken Murphy, the Southwest Minnesota State University (SMSU) Planetarium has been an active user of OpenSpace since February 2019. Prior to using OpenSpace, the SMSU planetarium maintained a license with SCISS for access to Uniview (since 2009). Spring 2019 was used to learn and adapt to OpenSpace. What grabbed the attention of the public and local media to OpenSpace was a highly successful "50th Anniversary Of Apollo 11 in July 2019" series. In Year Seven, SMSU continued to present engaging programs for the public, including a Holiday show series in December 2021 highlighting JWST, as well as a family weekend program and Homecoming "Tour of the Universe." Additionally, SMSU used OpenSpace for programs targeting Kindergarten-12th grade students. In total this year, SMSU reached 3,630 people on-site.

Due to the exceptional adaptation of OpenSpace at SMSU, other planetariums in the region became interested in using OpenSpace and turned to SMSU for additional support. Dr. Murphy presented OpenSpace to donors and the public to fundraise for renovations to the Minnesota North College Planetarium in Hibbing, MN. Murphy also hosted multiple OpenSpace training sessions for staff at the Como Planetarium and Minnesota State University Moorhead Planetarium, and the Penn State Behrend Planetarium in Erie County, PA. Additionally, Dr. Murphy, worked with shared OpenSpace with two planetariums in Nebraska that are detailed below.

*SpaceDome Mobile Planetarium (Zürich, Switzerland): School teacher Erich Strehler started SpaceDome to spread his appreciation for astronomy and cultivate an interest for the night sky with children and young adults. In his mobile planetarium shows, Strehler combines the digital renderings in OpenSpace with live stargazing, taking audiences to the edge of the known universe then back home to Earth for a view of the stars through traditional telescopes and EAA smart telescopes. Strehler found OpenSpace online in Year Seven and has presented over a dozen shows at public schools in the greater Zürich area and one show at a public library near Zürich. In addition to the traveling planetarium show, the SpaceDome Mobile Planetarium is used regularly in the astronomy workshop at the public school where Strehler teaches.

Springfield Science Museum (Springfield, MA): In Year Seven, Springfield Science Museum planetarium manager Kevin Kopchynski began using OpenSpace regularly as part of the monthly virtual program "AstroQuest Online." The three videos featuring OpenSpace have been viewed 75 times online.

*Towson University (Towson, MD): Professor Christian Ready attended the MIE Alliance webinar in June 2022 where he met Co-I Carter Emmart and Software Integration Engineer

Micah Acinapura. Shortly thereafter, Ready installed OpenSpace at the Towson University Planetarium. In just four months, Ready has given 15 presentations using OpenSpace, with varying themes including a tour of the solar system, which is typically aimed at younger audiences, a grand tour of the universe, and the deployment and early science results of the James Webb Space Telescope. Since September, approximately 380 audience members have experienced OpenSpace presentations at the Towson University Planetarium. Professor Ready noted the significance of these attendance figures as the planetarium is commonly used for classes, not open programs. Additionally, a former student of Ready's who is a Computer Science major, will assist in developing a custom user interface for presenters to deliver shows in Year Eight.

*University of Nebraska–Lincoln Ralph Mueller Planetarium (Lincoln, NE): After much interest, OpenSpace was installed in the Ralph Mueller Planetarium this year. Dr. Ken Murphy of Southwest Minnesota State University hosted an OpenSpace training for Earth and space science educators at the Mueller Planetarium. Educators are currently developing a program in OpenSpace with the help of an undergraduate intern and plan to use the software for online astronomy programs.

Versant Power Astronomy Center, University of Maine (Orono, ME): OpenSpace was installed in the Vesant Power Astronomy Center's dome in Year Six. In Year Seven, Versant Power has continued to use OpenSpace for both its in-person and virtual programs. In July 2022, Versant Power Astronomy Center used OpenSpace for a presentation during its JWST Pre-Launch event. OpenSpace is also used during monthly Science Lecture Series presentations.

The following users either continued with the same activities as in previous years or are just getting started with using OpenSpace:

- Fiske Planetarium, University of Colorado Boulder (Boulder, CO)
- Lower Eastside Girls Club (New York, NY)
- *National Museum of Science and Technology (Stockholm, Sweden)
- *Naturhistorisches Museum Wien (Vienna, Austria)
- New York University (New York, NY)
- *Umevatoriet (Umeå, Sweden)
- *Universeum (Gothenburg, Sweden)
- University of Utah (Salt Lake City, UT)

The Elumenati's GeoDome Network includes 15 planetariums that utilize OpenSpace for a variety of programs and classes:

- *Como Park Elementary School (Saint Paul, MN)
- *Hampden Sydney College (Hampden Sydney, VA)
- *Herndon High School (Herndon, VA)
- Hubble Planetarium (Brooklyn, NY)

- *Intrepid Sea, Air & Space Museum (New York, NY)
- *Mankato East High School (Mankato, MN)
- *Mayo High School (Rochester, MN)
- Minnesota State University Moorhead Planetarium (Moorhead, MN)
- *Muscle Shoals Middle School (Muscle Shoals, AL)
- *New Brighton Area Schools (New Brighton, PA)
- *Oakton High School (Oakton, VA)
- Paulucci Space Theater (Hibbing, MN)
- *The Journey Museum (Rapid City, SD)
- *Wauwatosa West High School (Wauwatosa, WI)
- *West Springfield High School (West Springfield, VA)

Finally, OpenSpace has received interest or started installation conversations with six institutions in Year Seven, that we will pursue into Year Eight:

- Canberra Deep Space Communication Complex (Paddys River, Australia)
- Henry Ford College Hammond Planetarium (Dearborn, MI)
- Ontario Science Centre (Toronto, Ontario)
- Pottsville Area High School (Pottsville, PA)
- University of Texas Arlington Planetarium (Arlington, TX)
- Williamsville Space Lab Planetarium (Williamsville, NY)

As an open-source software, OpenSpace is freely available to anyone, anywhere. As such, it is likely that OpenSpace is utilized by many more institutions and individuals than we can track. The map on the following page shows the location of startups of OpenSpace software during Year Seven.[9] Most startups occurred in the United States with 53,448 start ups, followed by Sweden with 10,793. Other countries with over one thousand startups were Turkey, Austria, France, Germany, and Switzerland.

[9] An interactive map showing startups since 2020 is available at http://status.openspaceproject.com/usage/.


Greenland
Iceland
North Pacific Ocean
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Mongolia
Algeria
Libya
Egypt
Saudi Arabia
Chad
Nigeria
Colombia
Peru
DRC
Tanzania
Angola
Namibia
Madagascar
South Africa
Papua New Guinea
Year Seven OpenSpace Software Startups

Planetarium vendors
As more institutions consider installing OpenSpace, developing and growing relationships with vendors is an important area of focus for the project team.

The Elumenati has continued to actively install and update OpenSpace software in their GeoDome Network of planetariums, which spans 16 planetariums in eight states. We partnered with The Elumenati to share OpenSpace software on a GeoDome and GeoGlobe at the Association of Science and Technology Conference (ASTC) in September.

Additionally, we have collaborated with **SSIA Technologies** to install OpenSpace on several domes. Our Software Integration Engineer has been working closely with their technicians to update the OpenSpace integration with their installations.

Our Software Integration Engineer has also connected with **Ash Enterprises** and has started the process of installing OpenSpace on their planetariums.

Finally, **SureyyaSoft Planetarium Technologies** integrated OpenSpace and its own Shira Presenter technology into the Shira Dome Console. This integration allows OPenSpace data to be used in planetariums using Shira software, which is based in Turkey.

III. Status/Changes/ Issues

Personnel Changes
Corrie Roe, previously OpenSpace Production Coordinator, left her role at the conclusion of Year Six. Megan Villa has joined the OpenSpace team at AMNH as Project Coordinator.

Project Scope
With funding of our augmentation proposal, the scope of our work has expanded to include a cloud-served version of OpenSpace. *OpenSpace Cloud* will create a real-time communication solution that will enable users to engage with OpenSpace on popular consumer devices such as tablets and low-end laptops, in addition to high-performance machines.This work will take place in Years 8-10.

IV. Dissemination Activities, Collaborators and Cross-Collaboration Agreements Activities

Website (www.openspaceproject.com)
The OpenSpace website remains the entry point for potential new users, offering an overview of the project, introduction to the team, opportunities for participation, and a link to download the

software. From the website, visitors can connect with our community workspaces and social media platforms as well as learn about upcoming events.

Since November 2021, OpenSpaceProject.com has received over 54,000 total visits. Of these visits, United States IP addresses again led in geography, accounting for over 23,000 (43.1%) visitors. This was followed by seven countries with over 1,000 visits: India, Sweden, Germany, United Kingdom, Turkey, Canada, and Brazil. An additional 43 countries had over 100 visitors each. Our geographical spread has continued to grow.

About 44% of visits originate through search engines like Google, Bing, and DuckDuckGo, but almost the same amount (43%) are direct, meaning visitors do not search for or click on a link, but type in the website address.

Support and Community Channels

Wiki (wiki.openspaceproject.com): We have continued to update this public wiki-style website for users, content creators, and developers. This site includes more in-depth documentation on release notes and changes targeted specifically for each audience. New additions this year include instructions on joystick navigation and camera navigation.

GitHub (https://github.com/OpenSpace/): GitHub is the public source code repository for OpenSpace. Users and developers can also report technical problems with the software, offer bug fixes, and make contributions to the code.

Reddit (https://www.reddit.com/r/OpenSpaceProject/): OpenSpace Reddit serves as an additional support channel and place to share uses of the software. We currently have 72 members that largely discuss ways to visualize new content in the software.

Slack (openspacesupport.slack.com; team-openspace.slack.com): In addition to supporting work across the project team, these messaging and file sharing spaces also act as a community-driven forum for collaboration. In Year Seven, we continued to create private channels for institutions to connect directly with software developers, while also encouraging users to participate in public channels. The public OpenSpace Support Slack currently has 712 members, with an average of 34 active members per week.

Newsletter (example: https://mailchi.mp/amnh/thisweekinopenspacefeb16): Our newsletter has had a steady audience of 379 subscribers, including ISI professionals, SMEs, and members of the public. This year, in response to the growth of other effective communication channels, we switched from a weekly to a monthly distribution. The newsletter was opened over 800 times with an average of 5.6% direct engagement.

OpenSpace Social Media Platforms

Instagram (@openspaceproj): The OpenSpace Instagram account continued to grow and expand over the past year. In Year Seven, we again more than tripled our followers to 1,970, received more than 2,600 profile visits, an increase of 78% over Year Six, and reached over 26,000 unique accounts. The 5 content-focused videos we shared have garnered 29,083 views to date.

YouTube (www.youtube.com/c/OpenSpaceSoftware): This year, the OpenSpace YouTube channel saw over 337,477 impressions, 23,302 views, and over 1,400 watch hours. This does not include the AMNH flagship or other partner YouTube channels. Our total subscribers, 3,002, is a 10% increase from our previous total. The top geography of our viewers at 25% had US IP addresses.

Facebook (@OpenSpaceVisualization): Our OpenSpace Facebook followers increased to 942. The account received 276 profile visits.

Twitter (@openspaceproj): Our followers grew to 907, up by 15% from last year. The account also received 12,417 impressions, 14,155 profile visits and 226 mentions.

Press Coverage

OpenSpace visualizations were included in multiple news articles highlighting B612 Foundation's work tracking asteroids, which was covered by the New York Times[10], Discovery[11], Wired[12], GeekWire[13], as well as other international publications. Additionally, a press release on findings by the Brown Dwarfs in New York City Research Group (BDNYC) based at AMNH resulted in an article by SETI Institute, which includes a visualization in OpenSpace.[14]

[10] Kennneth Chang, *Killer Asteroids Are Hiding in Plain Sight. A New Tool Helps Spot Them,* The New York Times (May 31, 2022). *https://www.nytimes.com/2022/05/31/science/asteroids-algorithm-planetary-defense.html?smtyp=cur&smid=tw-nytimes*

[11] *Saving Earth from Killer Asteroids*, Discovery. https://www.discovery.com/science/saving-earth-from-killer-asteroids

[12] Ramin Skibba, *The First Privately Funded Killer Asteroid Spotter Is Here*, (June 3, 2022), https://www.wired.com/story/the-first-privately-funded-killer-asteroid-spotter-is-here/

[13] Alan Boyle, *Astronomers demonstrate how using the cloud can rev up the race to find asteroids,* (May 31, 2022). https://www.geekwire.com/2022/astronomers-demonstrate-how-using-the-cloud-can-rev-up-the-rate-of-discovery-for-asteroids/

[14] Lauren Glattly, *The 14 Herculis System: A Planetary Dynamical Crime Scene*, (January 20, 2022). http://www.bdnyc.org/2022/01/the-14-herculis-system-a-planetary-dynamical-crime-scene/; Beth Johnson, *The 14 Herculis System: Eccentric, Strange, and Violent,* SETI Institute (February 2, 2022). https://www.seti.org/14-herculis-system-eccentric-strange-and-violent

Conferences, Colloquia, and Symposium

With the return of on-site conferences, the project determined that they should maximize conference attendance this past year. Looking ahead, we will alternate our conference participation based on this experience.

Astromaterials Data Management in the era of Sample Return Missions Workshop (November 11-10): Co-I Dr. Rachel Smith showcased OpenSpace to 190 scientists during the hybrid workshop at the University of Arizona. Featured content included the Moon video on exhibit at NCMNS.

American Astronomical Society's 52nd Annual Meeting of the Division for Dynamical Astronomy (AAS DDA 53) (April 25-28): Dr. Jackie Faherty presented a public program for meeting attendees at the American Museum of Natural History's Hayden Planetarium. Approximately 100 scientists attended (along with 306 members of the public).

Seeing the Future: Of the Universe, Data, Learning, & Digital Scholarship conference (May 1-4): Co-Is Carter Emmart and Dr. Alexander Bock participated on the panel "Data Visualization Tools in the Era of Big and Wide Data" with Dr. Jackie Faherty and Dr. Peter Williams. The panel was attended by 86 scientists. Software Integration Engineer Micah Acinapura also presented a flash talk demonstrating OpenSpace.

Astrobiology Science Conference (AbSciCon) (May 15-20): NCMNS Co-I Dr. Rachel Smith demonstrated OpenSpace at the NASA SCoPE exhibit booth for 15 scientists.

Middle Atlantic Planetarium Society conference (May 18-21): Co-I Emmart presented "What is OpenSpace" for OpenSpace for 75 planetarium professionals. Dr. Kathy Mills, research scientist at the Gulf of Maine Research Institute, presented "Sharing Local Climate Impacts in the Dome" which focused on how climate change is affecting the movement of marine life in the Gulf of Maine. The dome presentation used OpenSpace software to share a global view before moving into the localized story.

Astrovisualization — The role of images in Astronomy and Space sciences Symposium (June 2-3): At this event organized by the Royal Swedish Academy of Sciences, Co-I Dr. Alexander Bock presented "An open-source astrovisualization framework to visualize the universe." Dr. Jackie Faherty was an invited guest speaker and shared "Immersive Astrophysical Experiences in Planetariums." California Academy of Sciences Co-I Ryan Wyatt also presented OpenSpace content for attendees.

NASA Community Coordinated Modeling Center (CCMC) 2022 Workshop (June 6-10): OpenSpace Co-I Vivian Trakinski and CCMC Developer Elon Olsson presented the software's educational applications during the "What should CCMC's education focus be?" discussion. Elon was joined by graduate researchers Måns Aronsson and Simon Brefält to present "OpenSpace visualization and topological analysis of the magnetosphere."

American Astronomical Society (AAS) 240th meeting (June 12-16): Co-I Emmart piloted OpenSpace for 30 early-career scientists during the NASA SCoPE splinter session. Co-I Dr. Rachel Smith presented her research using pre-rendered videos of the Maunakea observatories in OpenSpace. There were 25 scientists in attendance.

Live Interactive Planetarium Symposium (August 3-5): DMNS Co-I KaChun Yu led 60 planetarians and ISI professionals through New Mexico's Carlsbad Caverns visualized in OpenSpace software. OpenSpace was also a conference sponsor.

85th Annual Meeting of The Meteoritical Society (August 14-19): NCMNS Co-Is Dr. Rachel Smith, AMNH Co-I Dr. Denton Ebel and AMNH Doctoral candidate Marina Gemma hosted a table demonstrating OpenSpace to attendees. Co-I Smith also presented a science talk using OpenSpace for 50 attendees.

Southeastern Planetarium Association (SEPA) annual conference (August 22-27): The OpenSpace team hosted an exhibition booth at SEPA, engaging 35 planetarians and ISI professionals. Co-I Emmart also presented OpenSpace in the U.S. Space & Rocket Center's INTUITIVE planetarium for 80 attendees.

Association of Science and Technology Centers (ASTC) Annual Conference (September 12-15): OpenSpace collaborated with The Elumenati to host an exhibition booth complete with GeoDome and GeoGlobe. The GeoDome utilized a touch screen kiosk to fly OpenSpace on a curved screen and the GeoGlobe was outfitted to mirror the planetary body shown on the dome on a mounted sphere. The team engaged 200 attendees in the booth. Co-I Emmart also shared five presentations about Mars, the Moon and the James Webb Space Telescope in OpenSpace for 20 ISI professionals. Additionally, Emmart presented a tour of the universe on the NASA Hyperwall, reaching an additional 35 science and museum professionals.

The Right Connection: CENIC 2022 Annual Conference (September 26-28): CAS Co-I Ryan Wyatt collaborated with Co-I Carter Emmart and Brian Day of NASA Ames on the hybrid presentation "Networking Planetariums to Leverage NASA Solar System Data" at CENIC 2022. There were 60 attendees in-person with additional viewers online.

Geological Society of America (GSA) Annual Meeting (October 9-12): AMNH Co-I Dr. Denton Ebel presented "OpenSpace: Visual Learning For Planetary And Solar System Exploration" in an oral session for approximately 30 scientists. Ebel and Dr. Rachel Smith also presented OpenSpace on the NASA Hyperwall in the exhibition space, reaching an additional 200 scientists.

Great Lakes Planetarium Association (GLPA) annual conference (October 18-22): OpenSpace was a sponsor at the GLPA conference in Buffalo, NY where the project team engaged with 100 planetarians.

Academic Publications

D. S. Ebel, M. E. Gemma, C. Emmart, V. Trakinski, R. L. Smith, M. Acinapura, B. Abbott, J. Faherty, M. Villa, and R. Kinzler (2022), *OpenSpace: Interactive Visualization Of Space Science*, 85th Annual Meeting of The Meteoritical Society 2022. Abstract #6160.

D. Ebel, M. E. Gemma, M. Villa, C. Emmart, V. Trakinski, R. Smith, R. Wyatt, M. Acinapura, B. Abbott, and R. Kinzler (2022), *Openspace: Visual Learning For Planetary And Solar System Exploration,* Geological Society of America 2022 Annual Meeting. Abstract #258-6.

Graduate Theses

OpenSpace continues to be a focus of master student work at Linköping University; NASA Community Coordinated Modeling Center, Goddard Space Flight Center; New York University and University of Utah. The following theses were submitted in Year Seven:

- Aronsson, M. and Brefält, S. *Advanced Fieldline Rendering for Space Weather Visualization* (Master's Thesis, NASA Community Coordinated Modeling Center). 2022.
- Bergman, N. and Björknert, H. T. *Designing a Streaming Pipeline for the Public Dissemination of Astronomy Data* (Master's Thesis, Linköping University, Linköping, Sweden). 2022.
- Paulusson, C. *Real-time Fieldline Rendering for Temporal and Heliophysical Data* (Master's Thesis, NASA Community Coordinated Modeling Center). 2022.
- Segolsson, E. and Storesund, L. *A Cosmic View of Life on Earth* (Master's Thesis, American Museum of Natural History). 2022.

SMD Collaborators, Cross-CAN Awardee, and NASA Infrastructure Collaboration Activities

We have had ongoing conversations, development activities, and public programming in collaboration with NASA Subject Matter Experts and other awardees.

<u>Cross-Collaboration with Science Activation Awards</u>

Cosmic Storytelling with NASA Data: This year, we built upon previous collaborations with the CosmicDS team to continue to develop the code needed to bring data from Glue and AAS WorldWide Telescope into OpenSpace. We plan to continue this ongoing collaboration in Year Eight.

Gulf of Maine Research Institute (GMRI): The OpenSpace team shared their expertise in immersive storytelling with the GMRI project team to collaboratively create a dome presentation for the Middle Atlantic Planetarium (MAPS) conference. The OpenSpace team worked with GMRI Research Scientist Dr. Kathy Mills to depict the climate story of species range and expansion in the Gulf of Maine. The successful collaboration shared the local climate change story with 75 planetarium professionals. We hope to build upon

this collaboration to create a framework for local and regional climate change stories in planetariums using OpenSpace.

Smoky Mountains STEM Collaborative: The OpenSpace team provided support to SMSC staff who developed programming using the software, including a live OpenSpace demonstration at the Highlands Biological Station in North Carolina.

**STEM Enhancement in Earth Science (SEES):* The OpenSpace team planned to provide a demonstration to SEES students during the high school internship program, however this effort was postponed to Year Eight.

Cross-Collaboration with NASA Infrastructure Projects

Museum & Informal Education Alliance: The OpenSpace team organized one webinar for the MIE Alliance's audience. The webinar featured examples of OpenSpace in informal science institutions and an in-depth demonstration of the new features of version 0.18.0 such as the James Webb Space Telescope profile.

NASA's Eyes: We continued to collaborate with Eyes personnel to exchange data, resources, and strategies for covering upcoming mission milestones.

NASA Solar System Treks: This year, our software engineers incorporated approximately 1,000 map layers from NASA Treks into OpenSpace.

Solar System Ambassadors: SSA worked with MIE Alliance and OpenSpace to share the previously mentioned OpenSpace training webinar. In future collaborations we hope to utilize the SSA team to provide training created to address specific ambassador needs.

In addition to the above formal cross-collaboration agreements, the OpenSpace project team has participated in efforts led by the Conference and Event Coordination SciAct Infrastructure group, and the Visualization Community of Practice. The following informal collaborations also occurred in Year Seven:

- Lunar and Planetary Institute (LPI): OpenSpace distributed 142 lunar orbiter prints from LPI's Regional Planetary Image Facility at three conference booths. These prints were circulated to ISI professionals, many of whom had plans to display the prints in their museums or planetariums.
- NASA SCoPE: OpenSpace collaborated with the NASA SCoPE team to share the software with SMEs at AAS and AbSciCon. Members of the OpenSpace team also contributed to planning sessions for the hybrid splinter session at AAS.
- NISE Network: The OpenSpace team created a new video describing the adaptability of OpenSpace for ISIs. This video was presented to 50 informal science institution educators and staff during the NISE Net NASA Showcase. Co-I Emmart and Project

Coordinator Megan Villa also participated in the accompanying webinar session to share OpenSpace resources with 25 interested professionals.

NASA-Funded SMEs in Year Seven

In Year Seven, 18 NASA-funded Subject Matter Experts contributed to and/or used OpenSpace, six of whom are new to the project (indicated with an *asterisk). This brings the total number of unique SMEs to 88. We have grouped this year's SMEs based on their relationship to OpenSpace; in some instances, SMEs are counted in more than one use category, so the total will exceed 18.

Used OpenSpace in public programming: 9

- *Dr. Alfonso Davila (Research Scientist, NASA Ames Research Center)
- Dr. Brian Day (Deputy Staff Scientist, NASA Solar System Exploration Research Virtual Institute)
- Dr. Denton Ebel (NASA Emerging Worlds Grant; AMNH)
- Dr. Jackie Faherty (Co-PI, ROSES ADAP)
- Marina Gemma (NASA Emerging Worlds Grant; PhD Candidate, Columbia University)
- Dr. Martha Gilmore (Co-I, VERITAS and DAVINCI+ NASA Missions)
- *Dr. Raffaella Margutti (Northwestern University)
- *Dr. Victoria Meadows (PI, Virtual Planetary Laboratory)
- Dr. Rachel Smith (PI, NASA Emerging Worlds Research Program, Astrobiology)

Used OpenSpace in formal education setting: 3

- Dr. Jackie Faherty (Co-PI, ROSES ADAP)
- *Dr. John Keller (PI, ROSES, University of Colorado Boulder)
- Dr. Rachel Smith (PI, NASA Emerging Worlds Research Program, Astrobiology)

Used OpenSpace in research capacity: 1

- Dr. Jackie Faherty (Co-PI, ROSES ADAP)

Collaborated on new or improved data or functionality: 9

- Dr. Darren De Zeeuw (Research Associate, NASA Goddard Space Flight Center Community Coordinated Modeling Center)
- *Dr. Mostafa El Alaoui (Research Associate, NASA Goddard Space Flight Center Community Coordinated Modeling Center)
- Dr. Alyssa Goodman (PI, Harvard University)
- Dr. John Keller (PI, ROSES, University of Colorado Boulder)
- Dr. Masha M. Kuznetsova (Director, NASA GSFC CCMC)
- Dr. Leila Mays (Deputy Director, NASA GSFC CCMC)
- Jeff Nee (Education Specialist, NASA Jet Propulsion Laboratory)

- Dr. Lutz Rastaetter (Research Assistant, Fields And Particles, NASA GSFC CCMC)
- *Catherine Zucker (NHFP Hubble Fellow, Space Telescope Science Institute)

Other SMEs in Year Seven

An additional (non-NASA) 11 SMEs also used OpenSpace as a tool for exploring and communicating space science data for a broad audience, including six new SMEs (indicated with an *asterisk). This brings the total of unique (non-NASA) SMEs to 38. As above, we have grouped based on their relationship to OpenSpace; in some instances, SMEs are counted in more than one use category, so the total will exceed 11.

Used OpenSpace in public programming: 4

- Dr. Dan Caton (Professor of Physics and Astronomy, Director of Observatories, Appalachian State University)
- Dr. James Hedberg (Director, CCNY Planetarium, City College of New York)
- Dr. Ed Lu (Executive Director, the Asteroid Institute, B612 Foundation)
- Dr. Bob Raynolds (Research Associate, DMNS)

Used OpenSpace in formal education setting: 2

- Dr. Dan Caton (Professor of Physics and Astronomy, Director of Observatories, Appalachian State University)
- Dr. James Hedberg (Director, CCNY Planetarium, City College of New York)

Used OpenSpace in research capacity: 3

- *Dr. Daniella Bardalez Gagliuffi (Assistant Professor of Astronomy, Amherst College)
- *Dr. Johanna Vos (Postdoctoral Fellow in Astrophysics, AMNH)
- *Mark Popinchalk (PhD Candidate, CCNY and AMNH)

Collaborated on new or improved data or functionality: 6

- Dr. James Hedberg (Director, CCNY Planetarium, City College of New York)
- Dr. Ed Lu (Executive Director, the Asteroid Institute, B612 Foundation)
- *Allan Posner (Astrodynamicist, the Asteroid Institute, B612 Foundation)
- *Dr. Alex Ji (Assistant Professor, Astronomy and Astrophysics, University of Chicago)
- *Trent Hare (Cartographer, USGS Astrogeology Science Center)
- Lucian Plesea (Web GIS developer, ESRI)

V. Evaluation

Evaluation by HG&Co

The OpenSpace project's external evaluator is HG&Co (118 Franklin Street, Concord, NH; 301-655-1925; kate@hgandco.com). In Year Seven, HG&Co worked with the AMNH team to conduct five strands of evaluation activity: a survey administered to audience members of OpenSpace programs across the OpenSpace ISI Network; a survey-based evaluation to assess the

health of the funded OpenSpace partnership; a survey to assess software use and needs of known OpenSpace users outside the funded partnership; qualitative interviews with subject matter experts who have engaged with OpenSpace; and qualitative evaluation of OpenSpace internships. The attached Evaluator Report includes a summary of these activities along with full reports .

Top-Level Metric Projections

The top-level metric for OpenSpace in the first phase of funding was the number of interactive "scenes," now "profiles", of NASA data available within the software. In our extension application, we identified a metric to represent the growth of the project in Phase II, the number of OpenSpace users, with the goal to reach 100 users by the end of Year 10. At the end of Year Seven, we have 49 active users of OpenSpace.

SciAct Alignment

The OpenSpace PIs and evaluator worked together to ensure the project is appropriately engaged with the SciAct portfolio-level activities led by PRE, including aligning with mid-level objectives and determining which specific program indicators track back to those objectives.

OpenSpace is currently aligned with SciAct MLOs 1b, 1c, and 3c:

1b) Provide opportunities for participants to engage with the disciplinary content related to NASA science and engineering.
1c) Increase number of and frequency with which NASA SMD assets are used by learners across the US.
3c) Engage participants in learning experiences that promote development of skills for STEM careers.

(1b, 1c) As noted elsewhere in this report, OpenSpace focuses on increasing public engagement in NASA science and engineering via ISI programs for public audiences of all ages. In Year Seven, 203+ programs and 4 exhibits utilized OpenSpace to communicate science and engineering concepts, 127 of those programs were hosted by the OpenSpace ISI Partner Network (the ISIs funded as part of the NASA SciAct grant). Year Seven activity brings the total number of OpenSpace programs to 587. On-site programs and exhibits reached 513,329 people this year, bringing the total on-site reach to 1.6 million.

(1b, 1c) Another method of engagement that we have seen grow this year is online reach, which includes views of online programs, recordings of these programs, and produced videos. In Year Seven, OpenSpace reached approximately 38.5 million people online, increasing online reach to 50.5 million. Additional online reach—through the OpenSpace website and OpenSpace social media platforms—this year totaled over 400,000, bringing the total website and social media reach of OpenSpace content to over 5 million.

(1b, 1c, 3c) The ISI Partner Network hosted 29 interns ranging from high school to undergraduate in a variety of multi-week, semester, and year-long internships and mentored experiences with data visualization and code development. Cumulatively, OpenSpace has been the focus of 219 internships. One of the main ongoing evaluation activities is an in-depth qualitative evaluation of the internship programs with internship journals and post-internship interviews.

Total Activity, Years 1-7

	NASA SMEs	ISIs and other organizations	Programs	On-site reach[3]	Online reach[4]	Other online reach[5]
Y7	18[1]	49[2]	203	513,329	38,548,611	431,546
Y1-7 Total	**88**	**63**	**587**	**1,620,229**	**50,504,011**	**5,475,546**

1 Three of the NASA-affiliated SMEs are new to the project in Year Seven.
2 25 of the public institutions are new to the project in Year Seven.
3 On-site reach includes programs and exhibition experiences on-site at ISIs and other public institutions.
4 Online reach includes views of online programs, recordings of these programs, and produced videos.
5 Other online reach includes visits to the OpenSpace website, the reach of OpenSpace social media, and views of OpenSpace content.

VI. Known Future plans

In Year Eight, we will continue to build our community of users by identifying and addressing points of friction that slow down or prevent adoption of the software by a broad range of users as well as adding new data sets for expanded programming.

Software and Content Development Goals
Software and content development activities planned for Year Eight include:

- New features, including:
    - Star rendering overhaul
    - Video playback on globes
- New content to be explored for potential development include:
    - Upcoming missions, including Artemis
- Ancillary materials
    - Documentation
    - Program guides
    - Training videos
- Begin development of *OpenSpace Cloud*

ISI Partner Network Goals

ISI Partner Network programs planned for Year Eight include:

- *Frontiers Lecture with Dr. Martha Gilmore* (November 2022, AMNH)
- *Astronomy Live: Updates from the James Webb Space Telescope* (December 2022, AMNH)
- *Astronomy Days* (January 2023, NCMNS)
- *Frontiers Lecture with Dr. Harold Connolly* (January 2022, AMNH)

Additional goals for the ISI Partner Network include:

- Consulting accessibility and Universal Design for Learning (UDL) experts to improve public programs
- Engage in discussions on telling stories of climate change

Dissemination and Adoption Goals

To support existing users and encourage further adoption of the software, we are planning the following dissemination activities for Year Eight:

- Develop and distribute additional online resources for users, developers, and scientists, including tutorial videos, program guides, and training materials
- Hold training webinar(s) for MIE Alliance and Solar System Ambassadors
- Attend and present at AGU (December 2022) in three sessions:
    - "ED12B: Sharing Best Practices for Earth and Space Science Outreach and Engagement"
    - "ED35B: Open Source, Open Access, Open Science: Transforming Earth and Space Science Education Through Decentralized Design"
    - "ED55B: Amazing Technologies and Capabilities That Contribute to STEAM"
- Develop dissemination strategy pertaining to the following conferences:
    - LPSC (March 2023)
    - AAS (June 2023)
    - Regional Planetarium Conference (June 2023)
    - GRC (July 2023)
    - LIPS (August 2023)
    - ASTC (October 2023)
    - GSA (October 2023)
    - AGU (December 2023)

VII. Appendix A: OpenSpace Profiles

Apollo: This profile contains models and trajectories for the NASA Apollo 8 mission circling the Moon, including when the iconic "Earthrise" image was photographed. It also contains additional datasets showing the landing sites of Apollo 11 and 17, and photogrammetry of boulders from Apollo 17 station sites.

Asteroids: More than 936,000 asteroids and comets from JPL Horizons Small-Body Database, including: Amor Asteroids, Apollo Asteroids, Aten Asteroids, Atira Asteroids, Centaur Asteroids, Chiron-Type Comets, Encke-Type Comets, Halley-Type Comets, Inner Main Asteroid Belt, Jupiter Family Comets, Jupiter Trojan Asteroids, Main Asteroid Belt, Mars Crossing Asteroids, Outer Main Asteroid Belt, Potentially Hazardous Asteroids, and Trans-Neptunian Asteroids.

Bastille Day 2000: This profile shows the Coronal mass ejection (CME) that occurred on Bastille Day, July 14, 2000. The visualizations to highlight the CME include: a volume rendering of the density of the material ejected from the sun; field lines showing the Sun's magnetic structure; magnetograms which are texture layers on the sun showing variation in strength of the magnetic field; an extreme ultraviolet (EUV) image sequence layer shown on the sun; a light speed indicator to compare the speed of the CME; cut plane sequences showing the flux values of the CME, one equatorial cut plane and one meridional. Also there are flux nodes that show flux values, which are accompanied by a legend describing the color scheme.

Dawn: This profile contains a 3D model and trajectory of the NASA Dawn spacecraft, and bodies and trajectories for Ceres and Vesta.

Default and Default Full: This profile is enabled on default and provides the ability to look at detailed terrain models of the Earth, Moon, Mars, other planets, and the Digital Universe extrasolar catalog. Default Full has more optional content, including Earth satellites and more moons in our solar system.

Gaia: This profile contains a new rendering method to show the dataset from ESA Gaia's Data Release 2 (DR2). By default, it loads 7.224 million stars of the Gaia DR2 that contain radial velocities.

Juno: This profile shows a model and approach of the NASA Juno space probe to the Jupiter system and its initial orbits around the gas planet in July 2016. Future work will include visualization of the Juno cam imaging.

James Webb Space Telescope: This profile visualizes the NASA-ESA-CAN James Webb Space Telescope, which launched on December 25, 2021. The profile includes two visualizations of the Webb trail: One plotted with respect to the Earth-Sun L2, where it will be stationed; and another with respect to the Sun, as we plot the orbits of the planets. The profile includes a

dynamic model of Webb and a time lapse of its deployment and unfolding. The profile includes the capability to point the telescope with an associated view frustum to any celestial coordinates. The orientation can be controlled by entering Right Ascension (R.A.) and Declination (Dec.) on an external webpage.

Mars: This profile adds visualizations for the NASA Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission, including a trajectory towards Mars, model of lander, entry into the Martian atmosphere, and subsequent descent and landing on November 26, 2018; and NASA's Mars 2020 mission, including a trajectory and model of Perseverance rover on the surface.

Messenger: This profile contains a model and trajectory of the NASA MESSENGER spacecraft with craft pointing data from March to June 2011. In addition, a rendering of Mercury's magnetosphere based on data recorded by MESSENGER can be enabled and viewed around the planet. Along with the mission data, additional maps were added to Mercury showing element abundances on the surface and a multi-color mosaic from the Mercury Dual Imaging System (MDIS) instrument.

New Horizons: This profile shows the acquisition of NASA New Horizons' images of the Plutonian system in July 2015. The profile starts at around 10:00 GMT on July 14, about 10 minutes before a new image campaign starts. By selecting Pluto as the Focus and moving time faster, you can see the imprint of the instrument's field-of-view on the planetary surface and see the images being projected. A timer on the top left of the screen shows when the next image is being taken.

OSIRIS-REx: This profile demonstrates the entire lifetime of the NASA OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer) spacecraft on its way to the 101955 Bennu asteroid and its subsequent journey back to Earth. The profile starts at Earth before the spacecraft's launch and has information throughout the entire mission until the sample's 2023 landing back in Utah. Models of OSIRIS-REx and Bennu are available, as well as a preliminary instrument timing and some of the imaging campaign, which uses the same projection technique as employed in the New Horizons and Rosetta profiles.

Rosetta: This profile shows the entire mission of the ESA Rosetta spacecraft around comet 67P, also known as Churyumov-Gerasimenko. The spacecraft's images are projected onto the comet and the separation of the Philae lander is visible as well.

Solar Storm 2012: This profile, created in collaboration with NASA GSFC's Community Coordinated Modeling Center (CCMC), shows several coronal mass ejections (CMEs) during July 2012.The interaction of the flow of the solar wind and Earth's magnetosphere is simulated by CCMC's Bats-R-US code, and the ENLIL real-time solar wind application is

used as a volumetric dynamic simulation visualization. There is also a one time step of the PFSS model showing the Sun's local magnetic structure.

Touch: This profile provides five demonstration experiences for a Windows touch table: Explore the galaxies, explore the solar system, explore Jupiter and its moons, explore weather events on Earth, and explore interesting sites on Mars. These experiences were created by students as examples. OpenSpace users can create their own experiences with the content they would like to show.

Voyager: This profile contains the NASA Voyager 1 and Voyager 2 missions as they were launched from Earth in the 1970s and observed the gas giants in the solar system. The spacecraft models are included and are pointed accurately throughout the mission. Position and orientation information are available until the second half of the 21st century.

VIII. Appendix B: Evaluation Reports

- OpenSpace Year Seven Summary Evaluation Report
- OpenSpace Year Seven: Public Programs Report
- OpenSpace Year Seven: Network Survey Report
- OpenSpace Year Seven: Subject Matter Expert (SME) Evaluation Report
- OpenSpace Year Seven: Collaboration Memo

SciAct 2.0, 2022:
OpenSpace Evaluation Report

This brief report covers the highlights of evaluation findings for the OpenSpace project for Year 7 as of October 2022.

OpenSpace Informal Science Institutions (ISIs) created opportunities to reach new audiences through virtual, hybrid, and in-person programs on a diversity of topics, during this third year of the COVID pandemic. Multiple attendees requested that the virtual programs continue even though many COVID restrictions are lifted, as they would not be able to attend in-person programming as frequently or at all. Year 7 programs reached more than 197,000 in-person individuals and over 3,000 viewers online, totaling more than double the number compared to this time in Year 6 (86,500). (Recordings of online programs have received an additional 336,000 views to date.)

Internships also continued successfully with 27 participants, who reported increased knowledge and enthusiasm about space and space-related careers. Working behind the scenes, the ISI network reports healthy connections and communication, ensuring the continuation of successful outreach for the coming years.

The OpenSpace Project has multiple core audience constituencies:

- **Informal science institution audiences** including families, adults, and school groups;
- **Students and youth** including middle school, high school, undergraduate, and graduate level students; and
- **Informal science institution professionals** and their informal social and education networks.

Programs included hybrid events like *Insights from the James Webb Space Telescope* at AMNH; lectures like *The Search for Living Worlds Beyond the Solar System* at Cal Academy; livestreams like *From Stonehenge to Skyscrapers* in Denver; and in-person talks like *The Search for Life Beyond Earth* at a Gem & Mineral Club via NCMNS.

To assess the impact of OpenSpace during Year 7, we used different methods to reach these core audiences. For the educational programs at the various partner ISIs, we conducted online surveys of core audiences (Public Programs Evaluation). As response rates for online surveys of public programs can be quite low, we mailed NASA decals to individuals as a thank-you for filling out the survey. To gain a detailed understanding of potential outcomes from use of OpenSpace, we conducted telephone interviews of high school, university, and graduate students who were interns at the ISIs (Internships Evaluation). This year, we added a survey of the larger set of OpenSpace users to understand how these individuals and organizations made use

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of OpenSpace, and how the OpenSpace team can support them further (Network Formative Evaluation). To complement this survey, we conducted case study interviews of Subject Matter Experts (SMEs) to understand the use cases of OpenSpace for Scientists and other experts (SME Formative Evaluation). Finally, in order to examine the health of our collaborative effort with the ISI partners, we again conducted an internal survey of collaboration indicators (Team Collaboration Evaluation).

Public Programs Evaluation

OpenSpace Presentations Had Strong Positive Impact on the Public

The American Museum of Natural History (AMNH) and their informal science institution (ISI) partners have continued to improve upon OpenSpace public program ratings, already remarkably high, as pandemic restrictions fluctuated in Year 7. Respondents gave higher ratings to the public programs' "great images," "awe-inspiring qualities," as well as "surprising" and "exciting" qualities. In qualitative prompts, audiences still love the visuals and had glowing reviews of the presenters. Many want more of the same: continue with in-person programs while still streaming events online for those who are unable to make it to the planetarium. Predictably and excitingly, we saw more social watches than prior years, likely because friends and family are able to be in the same room safely more now than in the last two years.

This year, we transitioned to an updated survey in order to cohesively gather data from each of the ISIs, as some questions were missing or different in previous years. Working with each of the ISIs to agree on a single survey tool that met their needs, we introduced the new "core" survey in April 2022. The data in this report are a blend of previous years' surveys and the 2022 core survey, which will be used alone in upcoming evaluation years. Continuing from prior years, NASA meatball decals were sent by mail to each of the recipients who opted in with their mailing address. This incentive is announced to the audience at the start and end of the public programs, and offered again at the end of the survey itself.

From October 2021 through September of 2022, survey responses from a total of 54 programs were collected across AMNH, California Academy of Sciences (Cal Academy), Denver Museum of Nature & Science (DMNS), and North Carolina Museum of Natural Sciences (NCMNS). From these programs, a total of 210 surveys were collected. During this period, some more OpenSpace public programs took place, but surveys were not collected during all programs.

Table 1: Most Responses from Hybrid AMNH Programs (n= 210)

AMNH (n=162)	Virtual Hybrid	2 programs (n=37) 2 programs (n=125)
Cal Academy (n=15)	Hybrid	39 programs (n=15)
DMNS (n=11)	Virtual	5 programs (n=11)
NCMNS (n=22)	In-person Virtual	3 programs (n=17) 3 programs (n=5)

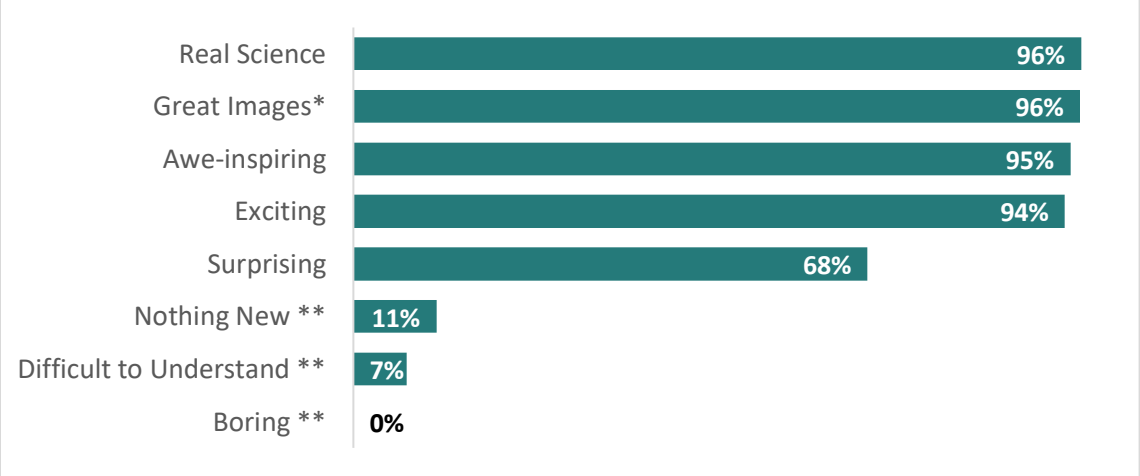
Note that there are no data from either Houston or Adler Planetarium in this report as again this year: Houston used only in-house surveys and Adler's OpenSpace focus is in their youth internships.

OpenSpace Programs Had Very Positive Impacts on Attendees

In line with the previous year's Programmatic Impact Report, participants in this year's OpenSpace programs were highly enthusiastic about the experience.

Out of 210 respondents across ISIs, a strong majority of those who responded said the program was either a 4- or 5-out-of-5 *Awe-inspiring* (95%) and *Exciting* (94%), with great images (96%) created from real science (also 96%). **This year, nobody rated the programs as boring (compared to 23% last year).** Overall, all ratings are up slightly this year compared to last year, except for minor increases in the ratings for *Nothing New* (11% compared to 6% last year), and *Difficult to Understand* (7% compared to last year's 4%).

Figure 1: Public Program Attendees Selected Strong Positive Words about the Programming (n= 210)



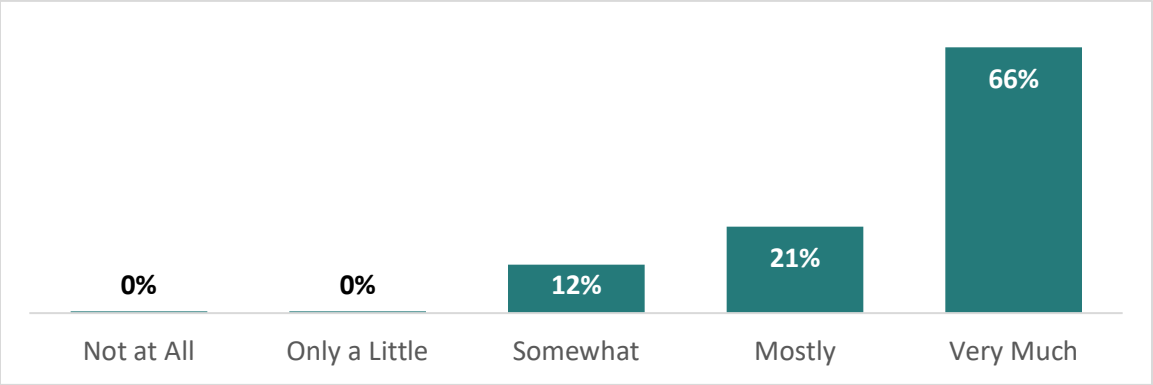
* This question is being phased out, so the sample size is lower at n=67.

**= Reverse-coded: the lower the percentage, the more successful the score.

Attendees Experienced Increased Interest and Understanding

In addition to being exciting, respondents at all sites reported the programs increased their understanding and interest**. Over all the sites, 100% of respondents said the programs helped them understand how scientists gather information about Earth and other objects in space** (with responses of *somewhat*, *mostly*, or *very much*). This is compared to 84% from last year's survey.

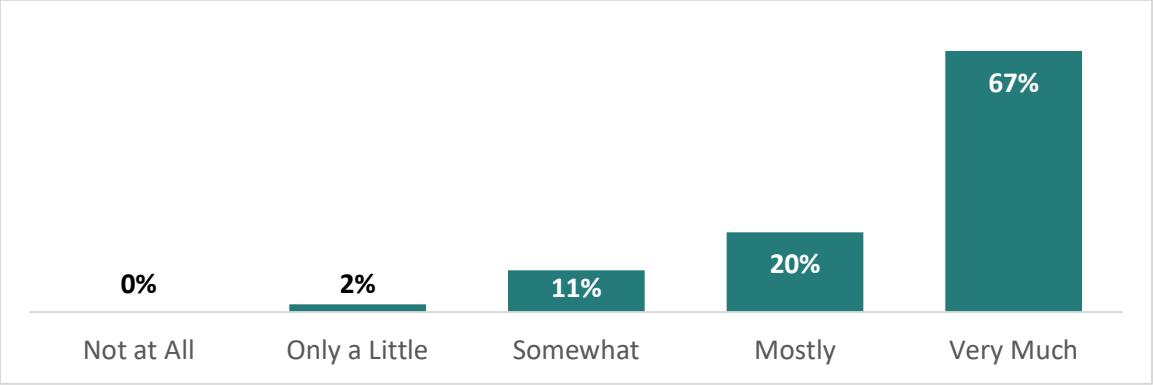
Figure 2: Understanding of How Scientists Gather Earth & Space Info was High (n= 210)



Respondents were clear that OpenSpace uses NASA scientific data to generate the visualizations. **Over all the sites, only 1 respondent (0.5%) believed that the imagery was based on an artist's imagination, while the remaining 99.5% expressed understanding that it was from scientific data.**

Over the past few years, majorities of surveyed program audiences have also said that their interest in learning about NASA's science and mission activities increased since attending the program. The percentage rating their interest as moderate (*somewhat*) or within the upper tier this year was 98%, the same as last year.

Figure 3: Interest in Learning about NASA Increased by Program Attendance (n= 205)



Programs Got Many Things Right

When we asked program attendees which aspects of the events worked well for them, we received several distinct types of responses. The visuals and images were highlighted as they are every year, along with the speakers' styles and abilities. This year, almost half of those who responded spoke about those two aspects as what worked especially well. There were many comments that fell into more than one category as well, praising visuals, speakers, and the efficacy of their work together. *Note that the table below is data from AMNH (n=114) more than DMNS (n=11), NCMNS (n=8), and Cal Academy (n=4) put together.*

Table 2: Audiences Loved Visuals, Speakers, & the Information They Provided (n= 136)

Great visuals	**49%**
Enjoyable speakers	**40%**
Appreciated content	**24%**
Liked the format	**14%**
General compliments	**7%**

Multiple responses allowed.

The visuals, navigation, and side-by-side comparisons were praised. (66 remarks total)

- *360-degree display anchored by the sun make it much easier to understand relative movement and distance.*
- *Imagery of the telescope [JWST] itself and the likeness to flight simming [simulations].*
- *I really loved how you had the JWST pointing to different objects and having on the same screen the zoomed in actual picture from Hubble. Highly effective!*

> *The moderator and speaker were informative and engaging, the visuals were incredible, the excitement and awe in the room were palpable. I can't wait to go back to a similar event.*

Audiences loved watching the speakers & their 'banter' while recognizing their expertise. (54 remarks total)

- *The common language and analogies to describe and help explain complicated aspects were great.*
- *I just thoroughly enjoyed every aspect of the presentation. Seeing Neil deGrasse Tyson in person was an unexpected joy, as was being in the presence of so many astrophysicists. Super cool!*
- *Dr. Faherty is a fabulous presenter - engaging, able to roll with the punches, and really skilled at knowledge translation.*
- *The casual nature of Dr. Faherty's and Dr. deGrasse Tyson's communication styles. Really wonderful job of making the science exciting and accessible!*
- *The presenters' knowledge and grasp of material was incredible. Also, their ability to talk from experiment execution to scientific data was fluid and clear.*

- *Loved Jackie's and Carter's showmanship and enthusiasm. They articulate this material well for a casual audience and more knowledgeable folks alike.*

The content was appreciated for its ease of access as well as specificity. (32 remarks total)

- *The common language and analogies to describe and help explain complicated aspects were great. Also loved the comparison to the Hubb telescope images.*
- *Advanced scientific language and detailed explanations*
- *True scientific data, and being live in person at the planetarium!*
- *Appreciated the diversity of topics covered over a general theme.*
- *The visuals and data shared was very interesting and easy to understand.*

The formats made a positive impact, whether in-person or online. (19 remarks total)

- *It was a joy to be back in the planetarium.*
- *Viewing photos and perspectives on planetarium dome was amazing*
- *YouTube is a great platform. In my opinion, it just works and is easy for end users.*
- *Watching when I have time, my one-person library makes it hard to get all the information the first time so watching again was really helpful.*

Once Again, Few Complaints

We also asked attendees what did NOT work well in the programs that they participated in. **Of the 188 who were asked the question, 65% said that everything worked for them and/or they had no suggestions.** This is about roughly equivalent last year, when 61% said that there was nothing to improve. Some did have specific requests, though, which are organized below. *The table below is data from AMNH (n=69) more than NCMNS (n=8), DMNS (n=4), and Cal Academy (n=3) put together.*

Table 3: Main Complaint Was Physical Discomfort (n=128)

Online or physical access caused challenges	**7.4%**
Uncomfortable in-person environment	**6.4%**
Information was too complex	**4.3%**
Presentation needed more clarity	**3.7%**
Phone use was disturbing	**3.2%**
Information was not complex enough	**2.1%**
Wanted more (context, details, images, length)	**2.1%**
Other	**3.7%**

*Multiple responses allowed.

Audiences wanted easier, reliable, comfortable access. (14 remarks total)

- *The logistics of getting up to the planetarium theater seemed confusing to most attendees - there was a lot of confused wandering on lower floors, and I think it contributed to people showing up late.*
- *The video and audio were going in and out on YouTube.*
- *Technical issues with video and audio freezing both on YouTube and Facebook live stream.*
- *Microphone made it a bit difficult to hear some sentences.*
- *No assigned seating [was offered].*

Participants found aspects of live viewing uncomfortable. (12 remarks total)

- *It's hard to keep one's head tilted up for an hour. It would be easier if the top of the seat was flexible.*
- *The curvature of the dome was a little confusing.*
- *The rapid movements.*
- *Pretty cold in the planetarium.*

I need basic astronomy to know my Milky Ways from my galaxies! For all audiences, a nod needs be given to Astronomy for Dummies.

The content was over the heads of some. (8 remarks total)

- *I would have appreciated more information going into the event; the description was vague. In addition, I would really appreciate is a one-pager or other resources links in the description so that I could learn a bit about the topic before attending. I would be able to engage with the talk with a bit more informed/refreshed perspective.*
- *Must be hard to balance the layman and the astrophysicist. Lots was totally over my head. Appropriately so, given so many smart people there.*

The presentation seemed to need more rehearsing. (7 remarks total)

- *They needed some kind of rehearsal; it seemed disorganized.*
- *Some of the information may have been more clear if it had been scripted.*
- *So much, so fast.*

Planetariums and phones don't mix. (6 comments total)

- *Phones, phones, phones!!! People were constantly taking their phones out to take pictures in a darkened planetarium!! It was awful.*
- *People used flash photography. There should be an announcement for no flash photography by people.*

Content was not complex enough for some. (4 remarks total)

- *This may be just a me problem, but I would have liked to see more obscure images that I hadn't seen before.*
- *I prefer that presenters assume the audience knows more than a sixth grader.*
- *I thought the information assumed a lower level of prior science knowledge than may other science lectures at the AMNH. I thought the speakers could have covered more information if they had assumed a higher level of base knowledge as other lectures at the museum generally do. This was very definitely not geared towards the same crowd as your Frontiers lectures are.*

Some wanted to go deeper with more content, images, and length. (4 remarks total)

- *Not long enough*
- *I wanted to see even more images*
- *I wish it was longer or a series*

Other (7 remarks total)

- *Ideally it would have been better if the event took place later in the day!*
- *Pointers being used on one side and sometimes not on the opposite side image.*
- *A little too much talking to get to the images.*

Final Comments Focused on Wanting More and General Compliments

We asked attendees for suggestions for future programs and received 62 replies (*46 from AMNH, 10 from NCMNS, 6 from Cal Academy, 0 from DMNS).* Some wanted to weigh in on topics, while others interpreted that question as asking what could be improved, similar to the prompt above. The final qualitative question asked "Anything else you'd like to share with the program team?" as a catch-all for any remaining thoughts that weren't covered by the survey. This prompt received comments from 67 respondents (*45 from AMNH, 8 from NCMNS, 7 from Cal Academy, 7 from DMNS).*

Because the similarity of these two questions and responses, we've combined them into one table with its own groupings, representing responses from 116 respondents overall.

Table 4: Respondents Mostly Wanted More of the Same, or Showed Satisfaction (n=116)

Do more of the same	**32%**
General positive	**30%**
Changes to event planning	**14%**
Topic suggestions	**14%**
Enjoyable speakers	**12%**
Was hard to understand	**7%**
Other	**4%**

Multiple responses allowed.

Audiences want more of what they were getting from in-person, (conversely) online, and overall high-quality programming. (37 remarks total)

- *Fabulous. Please keep offering digital earth by Zoom.*
- *I really loved watching on the platform with the live chat. I hope that you have many more!*
- *I really enjoy these on Zoom. I might not come to the planetarium to see them but can easily watch from my own home.*
- *Everything was perfect. I would love to have this kind of events in Italy as well*

- *Thank you for making this free.*
- *This should be available to more people since it was fantastic and very clear.*
- *I appreciate live chat moderators answering questions too; please keep doing it.*
- *Interesting to see the presenter's actual research.*

A lot of general positive feedback was shared. (35 remarks total)

- *I think this is a great resource for teachers!*
- *Absolutely loved this. My grandfather worked on the radar technology of the JWST so I am so excited about it.*
- *Thanks for a wonderful memorable evening.*

Some changes to the program planning are desired. (16 remarks total, some covering multiple points)

- **More time for questions** (5 comments)
  - *More time for audience Q&As or a mini panel between scientists would be a treat! Hearing the questions others ask, especially experts in the fields, adds a level of depth to a presentation.*
- **Prohibit phone use** (4 comments)
  - *Tell people to not use their phones. Especially flashes.*
  - *Advice people who attend the event to keep phones on their pockets.*
  - *Phones. Get rid of them. Ruins the experience completely.*
- **Chat adjustments desired** (3 comments)
  - *Setup as webinar to filter questions vs comments...turn off comments. Comments not easily managed on cell phone and interfere with presentation.*
  - *I do wish there was a way to monitor what was being typed in the chat box for all to see, since many of the comments were not appropriate and were taking my children's attention away from the presentation.*
- **Access/comfort needs** (3 comments)
  - *Stretching breaks and more interactive*
  - *Start on time.*
- **More focused presentations** (2 comments)
  - *Presenters should rehearse the presentation together.*
  - *Program aims and focus need to be razor sharp because so much to cover! That's perhaps why not so many* oohs *and* aahs*. But kudos anyway to presenters for passion for topic and tech dexterity.*

Please have the communications and education depts post this program onto YouTube as you had done during the Pandemic. The students' responses were out of this world and they are

Some topics were suggested (16 remarks total)

- **James Webb Space Telescope** (6 comments)
  - *After the Webb telescope starts getting images and data it'd be fun to have a follow up program*
  - *More JWST! Information on how the JWST users near and mid IR data combined to test hypotheses and gather information.*

- *Would love to have a presentation on what it would take to go to and land a human on Mars.*
- *A virtual stargazing session using OpenSpace (for people unable to see a dark sky) would be super cool! It could inspire people to value the celestial sights around them and get into amateur astronomy to see it for themselves :)*
- *Kid oriented programs.*
- *Maybe more theoretical programs about the what-ifs.*
- *Perhaps delve into the life cycle of stars with Star Forming Nebulae + protostars and the different ending stages stars can have! Incorporating black holes would also allow for showing the recent NASA black hole images from the past 3 years [plus, who doesn't love a good old (understatement of the year) black hole]?*
- *How and astronaut actually commands a space craft (all the parts.) And: DINOSAUR DAYS!!*
- *Comets!!!*
- *A show all about brown dwarves.*
- *Something on the Trappist system.*

Again, the presenters were highly praised. (14 remarks total)

- *Carter Emmart was really good at making it more accessible to lay people and Jackie Faherty had a lot of excitement that drove my excitement about things I did not understand. They were a good team!*
- *The main speaker was excellent. She has a powerful, yet engaging, style.*
- *Speaker was great, would see her talk about anything.*
- *Keep up the cute banter.*
- *Really liked that it was real scientists presenting*

Some found the programs hard to understand. (8 remarks total)

- *I had a great time, although some of the material (ok, most!) was definitely over my head (literally but I mean figuratively too!).*
- *The science is certainly interesting, but I'm not a scientist, but try to keep up.*
- *It would be good to add an introduction about the Webb (5 min explanation) - NASA has one, explaining how it got there, where in the solar system is located in the galaxy (better reference than the one provided), and project the images from the Webb in the whole Dome.*
- *The pictures from the JWST would be even better if there was a scale on them, in light years perhaps?*
- *The JWST has the potential to augment knowledge by a leap. The ways in which it can do that, weren't in my opinion clearly explained. It would help to do so especially with a broader audience that might get fascinated with the potential and more excited about it.*

Self-Identification

Again this year, a majority of respondents see themselves as Science Enthusiasts (52%), though the percentage dropped from last year (67%). There is a slightly higher percentage of Museum Members this year (39% compared to 31%). Perhaps the most notable change is that the percentage of students and teachers watching both went down, from 14 (students) to 7 (teachers) percentage points. Perhaps

this is due to a decrease in online programming during the school day since the initial flush of online classwork earlier in the pandemic.

Table 5: Majority of Individuals Were Science Enthusiasts (n=186)

Science enthusiast	**52%**
Museum member	**39%**
Parent/ Caregiver	**12%**
Student	**6%**
Teacher	**3%**
Other	**12%**

Multiple responses allowed.

The individuals in the *Other* category wrote in the following: Hobby Astronomer and IT Librarian, Librarian, Informal Science Educator, Museum staff, an attendee of the Division on Dynamical Astronomy Meeting, Astro-photographer, club members (of the Tarheel Gem & Mineral Club), volunteers, artists, informal students, and folks who luckily happened upon the program.

Audiences Watched Socially More Often

As we continue living with pandemic-related restrictions, we still are seeing more participants watching alone than with groups. This was also the most common way to watch in Years 5 and 6, but these percentage are dropping, down to 35% this year from 50% the year prior.

Table 6: Viewers Mostly Watched on Their Own (n=188)

Watched on my own	**35%**
Watched with family	**31%**
Watched with significant other	**28%**
Watched with friends	**19%**
Watched with roommates	**1%**
Other	**3%**

This year, 19% of respondents watched with friends, as compared to only 1% in Year 6. These were all from the in-person AMNH event about JWST, with ages ranging from 18 to over 75. Those who selected *Other* wrote in that they watched with astrophysicist colleagues, with their class, and "First date!" OpenSpace programming appeals in many different environments and situations.

Range of Geographic Locations Continues to Decrease

As pandemic restrictions wavered and in-person programs gained in popularity, less geographic range was recorded for programs this past year. **Of 210 respondents, 77% saw the program in person, either at AMNH (97%) or NCMNS (3%).** Still, 48 respondents participated with their program online via NCMNS (n=17), Cal Academy (n=15), DMNS (n=11), or AMNH (n=5). Of these 48, 34 said that they watched from the following states.

Earlier in the pandemic, in Years 5 and 6, program participants identified a wider geographic range than in Year 7. During Year 6, while 80% of viewers were within the United States, other attendees were from Japan, the UK, Malaysia, and Guatemala. Now in Year 7, only one respondent identified as out of the country. This may be due to a widespread desire to participate in more local programming after more strict pandemic restrictions have been lifted.

Introducing gender questions this year, it may be of note to NASA and others focused on gender equity in STEM that a majority of respondents were not cismen. Of the 140 participants who were asked to identify their gender, 52% identified as women, 39% as men, and 3% as gender minorities (either "trans or transgender" or "non-binary or genderfluid"). Five percent opted to not respond to the question.

Year 7's survey also introduced a race/ethnicity question to better understand equity of access to these public programs. As above with gender, 140 respondents were asked this question, as previous surveys did not include it. The categories below represent the conclusion of conversations with all ISIs to most fully represent their current and potential audience identities.

Table 7: Mostly White Respondents, with Some Asian and Some Latinx (n=140)

White or Caucasian	**69%**
Asian, Filipino, or Asian American	**9%**
Hispanic, Latino/a/x/e, Chicano/a/x/e, or Latin American	**9%**
Black, African American, or African	**3%**
American Indian, Native American, or Alaskan Native	**1%**
Native Hawaiian or Pacific Islander	**1%**
A race or ethnicity not listed	**5%**

Age categories, which had been asked in previous years' surveys, remained spread across the range, with lower percentages of young people. This year, 5% of respondents were under 18, compared to 13% last year and 24% the year before. This may be connected to seeing fewer teachers and students as outlined above.

Table 8: Broad Range of Attendee Ages (n=201)

Under 12	**1%**
12-17	**4%**
18-24	**2%**
25-34	**19%**
35-44	**19%**
45-54	**16%**
55-64	**18%**
65 or older	**24%**

Internships Evaluation

Interviews from the 2021 OpenSpace interns demonstrate the value of OpenSpace, and in the OpenSpace software in developing knowledge and understanding of space science. Interns used OpenSpace as a research tool and as a science communication tool. Using OpenSpace in this way increased interns' understanding of the need for visual science communication tools, and the power of those tools in increasing public knowledge about earth and space science.

OpenSpace internship programs are only one portion of the overall OpenSpace, yet they demonstrate **how OpenSpace contributes to the achievement of the SciAct Mid-level objectives**, specifically:

> **1B:** Increase number of and frequency with which NASA SMD assets are used by learners across the US.
> **1C:** Provide opportunities for participants to engage with the disciplinary content related to NASA science and engineering.
> **3C:** Engage participants in learning experiences that promote development of skills for STEM careers.

OpenSpace achieves these goals through a number of distinct efforts, including:

- increasing understanding the of the process of NASA research and Sciences and science outcomes,
- increasing access to and engagement with NASA SMD assets by underserved audiences, and
- promoting student engagement in 21st Century skills via NASA SMD assets.

Fundamentally, through their strong focus on the creation of OpenSpace videos and narrations, interns sparked new interest and gained enthusiasm, in addition to deepening their knowledge of space and space science.

OpenSpace internships also include a strong focus on career skills generally, and STEM careers in particular. Interns learned some new technology-based skills within their programs. Interns gained and deepened problem-solving skills, and technological skills. They also learned how to source, vet, and use resources, the importance of questions, and how to communicate space science concepts and facts. Interns developed a more nuanced view of space science careers and career paths. More significantly, they benefited from engagement with scientists, and the push for deeper thinking and problem-solving skills. Several interviews noted this internship made the contemplation of a career in space science more concrete.

Number of Interns and Evaluation Sample

In Year 7, OpenSpace ISIs hosted 29 interns, two fewer than last year. HG&Co interviewed 22 interns. Their ages ranged from high school- to college-aged, and they worked in a variety of multi-week, summer, or semester-long internships at Adler Planetarium, American Museum of Natural History (AMNH), North Carolina Museum of Natural Science (NCMNS), Houston Museum of Natural Sciences (HMNS). This is the first year that most interns were back on-site since the beginning of the pandemic; only AMNH's interns were remote.

Table 9: Internships & Interview Sample by Site

Adler Planetarium	Adler had 2 on-site, summer interns who were in high school. HG&Co interviewed both interns and the internship manager. Both interns completed the reflection journals.
American Museum of Natural History (AMNH)	AMNH had 5 six-month interns, all of whom were entering college. HG&Co interviewed 3 interns and the internship manager. One intern completed the reflection journal.
Houston Museum of Natural Sciences (HMNS)	HMNS had 21 on-site interns for 2-4 weeks each, all of whom were in high school. HG&Co interviewed 16 interns and the internship manager. Six interns completed reflection journals.
North Carolina Museum of Natural Science (NCMNS)	NCMNS had 1 on-site, summer intern who was in college. HG&Co interviewed this intern, who also completed the reflection journal.

This evaluation, which focuses on internship activity and seeks to highlight findings and opportunities to strengthen the internship program, includes analysis using open-ended, semi-structured interviews with interns and managers collected between June and October 2022. Additionally, this evaluation

incorporates written responses from interns who were asked to reflect on their experiences in an online journal every other week during the course of their internships.

OpenSpace Internships Fostered Multiple Outcomes

Results of the OpenSpace Internship evaluation have been consistent across years. While the type and duration experiences and well as ages of the OpenSpace interns varied, there were common themes in the impact.

Interns Gained New Knowledge about Space and Space Science

Interns broadened their understanding of Space Science. Interns said these internships opened their eyes up to the complexity and depth within astronomy.

> *I know of Cassini and whatnot, but I didn't really know what half of what they looked like. So seeing the models, seeing how detailed and complex they are- like OSIRIS-REx, for example, has a really cool arm that used to grab a sample… There's just so much, and just so much detail that you're able to see with OpenSpace, especially because we had to make all of the models ourselves, or we had to render them. And then just being able to see where they go and the cluster bodies they visit, and they take pictures… and seeing those pictures was also just a really cool experience because it also made it feel even more real.*

> *It definitely had me like looking at things and learning things about these missions I had never known before, which was super interesting and it definitely had me figuring out why certain spacecraft acted the way we did.*

> *One of my biggest gaps in knowledge was more on the galactic level of astronomy. Everyone can talk about the planets and how "Wow, Neptune is blue," or whatever, but just understanding the galactic aspect of astronomy, it's much less talked about in astronomy and being able to go through OpenSpace and seeing quasars and the cosmic microwave background radiation and all these things, that really opened up a lot of opportunities for me to research on my own.*

Interns Saw and Learned How Space Science Is Done

> *I definitely gained a lot of general understanding of our place in the universe and how everything interacts. And it's just eye-opening, all the astronomy things that I learned through just driving OpenSpace around, looking at things, figuring out things, and researching on my own.*

> *Yeah, I knew the basic knowledge, like what are the planets. But what I really liked about OpenSpace was that it also went through the observable universe. Because usually I know as far as to the Milky Way, and that's it. But on this one I was able to see all the other galaxies and what we're able to observe compared to what we can't and what we still have left of the unknown.*

Interns Deepened Their Understanding of Communicating Space Science and What Scientists Do

Through watching planetarium shows, chatting with their mentors, watching videos, and in the course of doing their work, interns said they learned about space. They both learned facts and gained perspective.

> *I think what Dr. Smith does is very cool and I think she was very helpful in helping me learn about all of OpenSpace and how the lab works, as well as working in a museum. She would talk about everything that she does and she'd show me what she does for her research and how to help people when they ask questions.*

> *One way that I understand space science differently is how it can be perceived. I thought space science was at a certain point; there's reason why you need to be extremely educated, extreme well versed in what you're talking about, but that's not always the case. Your average person can know about all these specific phenomenon, specific interactions with different particles and stuff like that. If you're able to break it down into a much simpler matter into a way that is easily accessible, easily digestible and easily shareable really. I think that's one big takeaway I've learned from this that time, is it's not only for people high up. It's for everyone and it's the way you convey it to others that makes it visible.*

> *I think it was just figuring out about communicating science to the public doesn't always have to be a super serious thing. Like really drawing people in to what space is, and what's all out there, without boring them with facts that they might not care about, or they might not initially understand. And kind of getting rid of that jargon, and just letting people enjoy something.*

Internships Sparked New Interests and Skills

Interns said their overall interest in space science increased because of the internships, gaining concrete skills to support future STEM careers.

Independent Problem-Solving

> *Because the hard thing about working with OpenSpace was that you can't really Google anything because it's just so unique… I think my problem-solving skills have definitely been increased through this internship. And just the ability to have a problem and then follow certain steps or process and solve it, and just developing a good fluid process to just be able to fix things… And these errors are unique OpenSpace, but I feel just being comfortable with seeing errors and being able to deal with it.*

> *It's definitely has given me some skills that I would use in the career direction that I planned to go towards, including one big skill that I learned was troubleshooting. Being able to go through the specific process of fact checking and failure, because failure's not a bad thing. Being able to go through failure and learning from your failures and prove yourself over and over again is one big thing that I learned.*

Coding & Computer Science

I think just the working with the data in general and the use of code is going to be pretty valuable just because I'd never really done anything computer science related before, and I think it's a useful skill to have… I think probably the code would be a big part of it because after having done the internship, it's become natural to create the code to mass emissions. We know what all of the different terms and functions do.

Confidence & Patience

I think before I started the internship, I wouldn't say 'under confident,' but I think I was definitely afraid to ask for help because I didn't want to be seen as unintelligent or not independent, I guess, but I think this internship, apart from skills, has taught me that it's okay to ask for help, I guess. It's okay not to know everything because you're going to learn. It's made me a more patient and confident person through failing so many times and then being able to overcome those and get it to work in the end.

Professional Communication

Another thing that I learned during this internship was some professionalism, how to conduct yourself, how to speak well, how to speak right and how to speak to your target audience, how you're supposed to speak target to your target audience.

Equity in Access

For sonification, that project specifically, what I learned throughout the entire thing was just really that this tool can really help people, especially the visually impaired population. I mean, if you really think about it, in the scientific world and with all the research that needs to happen for innovation and discovery, the more heads the better… But basically, this audio is just really worldly. We can actually harness the power and capability of audio, and non-verbal audio, non-speech audio. We can really make the whole world interested in this. And every culture, every region has scientists that can definitely benefit from his audio, can share their data with the rest of the world, can receive data, can test out data from different parts of the world. And that's ultimately our goal. We really want to work on this even past high school. And we plan to really stay together, and really polish this idea, and try to make some good progress with sonification.

OpenSpace Engendered Interest in Pursuing Space Science

The experiences interns had supported an increased interest in pursuing careers in STEM and specifically in space science.

There's something about working with the missions, because you realize the people behind each mission, that's their work, their career. It's a very long and arduous process to create them, and it has made itself a little appealing to me as a person who wasn't really sure exactly what I wanted to go into in college… But definitely as of now I'm going as an aerospace engineer. And I

definitely want to explore more of that option of potentially working with space probes and spacecraft and stuff like that. Work in astronomics, potentially.

I was already considering probably going down the STEM path for a specific career. But this internship strengthened that even more, because I was able to see how the public and normal people could find science fun. Because usually a lot of people think that it's just boring lab reports and research papers. But the museum just allows everyone to be able to experience that part of science.

Network Formative Evaluation

Goals and Sample

The purpose of this digital survey was to explore the interests, feedback, and demographics of known OpenSpace users, outside of funded partnerships. This is the first time that a sample of this community has been surveyed about their uses of OpenSpace.

While the sample is small, the findings in this report serve as an important baseline for the team to strategize growth and outreach to future users, as well as considerations of program augmentation and communication with existing users.

Feedback from these users largely mirrors ongoing feedback from the ISI partners, which attests to the effectiveness of the project design: collaborating with a funded group of ISIs who serve as beta testers for the software and provide ongoing feedback clearly serves the project well. Many of the desired improvements have already been implemented in the current version or are in development.

The sampled population was users who were known to the OpenSpace team, excluding funded partners. This list of 81 contacts, provided by the OpenSpace team, included users who had conversations with core team members or expressed interest at an OpenSpace event. There are likely many more users who are unknown to the team.

Invitations were sent to all 81 contacts, and those contacts were invited to share the survey with their colleagues, which resulted in 4 responses from outside the original list. Respondents were offered a mailed OpenSpace decal as an incentive. A response rate of 32.5% (standard for online surveys) provided us with insight from 26 OpenSpace users throughout July and August of 2022.

Summary of Findings

- 61% of 26 respondents use OpenSpace **at least once a month**.
- Two-thirds of 24 respondents use OpenSpace with **public audiences**, and over half use it with students or professional colleagues. About a third use OpenSpace on an individual basis. Respondents show **moderate levels of familiarity and comfort** with OpenSpace.
- A **lack of resources at their workplace or organization is the main obstacle preventing more frequent use**: not enough staff to run it, not enough time to learn it, or not enough technological capacity.
- 10 out of 24 respondents are using **old versions of the software**. Seven of those 10 are aware that an update is available.
- 70% of respondents were aware of and made use of OpenSpace support.
- To improve OpenSpace, respondents suggested **more intuitive UI, tutorials, and various back-end improvements.** Some of these suggestions had already been implemented, but users of older versions were not necessarily aware of these changes.

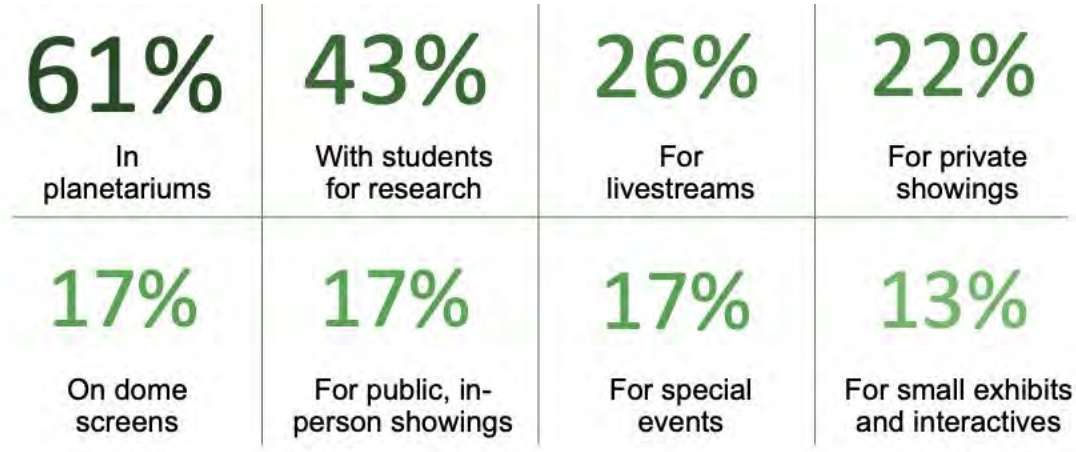
Organizations and roles of the 26 respondents showed a diversity of places OpenSpace is used: Roles at the locations were **mostly directors (11) and educators (9)**, with 4 Managers and 3 Scientists. There was also a technical lead, a volunteer, a dome technician, and an owner of a public planetarium.

Respondents use OpenSpace in the following locations: *

- 15 planetariums
- 9 colleges & universities
- 2 community colleges
- 4 public k-12 schools
- A middle school observatory
- 7 space & science museums
- 5 natural history museums
- A Visualization Center
- NASA Solar System Ambassadors

*Multiple responses allowed.

When asked what contexts they use OpenSpace in, 8 main uses were described by the respondents (n=23). Multiple responses were allowed.



When asked where their institution displays OpenSpace, most said it was in a planetarium dome (n=26).

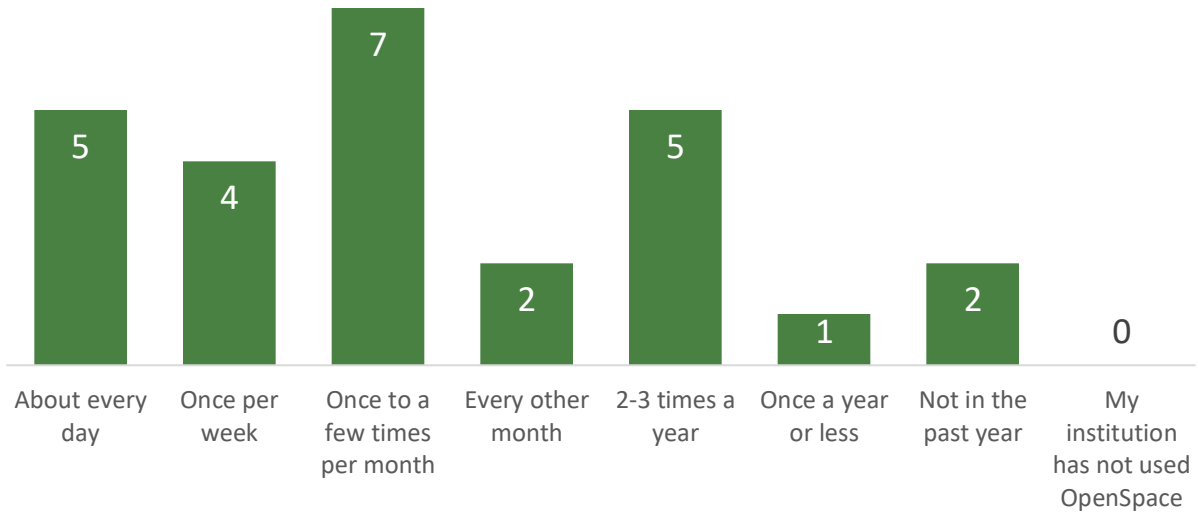
Table 10: Settings Used by OpenSpace Network Organizations (n=26)

Planetarium dome	73%	19
Classroom or library	27%	7
Live-streams	23%	6
Photos or videos on social media	15%	4
Museum exhibit	15%	4
Inflatable dome	8%	2
3-D theater	0%	0
Other publications (online or print)	0%	0
Another not listed	12%	3

Table 11: Most Respondents Use OpenSpace with Public Audiences, Learners, and Colleagues (n=24)

With public program audiences	67%	16
With students, interns, or other formal learners	58%	14
With coworkers or other professional connections	58%	14
Nobody; I use OpenSpace on an individual basis	29%	7
With informal groups or other science hobbyists	25%	6
With friends	17%	4
With other scientists	13%	3
With family	13%	3

Figure 4: 61% (16) used OpenSpace More Than Once per Month (n=26)



When asked for any last ideas about OpenSpace, 12 complimented the project and/or team. Some voiced a desire for expansion. Constructive suggestions reaffirmed needs for tutorials and friendlier UI. (n=16).

When asked for any last ideas about OpenSpace, 12 complimented the project and/or team. Some voiced a desire for expansion. Constructive suggestions reaffirmed needs for tutorials and friendlier UI. (n=16).

General Compliments (9 comments total)

> *It's a remarkable piece of software with tremendous capabilities. Thank you for the new releases, accounting for the latest developments in astronomy and earth science (James Webb, for example).*
>
> *It's changed my life - in a good way!*
>
> *It's incredible that OpenSpace exists.*
>
> *OpenSpace is a phenomenal tool and keeps getting more impressive as new versions are released. It is the center piece to my planetarium outreach efforts.*

Better UI & Tutorials Needed (5 comments total)

> *I enjoy its use but do not have the time I need to become more expert in it. Anything that can help that situation for me and others like me would be appreciated.*
>
> *Since I am a staff of 'one' I don't have a lot of time to tinker as much as I want to. Anything that helps me learn fast to adapt the program for my learners is incredibly helpful. I am driven by what my learners need; I am less interested in showing-off tricks.*
>
> *Please produce more tutorials aimed at making planetarium presentations. Also, basic step by step tutorials about programming for OpenSpace would be great!*

Team & Community are Helpful (4 comments total)

> *I love using OpenSpace, mostly because of the help from developers (MICAH!). I love that the users are so helpful too. Taking feedback from users is great.*
>
> *It's really great to see an open-source community growing in the dome.*
>
> *The OpenSpace team have created the best customer-service related experience I've ever had.*

Need to Disseminate & Expand (2 comments total)

> *I LOVE the program and it's fun to share, but the people I share it with do not have the hardware to run it themselves. A light version for educators may be helpful and might make the program more reliable to use for educational purposes.*
>
> *OpenSpace is an amazing project that deserves to be further developed.*

SME Formative Evaluation

Subject Matter Experts Have Three Primary Use Cases for OpenSpace

Summary of Findings

OpenSpace goals during SciAct 2.0 include the expansion of use of OpenSpace among Subject Matter Experts (SMEs). Growing the community of OpenSpace users, through increased use by scientists and other SMEs, will ultimately increase the quality and sophistication of data visualizations for the public, among other goals. The OpenSpace team has been aware of SMEs using OpenSpace in their work and their outreach. This year, the OpenSpace evaluation team interviewed SMEs to learn more about how SMEs used OpenSpace, benefits of use, barriers to use, and requests for future updates.

In our interviews, we spent significant time understanding how, under what contexts, and for what purposes SMEs used OpenSpace. As one SME put it, "OpenSpace is really good for both exploring your data but also communicating your data." Generally speaking, SMEs use OpenSpace in three primary ways:

1. Exploring data (visualizing complex numerical data in the context of conducting research),
2. Communicating data (using OpenSpace videos and still imagery through rendered content in technical and non-technical presentations), and
3. Showcasing data (presenting high quality "live flying" programs for various public audiences in a dome or other setting including live-streaming).

Once these particular SMEs saw OpenSpace in action or participated in programming, they each understood the potential for using OpenSpace in their own work. SMEs took OpenSpace back to their home machines did so with the goal of furthering their scientific work. These SMEs are willing to download the OpenSpace software and learn how to use it on their own. They particularly value OpenSpace's capacities to combine datasets, view things in real-time, and visualize multi-dimensionally. SMEs who use OpenSpace for furthering their scientific research rarely use a dome or other setting for showcasing these data or findings for the public. As needed, they make short videos and screenshots to share with colleagues and non-technical audiences in small settings. They do not need an expert pilot (or navigator) for most of these purposes. Interns and students are often involved in this capacity, making and editing videos.

Most of the SMEs whom we interviewed first heard about OpenSpace through Carter Emmart, reflecting the way the project was doing outreach to SMEs during SciAct 1.0. They partnered with Carter; invited Carter to talk, or attended a presentation associated with AMNH, Cal Academy, or another ISI partner. These SMEs know that when they need visuals of exceptional quality for big dome presentations or front-page publications, they can rely on Carter and the AMNH team to help them. They also know that, partnering with AMNH or other another ISI, they are going to make a big impact on audiences. During SciAct 2.0, OpenSpace team has broadened scope of SME dissemination, including multiple project staff

traveling to conferences, as well as working through cross collaborations and participating in SCOPE activities.

For using OpenSpace for high-impact larger scale public programs in domes, one significant factor is the dynamic between the SMEs and the experts flying in OpenSpace. One SME described the ideal partnership as a bus driver and tour guide working in concert. This analogy is useful in thinking about how the team can approach fostering adoption of the OpenSpace platform with future SMEs.

When asked what they would wish for in future development of OpenSpace, SMEs envisioned a variety of potential changes that would further support their work. In order of number of requests, they requested the following:

- A lightweight version,
- Improvement in resolution and precision,
- Increased support for emerging large-scale datasets to be easily incorporated into the software,
- More Earth-based content,
- A classroom version, and
- Expansion to other public venues.

Study Overview and Goals

HG&Co conducted in-depth interviews with seven (7) Subject Matter Experts (SMEs) who use OpenSpace. These scientists were selected because they have an existing relationship with the team at AMNH, and because each interacts with OpenSpace differently. Since this is a small, purposeful sample, the results are meant to give the OpenSpace context around SME usage and useful information for designing strategies for working with SMEs. This work is not intended to be representative of all SMEs, nor to gauge the amount of success of use of OpenSpace by SMEs. Instead, this evaluation focuses on generating useful information for the OpenSpace project team as they continue to grow the network.

In that vein, we asked the scientists a series of open-ended questions to understand:

1. Successful uses of OpenSpace for SMEs,
2. The aspects or affordances of OpenSpace that matter most to SMEs,
3. Factors for SMEs in adopting OpenSpace,
4. Barriers to use,
5. Desired features/updates by SMEs, and
6. Initial awareness of OpenSpace.

How SMEs Use OpenSpace

OpenSpace is intentionally designed to be used in myriad ways. The SMEs whom we interviewed about their work reflect this diversity of use. Analyzing these interviews, we find that OpenSpace can be roughly divided into three use cases:

1. Exploring Data: *To further research*
   In this usage, SMEs are using OpenSpace as a tool for conducting research, visualizing complex data, and quickly checking data. In this use case, OpenSpace allows SMEs to gain insight through integrated data sets, and in direction or motivation for their projects. Click-and-drag layers are useful to the SMEs for seeing new connections, attributes, or components. When SMEs are using OpenSpace in this way, they don't need their visualizations to be visually compelling, but they do need OpenSpace's precision for their work. In this usage, SMEs must have enough basic OpenSpace skills to be able to fly on their own.

2. Communicating Data: *To visualize (and present) complex data*
   In this usage, SMEs utilize OpenSpace to communicate with colleagues, students, and others, including giving professional papers. This use case is comprised of those generating videos or still imagery from OpenSpace, rather than OpenSpace being used live as it is in the following use case, below. These images and videos might be used in a variety of formats, from classroom use with students to use in museum exhibitions or data labs with the general public.

   SMEs need a higher production value here than in the Exploring Data use case, and they likely either require more advanced flying skills or someone with those skills who can support them. This use of OpenSpace generally needs to be more visually compelling in order to explain the data and phenomena to others.

3. Showcasing Data: *To present live programs*
   In this usage, SMEs make use of OpenSpace as a tool for dynamic programs or events. OpenSpace is flown "live" in this use case, and the SME is narrating the journey OpenSpace is showing. Often in a planetarium or similar setting, these are high-quality programs on a specific topic. There is an emphasis on storytelling within these programs, providing a narrative for the audience in addition to the visuals. SMEs in this setting need to rely on OpenSpace running smoothly. Generally, the SME is not the pilot of the OpenSpace software, allowing them to concentrate on the narrative and to be responsive to audience questions.

SME Use 1: Exploring Data

Many of the SMEs who were interviewed discussed using OpenSpace for "doing" science. This included:

- Making discoveries and exploring new research,
- Visualizing existing data to gain emergent insight, and
- Validating astronomical data and calculations.

These SMEs use OpenSpace for this work on their own machines. They share visuals and findings informally with colleagues; generally not getting too creative or adding unnecessary data layers. They learn how to add or rectify data, work with SPICE kernels, and create visualizations. Their goals are to

visualize their data in conjunction with other datasets, see aspects of their science that needed to be visualized, or help get on the same pages with their colleagues. For this use, the visuals generated need to be precise but not gorgeous. This type of OpenSpace usage is shared by other individuals within the greater OpenSpace network. For example, summer interns and students, specifically Linköping University's master students, work on known needs for furthering scientific research in OpenSpace.

Example of SMEs Using OpenSpace to Explore Data: Understanding Causal Relationships Between Baby Stars and Galaxy Super Bubbles

> *A lot of the work that I do involves creating models of our corner of the Milky Way galaxy. I work a lot with trying to piece models for different aspects of our galaxy together as a function of both space and time. And so that's why a lot of the work that I use involves OpenSpace, because it allows you to contextualize a lot of the models that I work with in a Milky Way like galaxy and understand how they can interact and affect the formation of new stars, which is what I focus on. I use OpenSpace to understand our galactic neighborhood of the Milky Way and actually make gains in the understanding of my own research, and to publish astronomical research. I have been looking at the positions of very young stars that have just been born. And then I have a model for where other features are in the galaxy. We actually live inside a giant bubble. I was able to overlay my model for a super bubble in the galaxy, a void in space, and compare it to where the young stars were in OpenSpace and understand why these things are connected. We used OpenSpace in part to help us understand that this bubble was blown by supernovae and it expanded over time and swept up all this gas and formed these young stars on the surface. W**e were able to explore causal relationships between different data sets in OpenSpace.***

Using OpenSpace to Share Data

In these examples, SMEs describe OpenSpace as a tool for communication and generating shared understanding with professional colleagues.

> *When I brought down my my lab mates and my advisor from the university, they were all floored by what they saw. We've looked at these data a lot on our computer screens, and we looked at them in different software packages, mainly GIS software packages, and it was nothing like looking at it in OpenSpace. That was really just the people I work with were just floored. In many cases, they were like, "Wow, so that's what it would actually look like if you were flying around?" For a lot of them, in a very general but very profound way, I think **OpenSpace transformed their understanding of the regions of Mars** where they were. It's hard to point to specific tangible research outcomes that came from that, but not everything needs to have a specific, tangible outcome in order to **fundamentally improve and motivate a project. It was very inspiring. It gave us all a 3D mental model of some of the subjects that we study, and that was really great.***

SME Use 2: Communicating Data

Some of the SMEs interviewed also use OpenSpace as a science communication tool to present findings to students or colleagues, or to create an image or video for public use. In this use case, the primary goal is to assist in understanding a particular phenomenon. Primarily they use videos and screenshots on local computers or on projected screens; rarely in live shows. These SMEs either have the skills to create videos and image stills, or they rely on interns or students to assist them. SMEs and their team will add additional data layers for context, and work to make the visualizations more polished so as to easily serve a more public audience. These images and videos might be used in a variety of formats, from classroom use with students to use in museum exhibitions or data labs with the general public.

Examples of SMEs using OpenSpace to Communicate Data: Creation of Animations

> *I do a lot of public speaking. And, a lot of times, as I'm talking about the mission, I'll say it's a "fly by." I'll have people ask questions like, "Well, when is it orbiting?" And so, it's clear that when people are hearing you say it's a fly by, it's easy to dismiss that piece of information no matter how hard you hit on it. But being able to show a visualization of the fly by is really important.* ***We had all sorts of very simple animations, but the value was in being able to show what the spacecraft's doing as it's flying by.*** *We could project the fields of view of the instruments in OpenSpace, project them from the New Horizon spacecraft onto Pluto, for example. And that really gives people a visceral feel of what you're doing. 'Oh, I understand now why you see more of the planet as you're flying by as you get closer.' It's a way of communicating complex geometric ideas in a way that people understand.*

SME Use 3: Showcasing Data

In this use case, SMEs make use of OpenSpace as a tool for dynamic programs or events for the public. For this outcome, responses from this particular group of SMEs indicate that they prefer to partner with AMNH or another ISI (which makes sense since the ISIs typically bring the audiences). OpenSpace is flown live in this use case, and the SME is narrating the journey OpenSpace is showing. The overall goal is to have the highest quality visuals, smooth flying, and a dynamic and responsive environment for learning. Often in a planetarium or similar setting, there is an emphasis on storytelling within these programs, providing a narrative for the audience in addition to the visuals. SMEs in this setting need to rely on OpenSpace running smoothly. Generally, the SME is not the pilot of the OpenSpace software, allowing them to concentrate on the narrative and to be responsive to audience questions. SMEs bring a depth of scientific knowledge to the presentation, and rely on others for production quality. SMEs spoke how these shows evoke awe in the audiences, increase knowledge, inspire interest in space, and help audience members shift their perspectives.

Example of SMEs using OpenSpace to Showcase Data: Fun Night Programming for the Public

> *Our common motif would be an evening at the museum. The public would come in and have a snack and they'd watch the show. And sometimes we do two shows per night, but it isn't as if it's a scientific meeting. It's not. It's a public venue. For example, we do the history of beer and we*

had three samples of beer. And then we've done wine tasting. They're sitting in the planetarium with three wines and then we're traveling to the places to show them the places where the wine comes from. And then we do things like bark beetle infestation and we put everybody in there to show them the demise of the forest of the west. I don't want to understate the fact that you can turn around and go into space. Of course, we'll do that from time to time. We'll say, "Well, let's compare ice patterns on Earth with ice patterns on Jupiter's moon or something." And we'll go from Antarctica to Ganymede or something. From a storytelling point of view, it's wonderful to have the base map and then we put all kinds of things on top of it. I've even shown PowerPoint on top of OpenSpace. It sounds horrible, but it works. They've got a bunch of slides, or I want to intersperse some images that are just simple images, that works.

An Analogy: Bus Drivers and Tour Guides

One SME likened an ideal program dynamic to a bus driver and a tour guide working together. The bus driver is adept at flying in OpenSpace; they transition fluidly, turning on and off layers, and can smoothly navigate a storyline. The tour guide is a subject matter expert; they are also familiar with OpenSpace. Because the goal of a big planetarium presentation is evoking a mixture of insight and awe, and the full visual power of OpenSpace is possible in the dome, there are two things at play: the excellence of the bus driver, and the artistry with which the bus driver and tour guide interact. This dynamic is afforded through practice, preparation (and a bit of personality).

*From my point of view, we cook up a story and the story, it can be anything from soup to nuts and then throw out a flight path and we have a pilot and we have a speaker and the **speaker speaks and the pilot pilots and the audience is mesmerized in a very comfortable situation in a planetarium**. So it's a good thing for everybody.*

*Driver & Tour Guide… it's a good metaphor. And I would say that I feel like I am a tour guide. I'm not proficient in driving, in running OpenSpace. **I'm sure I could be if I needed to, but I haven't needed to. And so, I think it works out well, the partnership.***

One SME voiced a desire to become a more proficient bus driver. This person is already using OpenSpace deeply for their scientific work, and sees value in not being so reliant on a pilot.

I personally feel like the subject matter experts should be proto-drivers. I think that the ideal relationship would be that I can substitute drive, or at least drive most of the way there, and then get support from the full-time drivers as needed…I would rather emphasize training drivers. I would much rather not be a passenger but actually work towards becoming more proficient myself, since I just would rather be less reliant on just a few people who know the most.

SME Requests for Future Development

When asked what they would wish for future development of OpenSpace, SMEs envisioned a variety of potential changes that would further support their work. In order of number of requests, they requested the following:

- A lightweight version,
- Increasing the Number of Data Formats,
- Support for large-scale datasets,
- More Earth-based content, and
- Expansion to other public venues.

Team Collaboration Evaluation

OpenSpace Team Collaboration Remains Healthy

The OpenSpace project involves many organizations and many individuals. In order to gauge the health of our collaborative effort, we asked the ISI network to take a 49-question survey, primarily consisting of closed-ended 1 to 7 rating scale questions. Through this, we can examine the health of the team collaboration, pinpoint areas of strength, and areas of possible improvement.

This survey was designed by HG&Co based on prior work focused specifically on Science Center collaborations *Collaboration: Critical Criteria for Success* (Dierking, 1995) and more general collaborations via the *Wilder Collaboration Factor Inventory* (Mattessich, Murray-Close, & Monsey, 2001).

In the scale used 7 represented Strongly Agree, 1 represented Strongly Disagree, with 4 being neutral.

- A rating between 5.5 and 7.0 does not require special attention at this time, and indicates **a strong and healthy collaboration;**
- A rating between 4.0 and 5.4 indicates a borderline aspect of the collaboration, and **may require special attention**;
- A rating below 4.0 indicates an area of concern for the collaboration and **will need to be addressed**.

As we can see in the table below, **the OpenSpace ISI network continues to have strong overall ratings for each of the eight categories tracked.** Within the table the current year numbers are bold, and the prior year numbers are in parentheses. While the sample is too small here to conduct significance testing, nearly all the averages are trending up.

Effective Communication was the category with the biggest increase up three-quarters of a point, and Clear Goals and Roles up nearly a half point. The AMNH team specifically worked to increase communication this year. There were no averages underneath a 4, indicating a pressing need for concern. Notably, most of the individual minimum ratings rose. Enhancing Value and Effectiveness fell slightly, the only category that did. Sufficient Capacity is now the lowest rated category, and while the rating is still not considered low enough to be of concern, it remains something the team continues to monitor.

Once again, the OpenSpace team continues to rate itself highly overall in each of the eight categories. Even the lowest-rated category—communication—is over 5 out of 7. The rating changes from last year are not significant, demonstrating the project is consistently strong.

Variance between category averages is small: in the tenths of a point. While it is notable that the averages have changed in *ranking* this year from last (see Year 6 ratings in parentheses), only slight rating differences mean that we should not put too much emphasis on this change. Nevertheless, Value & Effectiveness was ranked highest last year, with Goals and Roles at almost the same level, highly valued for their clarity. Trust, Listening, & Personal Investment rose from third-highest to the top. Capacity ratings increased from the lowest-rated category, with Communication falling to the bottom. Again recognizing only a slight change, half the categories were more positive than last year; the other half were more negative. Only the 3 lowest-rated categories fall below 5.5 and therefore in the "may require special attention" grouping, explained in the previous slide. **The big picture from these data is that OpenSpace collaboration continues to be strong with some smaller elements to continue to improve.**

Figure 5: Current OpenSpace Collaboration Scores (n=22)

		Average Rating in Category
	**Trust, Listening, & Personal Investment** 6 questions which focus on the personal interactions within the collaboration including trust, respect, and ability to listen.	5.91 (5.85)
	**Goals & Roles** 3 questions which measure whether project goals, roles, and responsibilities are clear.	5.79 (5.91)
	**Project Management** 7 questions which focus on how well the project is being managed.	5.73 (5.74)
	**Expectations of Investment** 5 questions which focus on whether organizational and expectations are clear and realistic.	5.69 (5.51)
	**Leadership** 2 questions which assess capabilities of the collaboration leadership.	5.66 (5.62)
	**Capacity** 5 questions which focus on whether individuals and organizations in the collaboration have the necessary capacity.	5.41 (5.33)
	**Value & Effectiveness** 5 questions focused on whether the team member believes the project is worthwhile at an institutional and societal level.	5.21 (5.95)
	**Communication** 7 questions focused on how well the members of collaboration communicate, including regularity and decision-making.	5.28 (5.44)

OpenSpace Year 7: Public Programs Report

October 25, 2022

Written by Madeleine Pope

The American Museum of Natural History (AMNH) and their informal science institution (ISI) partners have continued to improve upon OpenSpace public program ratings, already remarkably high, as pandemic restrictions fluctuated in Year 7. Respondents gave higher ratings to the public programs' "great images," "awe-inspiring qualities," as well as "surprising" and "exciting" qualities. In qualitative prompts, audiences still love the visuals and had glowing reviews of the presenters. Many want more of the same: continue with in-person programs while still streaming events online for those who are unable to make it to the planetarium. Predictably and excitingly, we saw more social watches than prior years, likely because friends and family are able to be in the same room safely more than the last two years.

This year, we transitioned to an updated survey in order to cohesively gather data from each of the ISIs, as some questions were missing or different in previous years. Working with each of the ISIs to agree on a single survey tool that met their needs, we introduced the new "core" survey in April 2022. This survey, now used exactly as is at each of the sites, is in the Appendix (starting on page 13). The data in this report are a blend of previous years' surveys and the 2022 core survey, which will be used alone in upcoming evaluation years. Continuing from prior years, NASA meatball decals were sent by mail to each of the recipients who opted in with their mailing address. This incentive is announced to the audience at the start and end of the public programs, and offered again at the end of the survey itself.

From October 2021 through September of 2022, survey responses from 54 programs were collected across AMNH, California Academy of Sciences (Cal Academy), Denver Museum of Nature & Science (DMNS), and North Carolina Museum of Natural Sciences (NCMNS). From these programs, a total of 210 surveys were collected. During this period, some more OpenSpace public programs took place, but surveys were not collected during all programs.

Table 1: Most Responses from Hybrid AMNH Programs (n= 210)[1]

AMNH (n=162)	Virtual Hybrid	2 programs (n=37) 2 programs (n=125)
Cal Academy (n=15)	Hybrid	39 programs (n=15)
DMNS (n=11)	Virtual	5 programs (n=11)

[1] *Where did you attend the program? (Select one. This may be online or in person.)*

NCMNS (n=22)	In-person Virtual	3 programs (n=17) 3 programs (n=5)

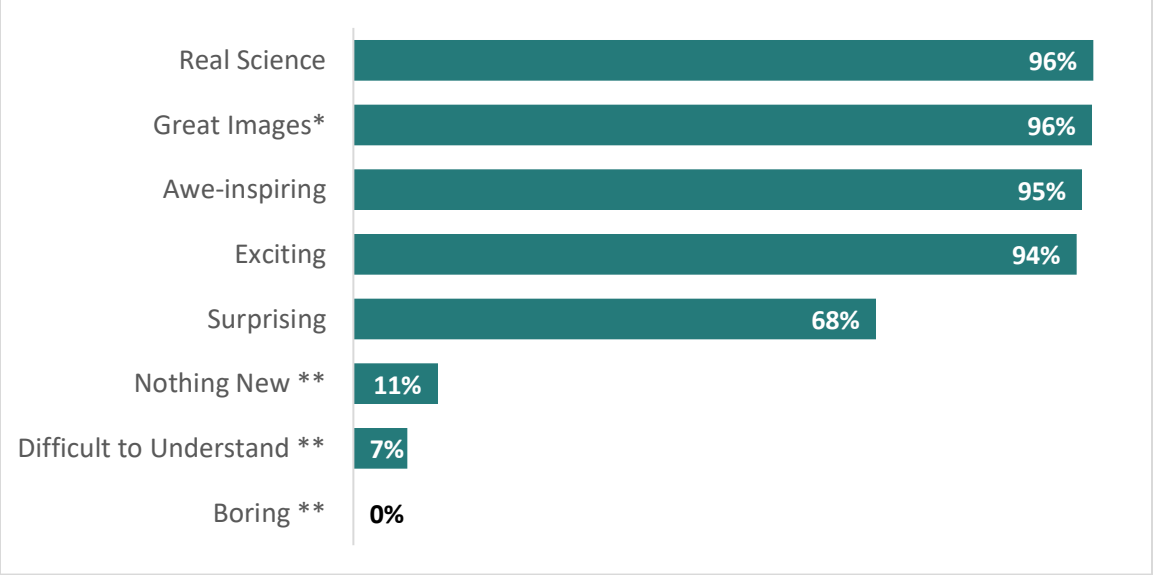
Note that there are no data from either Houston or Adler Planetarium in this report as again this year: Houston used only in-house surveys and Adler's OpenSpace focus is in their youth internships.

OpenSpace Programs Had Very Positive Impacts on Attendees

In line with the previous year's Programmatic Impact Report, participants in this year's OpenSpace programs were highly enthusiastic about the experience.

Out of 210 respondents across ISIs, a strong majority of those who responded said the program was either a 4- or 5-out-of-5 *Awe-inspiring* (95%) and *Exciting* (94%), with great images (96%) created from real science (also 96%). **This year, nobody rated the programs as boring (compared to 23% last year).** Overall, all ratings are up slightly this year compared to last year, except for minor increases in the ratings for *Nothing New* (11% compared to 6% last year), and *Difficult to Understand* (7% compared to last year's 4%).

Figure 1: Most Rated Each Positive Aspect Highly: a 4-5 out of 5 (n= 208-210)[2]



* This question is being phased out, so the sample size is lower at n=67.
**= Reverse-coded: the lower the percentage, the more successful the score.

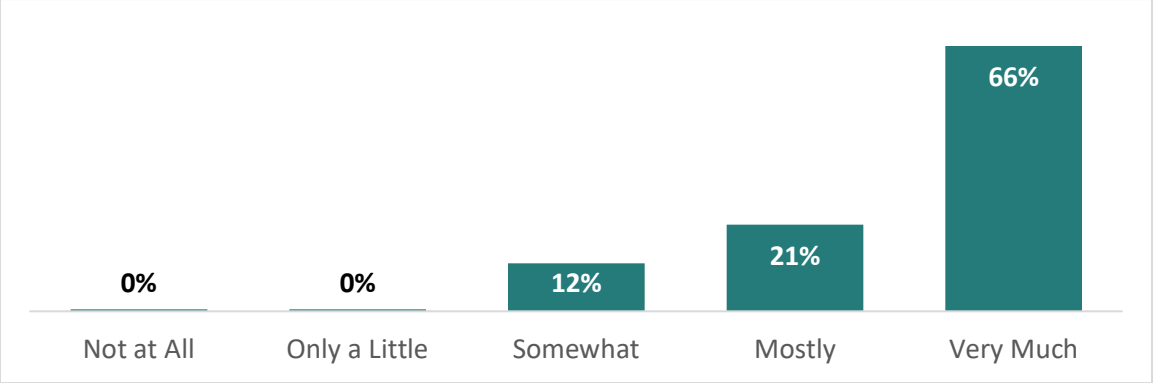
Attendees Experienced Increased Interest and Understanding

In addition to being exciting, respondents at all sites reported the programs increased their understanding and interest**. Over all the sites, 100% of respondents said the programs helped them understand how scientists gather information about Earth and other objects in space**

[2] *How much do these words describe the program?*

(with responses of *somewhat*, *mostly*, or *very much*). This is compared to 84% from last year's survey.

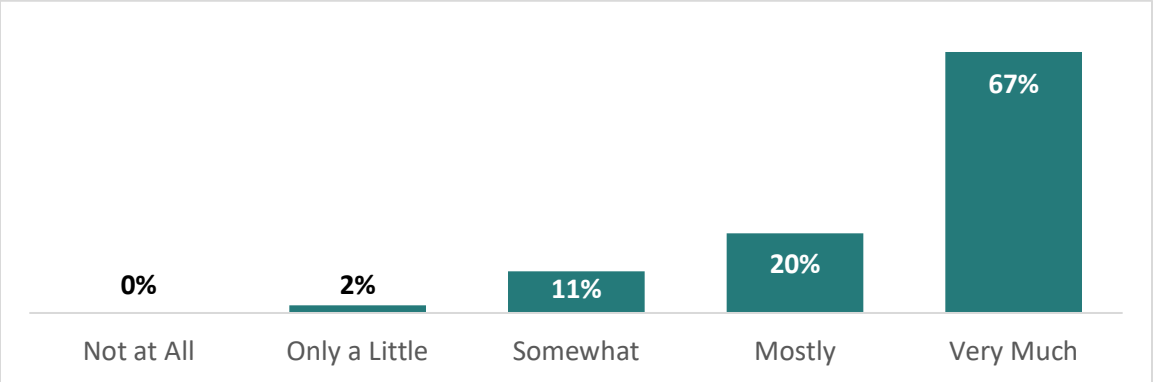
Figure 2: Understanding of How Scientists Gather Earth & Space Info was High (n= 210)[3]



Respondents were clear that OpenSpace uses NASA scientific data to generate the visualizations. **Over all the sites, only 1 respondent (0.5%) believed that the imagery was based on an artist's imagination, while the remaining 99.5% expressed understanding that it was from scientific data.**

Over the past few years, majorities of surveyed program audiences have also said that their interest in learning about NASA's science and mission activities increased since attending the program. The percentage rating their interest as moderate (*somewhat*) or within the upper tier this year was 98%, the same as last year.

Figure 3: Interest in Learning about NASA Increased by Program Attendance (n= 205)[4]



[3] *Did the program help you understand how scientists gather information about Earth or other objects in space? (Select one)*

[4] *Did this program make you more interested in learning about NASA's science and mission activities? (Select one)*

Programs Got Many Things Right

When we asked program attendees which aspects of the events worked well for them, we received several distinct types of responses. The visuals and images were highlighted as they are every year, along with the speakers' styles and abilities. This year, almost half of those who responded spoke about those two aspects as what worked especially well. There were many comments that fell into more than one category as well, praising visuals, speakers, and the efficacy of their work together. *Note that the table below is data from AMNH (n=114) more than DMNS (n=11), NCMNS (n=8), and Cal Academy (n=4) put together.*

Table 2: Audiences Loved Visuals, Speakers, & the Information They Provided (n= 136)[5]

Great visuals	**49%**
Enjoyable speakers	**40%**
Appreciated content	**24%**
Liked the format	**14%**
General compliments	**7%**

Multiple responses allowed.

The visuals, navigation, and side-by-side comparisons were praised. (66 remarks total)

- *360-degree display anchored by the sun make it much easier to understand relative movement and distance.*
- *Imagery of the telescope [JWST] itself and the likeness to flight simming [simulations].*
- *I really loved how you had the JWST pointing to different objects and having on the same screen the zoomed in actual picture from Hubble. Highly effective!*

> *The moderator and speaker were informative and engaging, the visuals were incredible, the excitement and awe in the room were palpable. I can't wait to go back to a similar event.*

Audiences loved watching the speakers & their 'banter' while recognizing their expertise. (54 remarks total)

- *The common language and analogies to describe and help explain complicated aspects were great.*
- *I just thoroughly enjoyed every aspect of the presentation. Seeing Neil deGrasse Tyson in person was an unexpected joy, as was being in the presence of so many astrophysicists. Super cool!*
- *Dr. Faherty is a fabulous presenter - engaging, able to roll with the punches, and really skilled at knowledge translation.*
- *The casual nature of Dr. Faherty's and Dr. deGrasse Tyson's communication styles. Really wonderful job of making the science exciting and accessible!*
- *The presenters' knowledge and grasp of material was incredible. Also, their ability to talk from experiment execution to scientific data was fluid and clear.*

[5] *What aspects of this program worked especially well for you?*

- *Loved Jackie's and Carter's showmanship and enthusiasm. They articulate this material well for a casual audience and more knowledgeable folks alike.*

The content was appreciated for its ease of access as well as specificity. (32 remarks total)

- *The common language and analogies to describe and help explain complicated aspects were great. Also loved the comparison to the Hubb telescope images.*
- *Advanced scientific language and detailed explanations*
- *True scientific data, and being live in person at the planetarium!*
- *Appreciated the diversity of topics covered over a general theme.*
- *The visuals and data shared was very interesting and easy to understand.*

The formats made a positive impact, whether in-person or online. (19 remarks total)

- *It was a joy to be back in the planetarium.*
- *Viewing photos and perspectives on planetarium dome was amazing*
- *YouTube is a great platform. In my opinion, it just works and is easy for end users.*
- *Watching when I have time, my one-person library makes it hard to get all the information the first time so watching again was really helpful.*

Once Again, Few Complaints about Program Aspects

We also asked attendees what did NOT work well in the programs that they participated in. **Of the 188 who were asked the question, 65% said that everything worked for them and/or they had no suggestions.** This is about roughly equivalent last year, when 61% said that there was nothing to improve. Some did have specific requests, though, which are organized below. *The table below is data from AMNH (n=69) more than NCMNS (n=8), DMNS (n=4), and Cal Academy (n=3) put together.*

Table 3: Main Complaint Was Physical Discomfort (n=128)[6]

Online or physical access caused challenges	**7.4%**
Uncomfortable in-person environment	**6.4%**
Information was too complex	**4.3%**
Presentation needed more clarity	**3.7%**
Phone use was disturbing	**3.2%**
Information was not complex enough	**2.1%**
Wanted more (context, details, images, length)	**2.1%**
Other	**3.7%**

Multiple responses allowed.

[6] *What aspects of this program did not work well for you?*

Audiences wanted easier, reliable, comfortable access. (14 remarks total)

- *The logistics of getting up to the planetarium theater seemed confusing to most attendees - there was a lot of confused wandering on lower floors, and I think it contributed to people showing up late.*
- *The video and audio were going in and out on YouTube.*
- *Technical issues with video and audio freezing both on YouTube and Facebook live stream.*
- *Microphone made it a bit difficult to hear some sentences.*
- *Would you ever consider having an evening event just in a planetarium, even if the Museum is closed?*
- *There were several very young children there who could not be kept quiet. There ought to be a suggested age (maybe 5 and up) for attendance.*
- *No assigned seating [was offered].*

Participants found aspects of live viewing uncomfortable. (12 remarks total)

- *It's hard to keep one's head tilted up for an hour. It would be easier if the top of the seat was flexible.*
- *The curvature of the dome was a little confusing*
- *The rapid movements*
- *Pretty cold in the planetarium*

I need basic astronomy to know my Milky Ways from my galaxies! For all audiences, a nod needs be given to Astronomy for Dummies.

The content was over the heads of some. (8 remarks total)

- *I would have appreciated more information going into the event; the description was vague. In addition, I would really appreciate is a one-pager or other resources links in the description so that I could learn a bit about the topic before attending. I would be able to engage with the talk with a bit more informed/refreshed perspective.*
- *Must be hard to balance the layman and the astrophysicist. Lots was totally over my head. Appropriately so, given so many smart people there.*

The presentation seemed to need more rehearsing. (7 remarks total)

- *They needed some kind of rehearsal; it seemed disorganized.*
- *Some of the information may have been more clear if it had been scripted.*
- *I think a more structured presentation would have helped. A more curated selection of what to talk about and what to show.*
- *So much, so fast.*

Planetariums and phones don't mix. (6 comments total)

- *Phones, phones, phones!!! People were constantly taking their phones out to take pictures in a darkened planetarium!! It was awful.*
- *People used flash photography. There should be an announcement for no flash photography by people.*

Content was not complex enough for some. (4 remarks total)

- *This may be just a me problem, but I would have liked to see more obscure images that I hadn't seen before.*
- *I prefer that presenters assume the audience knows more than a sixth grader.*
- *I thought the information assumed a lower level of prior science knowledge than may other science lectures at the AMNH. I thought the speakers could have covered more information if they had assumed a higher level of base knowledge as other lectures at the museum generally do. This was very definitely not geared towards the same crowd as your Frontiers lectures are.*

Some wanted to go deeper with more content, images, and length. (4 remarks total)

- *Not long enough*
- *I wanted to see even more images*
- *I wish it was longer or a series*

Other (7 remarks total)

- *Ideally it would have been better if the event took place later in the day!*
- *Pointers being used on one side and sometimes not on the opposite side image.*
- *A little too much talking to get to the images.*

Final Comments Focused on Wanting More and General Compliments

We asked attendees for suggestions for future programs and received 62 replies (*46 from AMNH, 10 from NCMNS, 6 from Cal Academy, 0 from DMNS)*. Some wanted to weigh in on topics, while others interpreted that question as asking what could be improved, similar to the prompt above. The final qualitative question asked "Anything else you'd like to share with the program team?" as a catch-all for any remaining thoughts that weren't covered by the survey. This prompt received comments from 67 respondents (*45 from AMNH, 8 from NCMNS, 7 from Cal Academy, 7 from DMNS).*

Because the similarity of these two questions and responses, we've combined them into one table with its own groupings, representing responses from 116 respondents overall.

Table 4: Respondents Mostly Wanted More of the Same, or Showed Satisfaction (n=116)[7]

Do more of the same	**32%**
General positive	**30%**
Changes to event planning	**14%**
Topic suggestions	**14%**
Enjoyable speakers	**12%**
Was hard to understand	**7%**
Other	**4%**

Multiple responses allowed.

Audiences want more of what they were getting from in-person, (conversely) online, and overall high-quality programming. (37 remarks total)

- *Fabulous. Please keep offering digital earth by Zoom.*
- *I really loved watching on the platform with the live chat. I hope that you have many more!*
- *i really enjoy these on Zoom. i might not come to the planetarium to see them but can easily watch from my own home.*
- *Thanks for virtual programs; now we can participate.*
- *Everything was perfect. I would love to have this kind of events in Italy as well*
- *Thank you for making this free.*
- *This should be available to more people since it was fantastic and very clear.*
- *I appreciate live chat moderators answering questions too; please keep doing it.*
- *Interesting to see the presenter's actual research.*

A lot of general positive feedback was shared. (35 remarks total)

- *I think this is a great resource for teachers!*
- *Absolutely loved this. My grandfather worked on the radar technology of the JWST so I am so excited about it.*
- *Thanks for a wonderful memorable evening.*

Some changes to the program planning are desired. (16 remarks total, some covering multiple points)

- **More time for questions** (5 comments)
  - *More time for audience Q&As or a mini panel between scientists would be a treat! Hearing the questions others ask, especially experts in the fields, adds a level of depth to a presentation.*
- **Prohibit phone use** (4 comments)
  - *Tell people to not use their phones. Especially flashes.*

[7] *Do you have any suggestions for future programs?* (and) *Anything else you'd like to share with the program team?*

    - *Advice people who attend the event to keep phones on their pockets.*
    - *Phones. Get rid of them. Ruins the experience completely.*
- **Chat adjustments desired** (3 comments)
    - *Setup as webinar to filter questions vs comments...turn off comments. Comments not easily managed on cell phone and interfere with presentation.*
    - *I do wish there was a way to monitor what was being typed in the chat box for all to see, since many of the comments were not appropriate and were taking my children's attention away from the presentation.*
- **Access/comfort needs** (3 comments)
    - *Stretching breaks and more interactive*
    - *Start on time.*
- **More focused presentations** (2 comments)
    - *Presenters should rehearse the presentation together.*
    - *Program aims and focus need to be razor sharp because so much to cover! That's perhaps why not so many* oohs *and* aahs*. But kudos anyway to presenters for passion for topic and tech dexterity.*

Please have the communications and education depts post this program onto YouTube as you had done during the Pandemic. The students' responses were out of this world and they are our future scientists.

Some topics were suggested (16 remarks total)

- **James Webb Space Telescope** (6 comments)
    - *After the Webb telescope starts getting images and data it'd be fun to have a follow up program*
    - *More JWST! Information on how the JWST users near and mid IR data combined to test hypotheses and gather information.*
- *Would love to have a presentation on what it would take to go to and land a human on Mars.*
- *A virtual stargazing session using OpenSpace (for people unable to see a dark sky) would be super cool! It could inspire people to value the celestial sights around them and get into amateur astronomy to see it for themselves :)*
- *Kid oriented programs.*
- *Maybe more theoretical programs about the what-ifs.*
- *Perhaps delve into the life cycle of stars with Star Forming Nebulae + protostars and the different ending stages stars can have! Incorporating black holes would also allow for showing the recent NASA black hole images from the past 3 years [plus, who doesn't love a good old (understatement of the year) black hole]?*
- *How and astronaut actually commands a space craft (all the parts.) And: DINOSAUR DAYS!!*
- *Comets!!!*
- *A show all about brown dwarves.*
- *Something on the Trappist system.*

Again, the presenters were highly praised. (14 remarks total)

- *Carter Emmart was really good at making it more accessible to lay people and Jackie Faherty had a lot of excitement that drove my excitement about things I did not understand. They were a good team!*
- *The main speaker was excellent. She has a powerful, yet engaging, style.*
- *Speaker was great, would see her talk about anything.*
- *Keep up the cute banter.*
- *Really liked that it was real scientists presenting*

Some found the programs hard to understand. (8 remarks total)

- *I had a great time, although some of the material (ok, most!) was definitely over my head (literally but I mean figuratively too!).*
- *The science is certainly interesting, but I'm not a scientist, but try to keep up.*
- *It would be good to add an introduction about the Webb (5 min explanation) - NASA has one, explaining how it got there, where in the solar system is located in the galaxy (better reference than the one provided), and project the images from the Webb in the whole Dome.*
- *The pictures from the JWST would be even better if there was a scale on them, in light years perhaps?*
- *The JWST has the potential to augment knowledge by a leap. The ways in which it can do that, weren't in my opinion clearly explained. It would help to do so especially with a broader audience that might get fascinated with the potential and more excited about it.*

Other (5 remarks total)

- *I have downloaded the OpenSpace software on my computer and it runs fine. I would like to do some basic presentations to our local schools. How do I make a dome or setup the projectors to get a 3D or 360° feel for the audience?*
- *More images, less narration.*
- *Maybe move the image a bit slower?*
- *I think it's better when there is a higher level of base knowledge assumed up front. But perhaps others who attend Astronomy Live events do not.*

Self-Identification

Again this year, a majority of respondents see themselves as Science Enthusiasts (52%), though the percentage dropped from last year (67%). There is a slightly higher percentage of Museum Members this year (39% compared to 31%). Perhaps the most notable change is that the percentage of students and teachers watching both went down, from 14 (students) to 7 (teachers) percentage points. Perhaps this is due to a decrease in online programming during the school day since the initial flush of online classwork earlier in the pandemic.

Table 5: Majority of Individuals Were Science Enthusiasts (n=186)[8]

Science enthusiast	**52%**
Museum member	**39%**
Parent/ Caregiver	**12%**
Student	**6%**
Teacher	**3%**
Other	**12%**

Multiple responses allowed.

The individuals in the *Other* category wrote in the following: Hobby Astronomer and IT Librarian, Librarian, Informal Science Educator, Museum staff, an attendee of the Division on Dynamical Astronomy Meeting, Astro-photographer, club members (of the Tarheel Gem & Mineral Club), volunteers, artists, informal students, and folks who luckily happened upon the program.

Audiences Watched Socially More Often

As we continue living with pandemic-related restrictions, we still are seeing more participants watching alone than with groups. This was also the most common way to watch in Years 5 and 6, but these percentage are dropping, down to 35% this year from 50% the year prior.

Table 6: Viewers Mostly Watched on Their Own (n=188)[9]

Watched on my own	**35%**
Watched with family	**31%**
Watched with significant other	**28%**
Watched with friends	**19%**
Watched with roommates	**1%**
Other	**3%**

This year, 19% of respondents watched with friends, as compared to only 1% in Year 6. These were all from the in-person AMNH event about JWST, with ages ranging from 18 to over 75. Those who selected *Other* wrote in that they watched with astrophysicist colleagues, with their class, and "First date!" OpenSpace programming appeals in many different environments and situations.

[8] *Did you attend the program in any of the following roles? (Select all that apply)*
[9] *Who else did you attend the program with? (Select all that apply)*

Range of Geographic Locations Continues to Decrease

As pandemic restrictions wavered and in-person programs gained in popularity, less geographic range was recorded for programs this past year. **Of 210 respondents, 77% saw the program in person, either at AMNH (97%) or NCMNS (3%).** Still, 48 respondents participated with their program online via NCMNS (n=17), Cal Academy (n=15), DMNS (n=11), or AMNH (n=5). Of these 48, 34 said that they watched from the following states.

Table 7: Online viewers watched from across the US, and 1 from the UK (n=34*)[10]

North Carolina	**14**
Colorado	**6**
Florida	**2**
New York	**2**
Virginia	**2**
California	**1**
Texas	**1**
United Kingdom	**1**

* Due to the small sample size, data are represented in counts rather than percentages.

Earlier in the pandemic, in Years 5 and 6, program participants identified a wider geographic range than in Year 7. During Year 6, while 80% of viewers were within the United States, other attendees were from Japan, the UK, Malaysia, and Guatemala. Now in Year 7, only one respondent identified as out of the country. This may be due to a widespread desire to participate in more local programming after more strict pandemic restrictions have been lifted.

Introducing gender questions this year, it may be of note to NASA and others focused on gender equity in STEM that a majority of respondents were not cismen. Of the 140 participants who were asked to identify their gender, 52% identified as women, 39% as men, and 3% as gender minorities (either "trans or transgender" or "non-binary or genderfluid"). Five percent opted to not respond to the question.

Year 7's survey also introduced a race/ethnicity question to better understand equity of access to these public programs. As above with gender, 140 respondents were asked this question, as previous surveys did not include it. The categories below represent the conclusion of conversations with all ISIs to most fully represent their current and potential audience identities.

[10] *Where did you watch the program from?*

Table 8: Mostly White Respondents, with Some Asian and Some Latinx (n=140)[11]

White or Caucasian	**69%**
Asian, Filipino, or Asian American	**9%**
Hispanic, Latino/a/x/e, Chicano/a/x/e, or Latin American	**9%**
Black, African American, or African	**3%**
American Indian, Native American, or Alaskan Native	**1%**
Native Hawaiian or Pacific Islander	**1%**
A race or ethnicity not listed	**5%**

Age categories, which had been asked in previous years' surveys, remained spread across the range, with lower percentages of young people. This year, 5% of respondents were under 18, compared to 13% last year and 24% the year before. This may be connected to seeing fewer teachers and students as outlined above.

Table 9: Broad Range of Attendee Ages (n=201)[12]

Under 12	**1%**
12-17	**4%**
18-24	**2%**
25-34	**19%**
35-44	**19%**
45-54	**16%**
55-64	**18%**
65 or older	**24%**

[11] *With which racial or ethnic group(s) do you identify? (Select all that apply)*
[12] *Please tell us your age range. (Select one)*

Appendix: Instrument

OpenSpace Audience Survey - 2022

We're so glad you attended today's program. Thank you for participating in our short survey!

* 1. Where did you attend the program? *(Select one. This may be online or in person.)*

- ◯ **Adler Planetarium** in Chicago
- ◯ **AMNH** (American Museum of Natural History) in New York
- ◯ **Cal Academy** (California Academy of Sciences)
- ◯ **DMNS** (Denver Museum of Nature & Science)
- ◯ **HMNS** (Houston Museum of Natural Science)
- ◯ **NCMNS** (North Carolina Museum of Natural Sciences)
- ◯ Another site:

* 2. On what date did you see the program? *(MM/DD/YYYY)*

* 3. Did you enjoy the program? *(Select one)*

1	2	3	4	5
Not at all	Only a little	Somewhat	Mostly	Very much
◯	◯	◯	◯	◯

* 4. How much do these words describe the program?

	1 Not at all	2	3	4	5 Completely
Awe-inspiring	◯	◯	◯	◯	◯
Boring	◯	◯	◯	◯	◯
Surprising	◯	◯	◯	◯	◯
Real Science	◯	◯	◯	◯	◯
Difficult to Understand	◯	◯	◯	◯	◯
Nothing New	◯	◯	◯	◯	◯
Exciting	◯	◯	◯	◯	◯

* 5. The imagery in this program was based **primarily** on: ***(Select one)***

◯ Scientific data.

◯ An artist's imagination.

* 6. Did the program help you understand how scientists gather information about Earth or other objects in space? ***(Select one)***

1 Not at all	2 Only a little	3 Somewhat	4 Mostly	5 Very much
◯	◯	◯	◯	◯

* 7. Did this program make you more interested in learning about NASA's science and mission activities? ***(Select one)***

1 Not at all	2 Only a little	3 Somewhat	4 Mostly	5 Very much
◯	◯	◯	◯	◯

8. Who did you attend the program with? *(Select all that apply)*
I attended...

- [ ] On my own.
- [ ] With my family.
- [ ] With my significant other.
- [ ] With my friends.
- [ ] With my class or camp.
- [ ] With my roommates.
- [ ] Other (please specify):

* 9. Did you see this program online or in-person? *(Select one)*

- ◯ Online
- ◯ In person

OpenSpace Audience Survey - 2022

* 10. On which platform did you watch this program? *(Select one)*

- ◯ Facebook
- ◯ YouTube
- ◯ Zoom
- ◯ Other (please specify):

* 11. Where did you watch the program from?

City:

State:

Country:

* 12. Where did you see this program? *(Select one)*

- ◯ In a planetarium dome at a museum
- ◯ In a theater at a museum
- ◯ On an exhibit kiosk or screen at a museum
- ◯ In a portable dome somewhere other than a museum
- ◯ Other (please specify):

OpenSpace Audience Survey - 2022

* 13. Did you attend the program in any of the following roles? ***(Select all that apply)***

- ☐ Teacher
- ☐ Student
- ☐ Parent or Caregiver
- ☐ Other (please specify):
- ☐ Science Enthusiast
- ☐ Museum Member
- ☐ None of these

14. What aspects of this program **worked especially well** for you?

15. What aspects of this program **did not work well** for you?

16. Do you have any suggestions for future programs?

OpenSpace Audience Survey - 2022

We're almost done! Please help us improve future programs by answering a few questions about yourself. You always have the option to select "Prefer not to say."

We ask these to learn more about our audiences and who we are serving with public programs.

* 17. Please tell us your age range. ***(Select one)***

- ◯ Under 12
- ◯ 12 - 17
- ◯ 18 - 24
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 - 64
- ◯ 65 - 74
- ◯ 75 +
- ◯ Prefer not to say

18. With which racial or ethnic group(s) do you identify? ***(Select all that apply)***

- ☐ American Indian, Native American, or Alaskan Native
- ☐ Asian, Filipino, or Asian American
- ☐ Black, African American, or African
- ☐ Hispanic, Latino/a/x/e, Chicano/a/x/e, or Latin American
- ☐ Native Hawaiian or Pacific Islander
- ☐ White or Caucasian
- ☐ Prefer not to say
- ☐ A race or ethnicity not listed:

* 19. With which gender(s) do you identify? ***(Select all that apply)***

- [ ] Female or Woman
- [ ] Male or Man
- [ ] Non-binary or genderfluid
- [ ] Trans or transgender
- [ ] Prefer not to say
- [ ] A gender not listed:

20. Anything else you'd like to share with the program team?

21. If you would like to receive information about future programs, please enter your email. ***(Optional)***

22. If you would like to receive a NASA sticker in the mail, please enter your address below. ***(Optional)***

Name:

Full Address:

Country:

OpenSpace Network Survey

September 2022

Madeleine Pope, HG&Co

Introduction: Purpose of Network Survey

The purpose of this digital survey was to explore the interests, feedback, and demographics of known OpenSpace users, outside of funded partnerships. This is the first time that a sample of this community has been surveyed about their uses of OpenSpace.

While the sample is small, the findings in this report serve as an important baseline for the team to strategize growth and outreach to future users, as well as considerations of program augmentation and communication with existing users.

Feedback from these users largely mirrors ongoing feedback from the ISI partners, which attests to the effectiveness of the project design: collaborating with a funded group of ISIs who serve as beta testers for the software and provide ongoing feedback clearly serves the project well. Many of the desired improvements have already been implemented in the current version or are in development.

Introduction: Network Survey Sample

The sampled population was users who were known to the OpenSpace team, excluding funded partners. This list of 81 contacts, provided by the OpenSpace team, included users who had conversations with core team members or expressed interest at an OpenSpace event. There are likely many more users who are unknown to the team.

Invitations were sent to all 81 contacts, and those contacts were invited to share the survey with their colleagues, which resulted in 4 responses from outside the original list. Respondents were offered a mailed OpenSpace decal as an incentive.

A response rate of 32.5% (standard for online surveys) provided us with insight from 26 OpenSpace users throughout July and August of 2022. Details on the demographics of respondents can be found on slide 6.

Contents of this Report

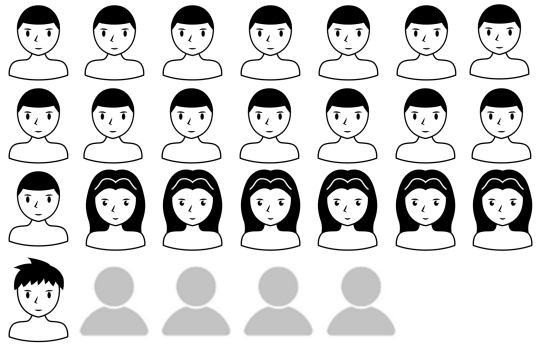
Notable Findings

- 61% of 26 respondents use OpenSpace **at least once a month**. (slide 12)
- Two-thirds of 24 respondents use OpenSpace with **public audiences**, and over half use it with students or professional colleagues. About a third use OpenSpace on an individual basis. (slide 10)
- Respondents show **moderate levels of familiarity and comfort** with OpenSpace. (slide 16)
- A **lack of resources is the main obstacle preventing more frequent use**: not enough staff to run it, not enough time to learn it, or not enough technological capacity. In lieu of OpenSpace, some respondents use other programs, like Digistar, Stellarium, or UniView. (slides 12-14)
- 10 out of 24 respondents are using **old versions of the software**. Seven of those 10 are aware that an update is available. (slide 11)
- 30% of respondents either **did not know about support options** (13%), or knew about the options but did not use them (17%). (slide 17)
- To improve OpenSpace, respondents suggested **more intuitive UI, tutorials, and various back-end improvements.** (slide 18) Some of these suggestions had already been implemented, but users of older versions were not necessarily aware of these changes.

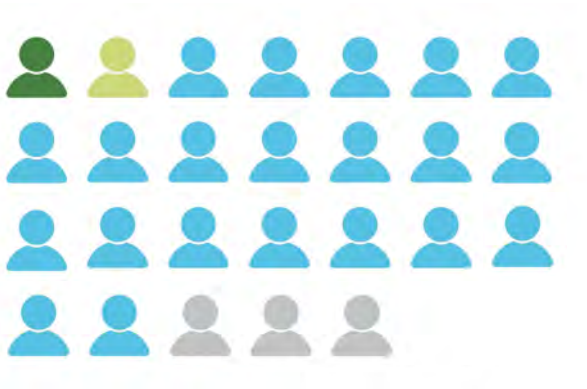
Respondents

Demographics of the 26 respondents:

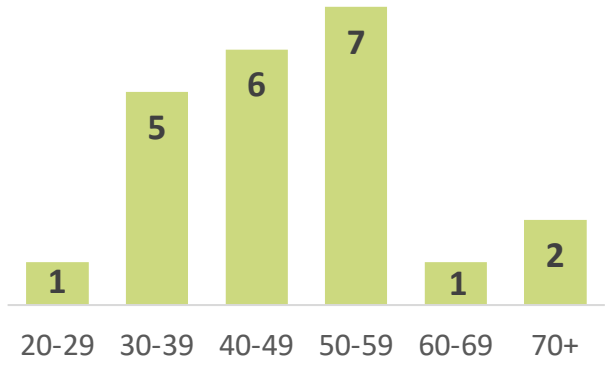
26 respondents answered from across the **continental US**, **Sweden**, **Austria**, **Germany**, and **Switzerland**.



A majority of respondents were **male (15 of 26),** with **6 female** respondents and **1 non-binary** respondent.
4 declined to answer.



1 Native American and **1 Black or African-American** respondent identified themselves in the survey among **21 white or European** respondents.
3 declined to answer.



Half of the respondents (13 of 26) were in their 40s or 50s.
4 declined to answer.

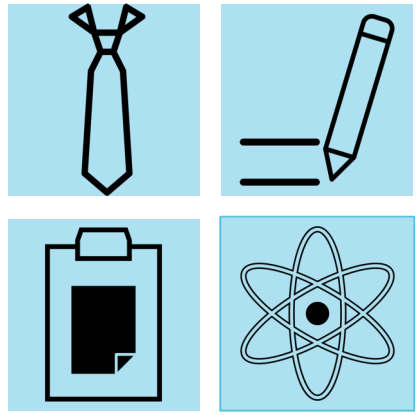
Respondents

Organizations and roles of the 26 respondents:

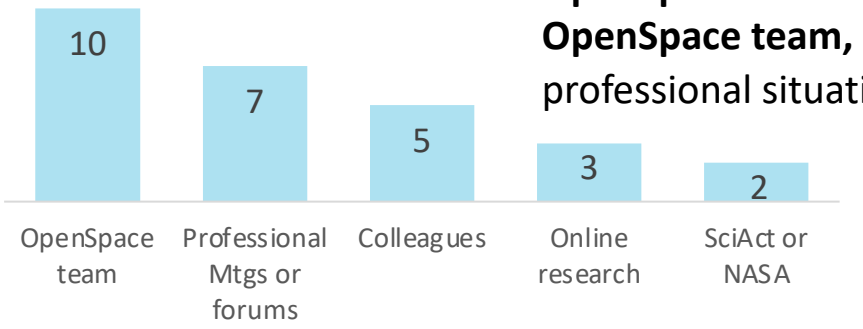
Respondents use OpenSpace in the following locations:*

- 15 planetariums
- 9 colleges & universities
- 2 community colleges
- 4 public k-12 schools
- A middle school observatory
- 7 space & science museums
- 5 natural history museums
- A Visualization Center
- NASA Solar System Ambassadors

*Multiple responses were allowed.



Roles at the locations were **mostly directors (11) and educators (9)**, with 4 Managers and 3 Scientists. There was also a technical lead, a volunteer, a dome technician, and an owner of a public planetarium.



Respondents first heard about OpenSpace directly from the OpenSpace team, or in professional situations (n=25).

Most are using OpenSpace across their institutions in a variety of roles:*

Planetarium professionals	42%	11
Educators: informal setting	35%	9
Students	31%	8
Nobody other than me	23%	6
Educators: formal setting	23%	6
SciAct collaborators	8%	2
Researchers	8%	2
Other	19%	5

*Multiple responses were allowed.

Respondents knew of planetarium workers, educators, and students also using OpenSpace within their location (n=26). “Other” included artists, filmographers, technicians, and a project PI.

HG &CO

Contexts of OpenSpace Use

When asked what contexts they use OpenSpace in, 8 main uses were described by the respondents (n=23). Multiple responses were allowed.

61% In planetariums	43% With students for research	26% For livestreams	22% For private showings
17% On dome screens	17% For public, in-person showings	17% For special events	13% For small exhibits and interactives

Locations Where OpenSpace is Displayed

When asked where their institution displays OpenSpace, most said it was in a planetarium dome (n=26).

Planetarium dome	73%	19
Classroom or library	27%	7
Live-streams	23%	6
Photos or videos on social media	15%	4
Museum exhibit	15%	4
Inflatable dome	8%	2
3-D theater	0%	0
Other publications (online or print)	0%	0
Another not listed »»»»»	12%	3

- » *Will be used in planetarium in 2023*
- » *Observatory Visitor Center*
- » *Auditorium*

Types of Interpersonal Use

Most respondents use OpenSpace with public audiences, learners, and colleagues (n=24).

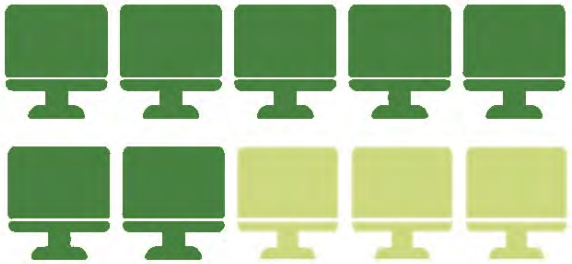
With public program audiences	67%	16
With students, interns, or other formal learners	58%	14
With coworkers or other professional connections	58%	14
Nobody; I use OpenSpace on an individual basis	29%	7
With informal groups or other science hobbyists	25%	6
With friends	17%	4
With other scientists	13%	3
With family	13%	3

Versions Used

Many users are not up-to-date on their software (n=24).

42% of respondents (n=10) are using out-of-date versions of the software, compared to **58% using version 18 (n=14)**.

Of those 10 using out-of-date versions, **most were aware that v.18 was released (n=7)**.

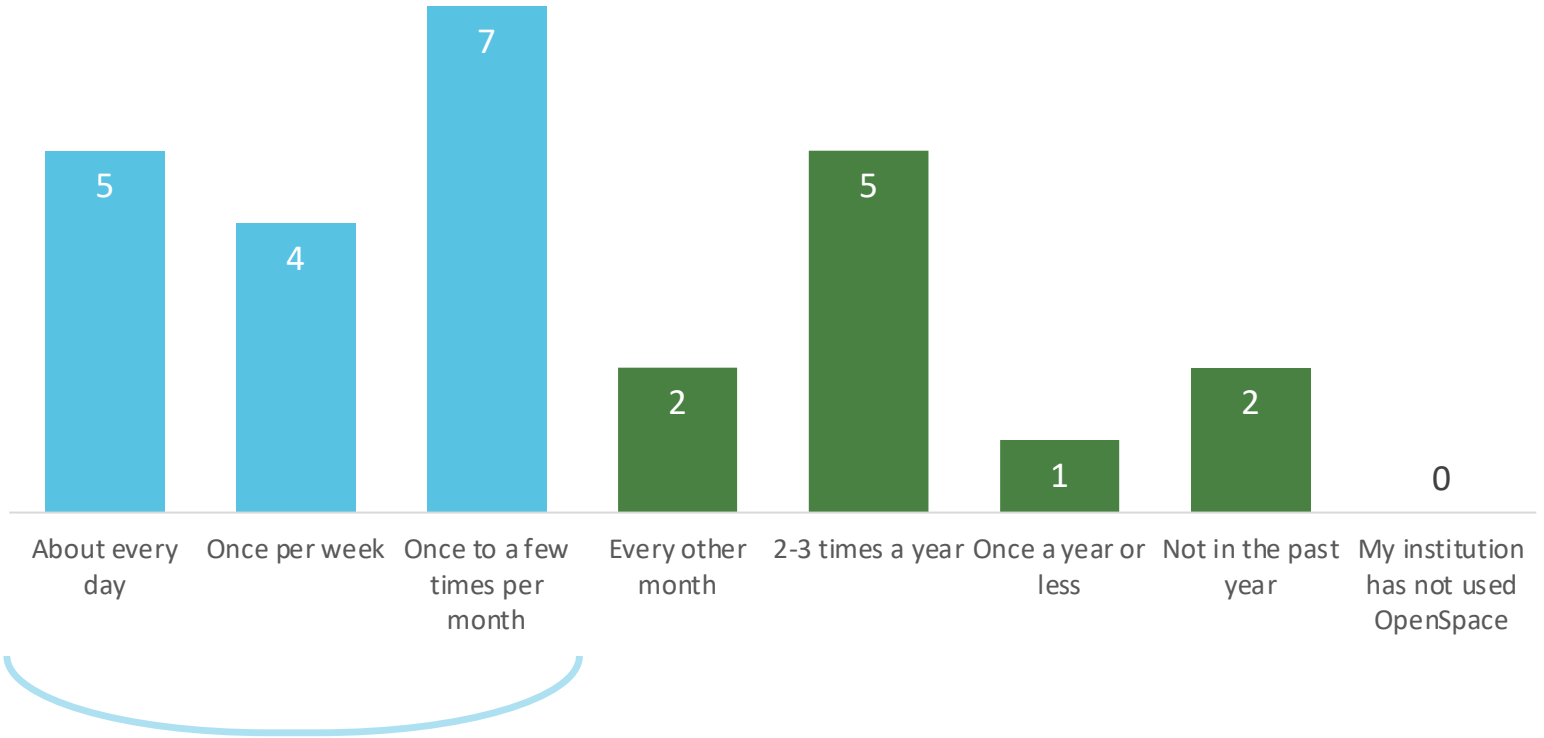


Version updates reached users through a range of sources, most via direct contact (n=14).

Direct communication with OpenSpace Team	5
Slack	3
Email	3
Newsletter	2
Website	2
GitHub	1
Mail	1
Downloading	1

Frequency of Use

There was a lot of variety in how often the sample used OpenSpace (n=26).



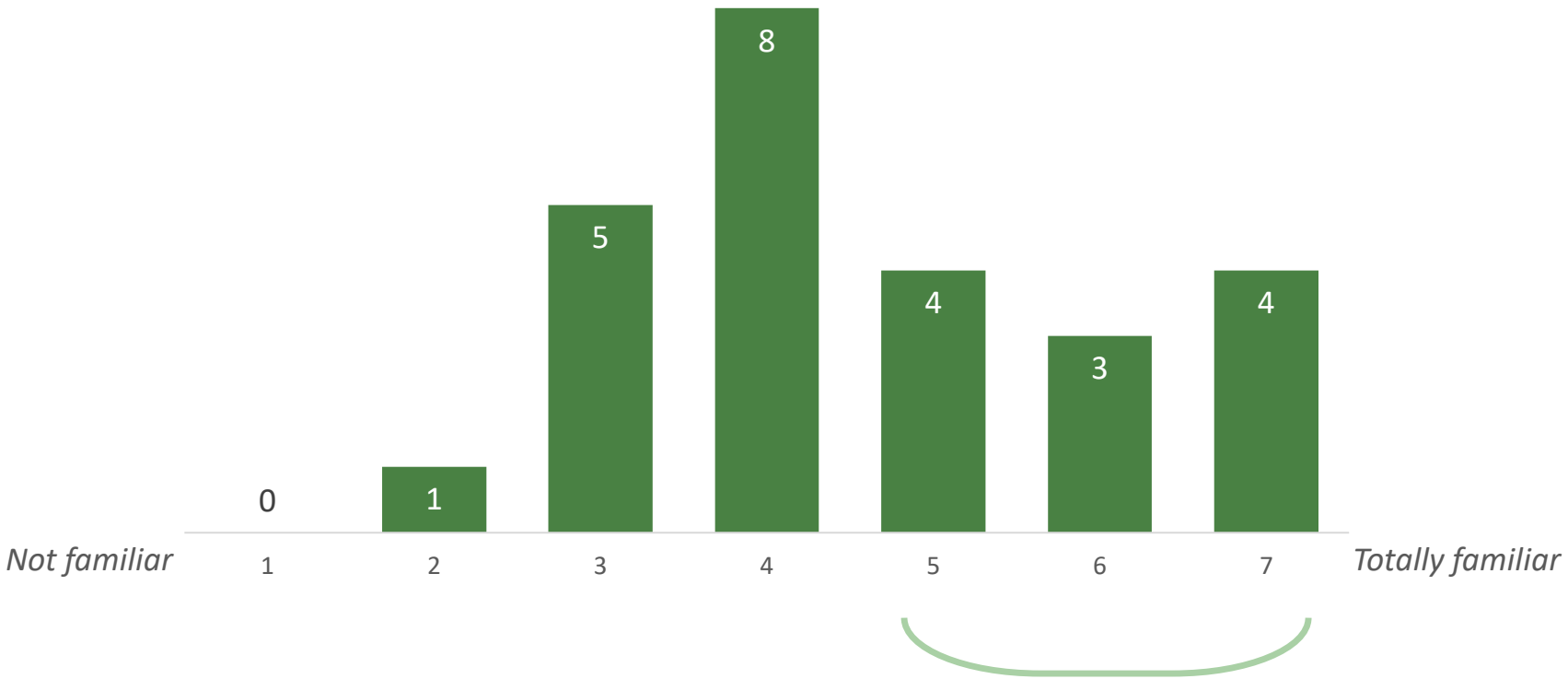
61% used OpenSpace more than once per month.

While most users used OpenSpace more the once a month, 2 users struggled with pandemic-related staff issues:

- *Manpower*
- *Due to the pandemic we have not had the time to learn a new software system, so we have continued with the one we have. Along with learning the software, it is challenging to format it for our 2-channel system. We do not have the technical staff onsite to assist us.*

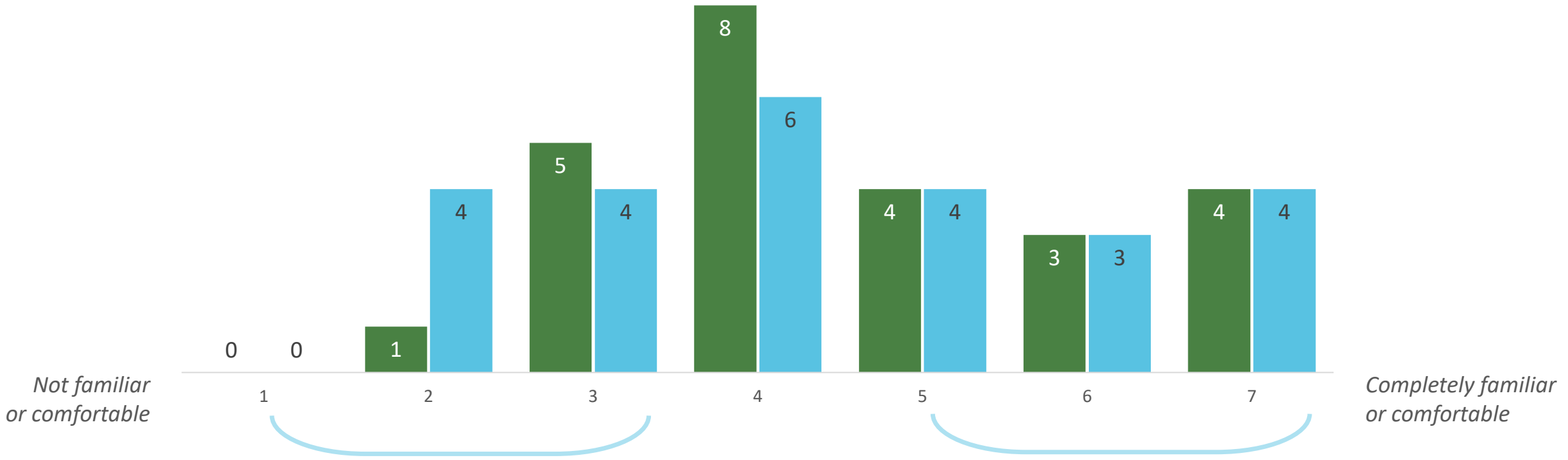
Familiarity with OpenSpace

Respondents mostly feel that they are somewhat to very familiar with the program (n=25).



Comfort with OpenSpace

Respondents are slightly more **familiar** than **comfortable** with the program, but a wide range of both are experienced by all, regardless of roles (n=25).



32% are still building confidence in OpenSpace.
(compared to 24% in familiarity)

44% feel confident about their use in OpenSpace.
(same as familiarity)

Support Systems Utilized

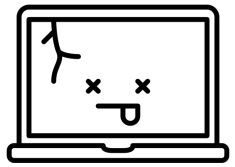
Respondents got the most help from the support team, website, and Slack channel (n=24).

Direct emails with the support team	58%	14
OpenSpace website	54%	13
OpenSpace Support Slack channel	50%	12
OpenSpace Wiki	38%	9
Zoom chats with the support team	33%	8
OpenSpace Github	17%	4
Talking with other OpenSpace user(s) in your institution	17%	4
I was aware of some options above but never sought support	17%	4
I did not know that any types of support were available until now	13%	3
OpenSpace social media	13%	3
OpenSpace newsletter	8%	2
I have not found these options to be useful	0%	0
Another not listed »»	8%	2

- » *Direct chat with Alex Bock, Carter, or Micah*
- » *Other OpenSpace users at other institutions*

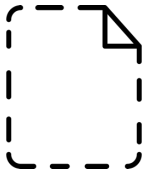
Obstacles to More Frequent Use

Main obstacles were lack of access to technology, of applicability to current work, and of support (n=25).



Necessary Tech Not Available (6 comments total)

- Using OpenSpace needs a good computer, which we have in the museum but not for personal use (in my role).
- The program crashes too often.
- We do not yet have OpenSpace natively installed in our dome.



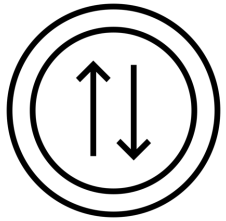
No Applicable Projects (5 comments total)

- Our dome is not yet ready to open (will open last half of 2023) and no other projects that needed OpenSpace
- Our institution does not have a strong need for OpenSpace outside for use with students in very specific situations.

Not Enough Support to Overcome Steep Learning Curve (4 comments total)

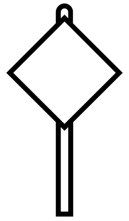
- OpenSpace is not very easy to use/understand. It's soo much you can do but that also makes it too complicated when the interface is not very user friendly for people who are not very familiar with the software.
- My main problem is the learning curve to do things. I wish there were better, user-friendly documentation.
- I need training that is up to-date with the version available and I need it to be time- efficient (easy to find and access and well-taught)
- There is a massive lack of tutorials on programming OpenSpace, and making click by click dome presentations with OpenSpace like we did with UniView!

Obstacles to More Frequent Use



Alternative Programs Are Currently Used Or Preferred (3 comments total)

- We don't have it in our public programming offerings. We use Digistar and Uniview, which suit our needs.
- The interface is not as user friendly as UniView (at least as far as I have investigated)… [we can’t yet be] making click by click dome presentations with OpenSpace like we did with UniView!

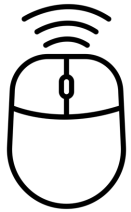


Other Obstacles (2 comments total)

- I was not able to promote it to our leaders in the museum.
- Lack of time to learn the customizations I want to do

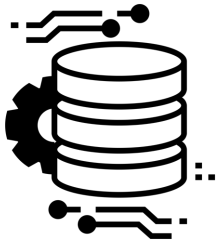
Improvements

When asked what improvements would be the most useful, respondents requested specific features, a more friendly user interface, and improved control (n=24).



More Friendly UI (10 comments total)

- A user friendly interface with the most common valuable functions more visible than others (there are sooo many layers and it is hard to know what they all can be used for).
- I am just barely learning how to use OpenSpace. But, a tile click by click interface (such as the one in UniView) to easily do planetarium shows would be very useful.
- Easier to implement caching on all assets, I have to do this each version and have not gotten a chance to do it with v18 yet.



Back-end Improvements (9 comments total)

- More volumetric models of deep space objects.
- Profiles that are editable while the main software is running.
- It still seems to have some memory leaks that causes sudden dramatic increases in memory usage and failure in the middle of shows.
- It needs to be more reliable. The frequent updates are cumbersome and it would help if there was an automatic prompt.

Better Tutorials (5 comments total)

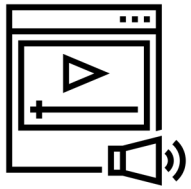
- User manuals with a collection of info from all the social media places and wikis. Something that can really set up a new user. Also, where and how to look for different resources. There are so many places to go, it can be overwhelming.
- Better explanation of when and how to use specific layers.
- A more up-to-date wiki with more details would be helpful.

Improvements

When asked what improvements would be the most useful, respondents requested specific features, a more friendly user interface, and improved control (n=24).

Easier Navigation (4 comments total)

- An EASY way to tag a location while exploring and then get back to it. I know there is a way but unless it has changed it is very cumbersome. I would like, for example, to mark or tag the location, zoomed in, of our observatory or classroom building so I can go to it quickly and then zoom out.
- Being able to launch off of Earth.
- More functions for finding places easily, for example: optional instruments for showing south, north, et cetera.



AV Integration (3 comments total)

- I would love to be able to integrate audio or video directly into the program.
- Ability to insert photos (overlay images), panoramas.
- Easy way to import images and display while presenting in open space.

Other Features Desired (4 comments total)

- A interface that can be used by guides in the museum on iPads.
- Constellations from Earth, something like a "planetarium" mode as Stellarium or Digistar provides.
- Committed long-term Mac support.
- I would like the ability to run OpenSpace natively on our dome.

Final Thoughts

When asked for any last ideas about OpenSpace, 12 complimented the project and/or team. Some voiced a desire for expansion. Constructive suggestions reaffirmed needs for tutorials and friendlier UI. (n=16).

General Compliments (9 comments total)

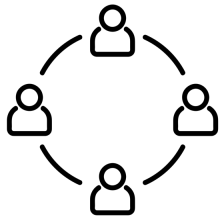
- It's a remarkable piece of software with tremendous capabilities. Thank you for the new releases, accounting for the latest developments in astronomy and earth science (James Webb, for example).
- It's changed my life - in a good way!
- It's incredible that OpenSpace exists.
- OpenSpace is a phenomenal tool and keeps getting more impressive as new versions are released. It is the center piece to my planetarium outreach efforts.

Better UI & Tutorials Needed (5 comments total)

- I enjoy its use but do not have the time I need to become more expert in it. Anything that can help that situation for me and others like me would be appreciated.
- Since I am a staff of 'one' I don't have a lot of time to tinker as much as I want to. Anything that helps me learn fast to adapt the program for my learners is incredibly helpful. I am driven by what my learners need; I am less interested in showing-off tricks.
- Please produce more tutorials aimed at making planetarium presentations. Also, basic step by step tutorials about programming for OpenSpace would be great!

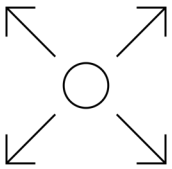
Final Thoughts

When asked for any last ideas about OpenSpace, 12 complimented the project/team and voiced a desire for expansion (n=16). Remaining suggestions reaffirmed need for tutorials and friendlier UI.



Team & Community are Helpful (4 comments total)

- I love using OpenSpace, mostly because of the help from developers (MICAH!). I love that the users are so helpful too. Taking feedback from users is great.
- Its really great to see an open-source community growing in the dome.
- The OpenSpace team have created the best customer-service related experience I've ever had.



Need to Disseminate & Expand (2 comments total)

- I LOVE the program and it's fun to share, but the people I share it with do not have the hardware to run it themselves. A light version for educators may be helpful and might make the program more reliable to use for educational purposes.
- OpenSpace is an amazing project that deserves to be further developed.

Appendix: Survey

OpenSpace Network Survey

Thanks for joining us!

Thank you for making the time for this survey! Your honest answers will help the OpenSpace project improve and evolve.

This survey is coming to you from OpenSpace's external evaluators. By providing us with your name, role, and institution, you will help us gain a better understanding of how and why institutions are using the software. You will also allows us to see how use changes over time. Each of these questions is optional, but highly useful for the team to grow the use of OpenSpace. The data collected for this survey will be discarded upon the conclusion of the study.

This survey should take about 15 minutes to complete. Thanks so much for your support of this important project!

1. What is your name? (optional, but encouraged)

OpenSpace Network Survey

Institutional Use of OpenSpace

Please fill out the following questions about one institution or organization where you use OpenSpace. Best guesses are fine!

If you use OpenSpace with more than one institution or organization, you'll have a chance to mention others at the bottom of this section.

2. What is the name of **one institution or organization** where you use OpenSpace the most? ((optional, but encouraged)

3. Where is this institution located?

City:

State:

Country (if not USA):

4. What is your title or role **in this institution**? (optional, but encouraged)

* 5. To the best of your knowledge, who else is using OpenSpace **within this institution?**
Select all that apply.

- [ ] Nobody other than me
- [ ] Educators: formal setting (schools, universities, etc)
- [ ] Educators: informal setting (museums, community spaces, public organizations, etc)
- [ ] Planetarium professionals
- [ ] Researchers: academic or institutional
- [ ] Researchers: hobbies or personal use
- [ ] SciAct collaborators
- [ ] Scientists
- [ ] Students
- [ ] Other individual or option not listed:

Appendix: Survey

* 6. Where does this institution display OpenSpace content? Select all that apply.

- ☐ Planetarium dome
- ☐ Inflatable dome
- ☐ 3-D theater
- ☐ Museum exhibit
- ☐ Classroom or library
- ☐ Live-streams
- ☐ Photos or videos on social media
- ☐ Other publications (online or print)
- ☐ Another not listed:

* 7. To the best of your knowledge, how often has **this institution** used OpenSpace in the past year? Select one that fits best.

- ○ About every day
- ○ Once per week
- ○ Once to a few times per month
- ○ Every other month
- ○ 2-3 times a year
- ○ Once a year or less
- ○ Not in the past year

OpenSpace Network Survey
Infrequent Users

* 8. What are the primary reasons why **this institution** has not used OpenSpace this past year?

OpenSpace Network Survey
Institutional Use (continued)

9. If you use OpenSpace with **any other institutions or organizations,** in addition to the one you just described above, please write their name(s) below.

OpenSpace Network Survey
Your Use of OpenSpace
Now we're going to switch gears and talk about **your personal experiences** with OpenSpace.

* 10. How familiar are **you** with OpenSpace software?

1 (not at all familiar) — 7 (extremely familiar)

* 11. How comfortable are **you** with OpenSpace software?

1 (not comfortable at all) — 7 (totally comfortable)

Appendix: Survey

12. Do you remember how **you personally** first learned about OpenSpace? If so, please briefly describe.

* 13. How often do **you personally** engage with OpenSpace software? Select one that fits best.

- ○ About every day
- ○ About once per week
- ○ Between once to a few times per month
- ○ About every other month
- ○ About 2-3 times per year
- ○ Once a year or less
- ○ I have not used OpenSpace in the past year.
- ○ I have seen OpenSpace software or presentations that use it, but I have not directly used the software before.

OpenSpace Network Survey
Infrequent Users

* 14. What are the primary reasons why **you personally** have not used OpenSpace this past year, or at all?

OpenSpace Network Survey
Personal Use (page 2)

* 15. Including the role you mentioned above for your institution, in which roles do **you personally** engage with OpenSpace? Select as many as apply.

- ☐ Astronomy enthusiast/ hobbyist
- ☐ Educator in a formal setting (schools, universities, etc)
- ☐ Educator in an informal setting (museums, community spaces, public organizations, etc)
- ☐ Planetarium professional
- ☐ Research- academic or institutional
- ☐ Research- hobbies or personal use
- ☐ SciAct collaborator
- ☐ Scientist
- ☐ Student
- ☐ Other individual or option not listed:

* 16. In what context(s) do you use OpenSpace? Please include contexts for **all roles and institutions** that you may use it in.

Examples might include using the software for planetarium shows, during amateur astronomy group meet-ups, or referencing information from the software for undergraduate research.

Appendix: Survey

* 17. Who do you use OpenSpace with, if anyone? Select all that apply, **including all roles and institutions.**

- ☐ With public program audiences
- ☐ With other scientists
- ☐ With family
- ☐ With friends
- ☐ With informal groups or other science hobbyists
- ☐ With students, interns, or other formal learners
- ☐ With coworkers or other professional connections
- ☐ Nobody; I have only used OpenSpace by myself (either alone or in public).
- ☐ Others not listed:

* 18. OpenSpace version 0.18.0 was released on May 6, 2022. Is this the version that you're currently using? Select one.

- ◯ Yes
- ◯ No

OpenSpace Network Survey
Versions

* 19. How did **you personally** find out about the most recent software release?

OpenSpace Network Survey
Awareness

* 20. Were you aware that version 0.18.0 was released?

- ◯ Yes
- ◯ No
- ◯ Other (please specify)

OpenSpace Network Survey
Personal Use (page 3)

* 21. Which operating system(s) do you use to run OpenSpace? Select all that apply, **considering all roles and institutions.**

- ☐ Windows
- ☐ Apple
- ☐ Linux or Unix

Appendix: Survey

* 22. What types of OpenSpace support are most helpful to **you personally**? Select up to three.

- [ ] Direct emails with the support team (either OpenSpace@amnh.org or Support@OpenSpaceProject.com)
- [ ] OpenSpace Github
- [ ] OpenSpace newsletter
- [ ] OpenSpace social media
- [ ] OpenSpace Support Slack channel
- [ ] OpenSpace website
- [ ] OpenSpace Wiki
- [ ] Talking with other OpenSpace user(s) in your institution
- [ ] Zoom chats with the support team
- [ ] I was aware of some options above but never sought support.
- [ ] I did not know that any types of support were available until now.
- [ ] I have not found these options to be useful.
- [ ] Another not listed:

* 23. What improvements to OpenSpace would be most useful to **you personally**?

OpenSpace Network Survey

A Few Questions About You

Your demographics help us understand who OpenSpace is reaching and who it is missing. The external evaluators will never connect these answers to your name, institution, or role in their reporting.

* 24. How do you describe your gender? Select all that apply.

- [ ] Female or Woman
- [ ] Male or Man
- [ ] Non-binary or genderfluid
- [ ] Trans or transgender
- [ ] Prefer not to say
- [ ] A gender not listed:

* 25. How do you describe your race or ethnicity? Select all that apply.

- [ ] American Indian, Native American, or Alaskan Native
- [ ] Asian, Filipino, or Asian American
- [ ] Black, African American, or African
- [ ] Hispanic, Latino/a/x/e, Chicano/a/x/e, or Latin American
- [ ] Native Hawaiian or Pacific Islander
- [ ] White or Caucasian
- [ ] Prefer not to say
- [ ] A race/ethnicity not listed:

26. In what year were you born? (optional)

OpenSpace Network Survey

Final Thoughts?

Appendix: Survey

27. **Do you have any final thoughts about OpenSpace?** Anything we didn't cover above? (optional)

If you have provided your name but would like to share these thoughts anonymously, please write ANONYMOUS in the textbox before your answer.

28. **If you would like an OpenSpace decal in thanks for completing this survey, please enter your preferred mailing address below.** (optional: This information will not be attached to your answers, will not be used for any reason other than mailing you the sticker.)

Name

Address

Address 2

City/Town

State/Province

ZIP/Postal Code

Country

29. **We are excited to hear opinions about OpenSpace from lots of different users!** We invite you to forward this survey to others using the link that you received, or you can include their email address(es) here so we can invite them to take the survey. (optional)

Contact 1:

Contact 2:

Contact 3:

OpenSpace Year 7:
Subject Matter Expert (SME) Evaluation Report

October 31, 2022

Table of Contents

HG &CO
VISITOR-CENTERED PLANNING, STRATEGY, AND EVALUATION

Summary of Findings

OpenSpace goals during SciAct 2.0 include the expansion of use of OpenSpace among Subject Matter Experts (SMEs). Growing the community of OpenSpace users, through increased use by scientists and other SMEs, will ultimately increase the quality and sophistication of data visualizations for the public, among other goals. The OpenSpace team has been aware of SMEs using OpenSpace in their work and their outreach. This year, the OpenSpace evaluation team interviewed SMEs to learn more about how SMEs used OpenSpace, benefits of use, barriers to use, and requests for future updates.

In our interviews, we spent significant time understanding how, under what contexts, and for what purposes SMEs used OpenSpace. As one SME put it, "OpenSpace is really good for both exploring your data but also communicating your data." Generally speaking, SMEs use OpenSpace in three primary ways:

1. Exploring data (visualizing complex numerical data in the context of conducting research),
2. Communicating data (using OpenSpace videos and still imagery through rendered content in technical and non-technical presentations), and
3. Showcasing data (presenting high quality "live flying" programs for various public audiences in a dome or other setting including live-streaming).

Once these particular SMEs saw OpenSpace in action or participated in programming, they each understood the potential for using OpenSpace in their own work. SMEs took OpenSpace back to their home machines did so with the goal of furthering their scientific work. These SMEs are willing to download the OpenSpace software and learn how to use it on their own. They particularly value OpenSpace's capacities to combine datasets, view things in real-time, and visualize multi-dimensionally. SMEs who use OpenSpace for furthering their scientific research rarely use a dome or other setting for showcasing these data or findings for the public. As needed, they make short videos and screenshots to share with colleagues and non-technical audiences in small settings. They do not need an expert pilot (or navigator) for most of these purposes. Interns and students are often involved in this capacity, making and editing videos.

Most of the SMEs whom we interviewed first heard about OpenSpace through Carter Emmart, reflecting the way the project was doing outreach to SMEs during SciAct 1.0. They partnered with Carter; invited Carter to talk, or attended a presentation associated with AMNH, Cal Academy, or another ISI partner. These SMEs know that when they need visuals of exceptional quality for big dome presentations or front-page publications, they can rely on Carter and the AMNH team to help them. They also know that, partnering with AMNH or other another ISI, they are going to make a big impact on audiences. During SciAct 2.0, OpenSpace team has broadened scope of SME dissemination, including multiple project staff traveling to conferences, as well as working through cross collaborations and participating in SCOPE activities.

For using OpenSpace for high-impact larger scale public programs in domes, one significant factor is the dynamic between the SMEs and the experts flying in OpenSpace. One SME described the ideal

partnership as a bus driver and tour guide working in concert. This analogy is useful in thinking about how the team can approach fostering adoption of the OpenSpace platform with future SMEs.

When asked what they would wish for in future development of OpenSpace, SMEs envisioned a variety of potential changes that would further support their work. In order of number of requests, they requested the following:

- A lightweight version,
- Improvement in resolution and precision,
- Increased support for emerging large-scale datasets to be easily incorporated into the software,
- More Earth-based content,
- A classroom version, and
- Expansion to other public venues.

Study Overview and Goals

HG&Co conducted in-depth interviews with seven (7) Subject Matter Experts (SMEs) who use OpenSpace. These scientists were selected because they have an existing relationship with the team at AMNH, and because each interacts with OpenSpace differently. Since this is a small, purposeful sample, the results are meant to give the OpenSpace context around SME usage and useful information for designing strategies for working with SMEs. This work is not intended to be representative of all SMEs, nor to gauge the amount of success of use of OpenSpace by SMEs. Instead, this evaluation focuses on generating useful information for the OpenSpace project team as they continue to grow the network.

In that vein, we asked the scientists a series of open-ended questions to understand:

1. Successful uses of OpenSpace for SMEs,
2. The aspects or affordances of OpenSpace that matter most to SMEs,
3. Factors for SMEs in adopting OpenSpace,
4. Barriers to use,
5. Desired features/updates by SMEs, and
6. Initial awareness of OpenSpace.

How SMEs Use OpenSpace

OpenSpace is intentionally designed to be used in myriad ways. The SMEs whom we interviewed about their work reflect this diversity of use. Analyzing these interviews, we find that OpenSpace can be roughly divided into three use cases:

1. **Exploring Data:** *To further research*
   In this usage, SMEs are using OpenSpace as a tool for conducting research, visualizing complex data, and quickly checking data. In this use case, OpenSpace allows SMEs to gain insight through integrated data sets, and in direction or motivation for their projects. Click-and-drag layers are useful to the SMEs for seeing new connections, attributes, or components. When SMEs are

using OpenSpace in this way, they don't need their visualizations to be visually compelling, but they do need OpenSpace's precision for their work. In this usage, SMEs must have enough basic OpenSpace skills to be able to fly on their own.

2. **Communicating Data**: *To visualize (and present) complex data*
   In this usage, SMEs utilize OpenSpace to communicate with colleagues, students, and others, including giving professional papers. This use case is comprised of those generating videos or still imagery from OpenSpace, rather than OpenSpace being used live as it is in the following use case, below. These images and videos might be used in a variety of formats, from classroom use with students to use in museum exhibitions or data labs with the general public.

   SMEs need a higher production value here than in the Exploring Data use case, and they likely either require more advanced flying skills or someone with those skills who can support them. This use of OpenSpace generally needs to be more visually compelling in order to explain the data and phenomena to others.

3. **Showcasing Data:** *To present live programs*
   In this usage, SMEs make use of OpenSpace as a tool for dynamic programs or events. OpenSpace is flown "live" in this use case, and the SME is narrating the journey OpenSpace is showing. Often in a planetarium or similar setting, these are high-quality programs on a specific topic. There is an emphasis on storytelling within these programs, providing a narrative for the audience in addition to the visuals. SMEs in this setting need to rely on OpenSpace running smoothly. Generally, the SME is not the pilot of the OpenSpace software, allowing them to concentrate on the narrative and to be responsive to audience questions.

SME Use 1: Exploring Data

Many of the SMEs who were interviewed discussed using OpenSpace for "doing" science. This included:

- Making discoveries and exploring new research,
- Visualizing existing data to gain emergent insight, and
- Validating astronomical data and calculations.

These SMEs use OpenSpace for this work on their own machines. They share visuals and findings informally with colleagues; generally not getting too creative or adding unnecessary data layers. They learn how to add or rectify data, work with SPICE kernels, and create visualizations. Their goals are to visualize their data in conjunction with other datasets, see aspects of their science that needed to be visualized, or help get on the same pages with their colleagues. For this use, the visuals generated need to be precise but not gorgeous. This type of OpenSpace usage is shared by other individuals within the greater OpenSpace network. For example, summer interns and students, specifically Linköping University's master students, work on known needs for furthering scientific research in OpenSpace.

Examples of SMEs Using OpenSpace to Explore Data

Discover New Asteroids

We've shown that there's a brand-new technique for discovering asteroids that can pick up a lot of asteroids in historical dataset or in dataset that were never meant for asteroid discovery, where the telescopes were doing other science, but we can pick out asteroids and not just pick them out, but show that a single point of light in one image and maybe a point of light taken and some other times, some other date from even a different observatory. And yet another point of light taken from yet a different observatory and a different date that these are all the same object and that there is an asteroid right here whose orbit is this. And we've shown that we can discover asteroids this way.

Understand Causal Relationships Between Baby Stars and Galaxy Super Bubbles

*A lot of the work that I do involves creating models of our corner of the Milky Way galaxy. I work a lot with trying to piece models for different aspects of our galaxy together as a function of both space and time. And so that's why a lot of the work that I use involves OpenSpace, because it allows you to contextualize a lot of the models that I work with in a Milky Way like galaxy and understand how they can interact and affect the formation of new stars, which is what I focus on. I use OpenSpace to understand our galactic neighborhood of the Milky Way and actually make gains in the understanding of my own research, and to publish astronomical research. I have been looking at the positions of very young stars that have just been born. And then I have a model for where other features are in the galaxy. We actually live inside a giant bubble. I was able to overlay my model for a super bubble in the galaxy, a void in space, and compare it to where the young stars were in OpenSpace and understand why these things are connected. We used OpenSpace in part to help us understand that this bubble was blown by supernovae and it expanded over time and swept up all this gas and formed these young stars on the surface. W**e were able to explore causal relationships between different data sets in OpenSpace.***

Visualizing Heliosphere Polarity and Winds In 3D

*We were impressed with what we saw of OpenSpace; especially the experience of seeing data on multiple scales. Our staff was interested in visualizing our data of the heliosphere in a new way. We tried volumetric visualization because it was something we had the least experience with. Space weather forecasting was popular from a scientific point of view for seeing solar wind and eruptions from the sun in 3D. **Our most popular and impactful projects have been visualizing magnetic fields and flow lines of the heliosphere; displaying magnetic flowlines of the earth's magnetosphere; and showing radiation using dots with levels.***

Using OpenSpace to Share Data

In these examples, SMEs describe OpenSpace as a tool for communication and generating shared understanding with professional colleagues.

From the research end of things, a central piece is visualizing orbits that you've calculated. And so, you will generate an orbit for something which you've observed or something which you're

testing and you'll want to look at it. Can I compare this to another orbit? ***We use OpenSpace to visualize the tracks of orbit in the solar system. It becomes part of our workflow, but also we would provide OpenSpace visualization as a service too.*** *So that, if some researcher or an astronomer says, "Hey, I just discovered this asteroid. I want to look at the orbit…", they don't need to build and develop their own routines and get it on their machine and whatnot. They could just type it in or send it and get back from us a visualization. Everything we do is open source. OpenSpace fits in nicely into the things that we want to provide as a service.*

When I brought down my my lab mates and my advisor from the university, they were all floored by what they saw. We've looked at these data a lot on our computer screens, and we looked at them in different software packages, mainly GIS software packages, and it was nothing like looking at it in OpenSpace. That was really just the people I work with were just floored. In many cases, they were like, "Wow, so that's what it would actually look like if you were flying around?" For a lot of them, in a very general but very profound way, I think ***OpenSpace transformed their understanding of the regions of Mars*** *where they were. It's hard to point to specific tangible research outcomes that came from that, but not everything needs to have a specific, tangible outcome in order to* ***fundamentally improve and motivate a project. It was very inspiring. It gave us all a 3D mental model of some of the subjects that we study, and that was really great.***

Needs and Future Requests to Support this Use Case

In order to make use of OpenSpace for exploring and sharing data with others, SMEs have certain needs for the software. First, OpenSpace has an ability to work with large datasets, a core attribute of the software. As more SMEs take up OpenSpace, the need for integration of new data sets into OpenSpace is growing. SMEs discussed their need for OpenSpace to work with ever larger datasets in conjunction with their desire to be able to easily load and integrate data into a common platform – a key strength of OpenSpace.

As other users in the network have articulated, SMEs are also interested in having a lightweight version of OpenSpace that functions on Mac computers. This would give SMEs who are exploring data the ability to quickly check or visualize data.

One barrier, that I think is easier to overcome, is just being able to incorporate the data sets we want to visualize easily. I feel like my relationship with this Glue plugin has helped a lot with that.

The OS platform is an issue. It works on windows and is maybe loosely supported on Macs. But most of our scientists work on Macs or Linux machines. We would love to see AMNH host something in the cloud with a webapp so users don't have to have it on their machine. This would be good for lightweight applications; a way in. But for scientific use, the OS platform is a real issue. For science it's a big deal. [Note, OpenSpace does work on Linux, the interviewee was unaware of that capability.]

SME Use 2: Communicating Data

Some of the SMEs interviewed also use OpenSpace as a science communication tool to present findings to students or colleagues, or to create an image or video for public use. In this use case, the primary goal is to assist in understanding a particular phenomenon. Primarily they use videos and screenshots on local computers or on projected screens; rarely in live shows. These SMEs either have the skills to create videos and image stills, or they rely on interns or students to assist them. SMEs and their team will add additional data layers for context, and work to make the visualizations more polished so as to easily serve a more public audience. These images and videos might be used in a variety of formats, from classroom use with students to use in museum exhibitions or data labs with the general public.

Examples of SMEs using OpenSpace to Communicate Data

Creation of Animations

I do a lot of public speaking. And, a lot of times, as I'm talking about the mission, I'll say it's a "fly by." I'll have people ask questions like, "Well, when is it orbiting?" And so, it's clear that when people are hearing you say it's a fly by, it's easy to dismiss that piece of information no matter how hard you hit on it. But being able to show a visualization of the fly by is really important. ***We had all sorts of very simple animations, but the value was in being able to show what the spacecraft's doing as it's flying by.*** *We could project the fields of view of the instruments in OpenSpace, project them from the New Horizon spacecraft onto Pluto, for example. And that really gives people a visceral feel of what you're doing. 'Oh, I understand now why you see more of the planet as you're flying by as you get closer.' It's a way of communicating complex geometric ideas in a way that people understand.*

OpenSpace is successful in planned planetarium shows regarding a specific event that can be loaded… We use videos and show demos in presentations and lectures.

SME Use 3: Showcasing Data

In this use case, SMEs make use of OpenSpace as a tool for dynamic programs or events for the public. For this outcome, responses from this particular group of SMEs indicate that they prefer to partner with AMNH or another ISI (which makes sense since the ISIs typically bring the audiences). OpenSpace is flown live in this use case, and the SME is narrating the journey OpenSpace is showing. The overall goal is to have the highest quality visuals, smooth flying, and a dynamic and responsive environment for learning. Often in a planetarium or similar setting, there is an emphasis on storytelling within these programs, providing a narrative for the audience in addition to the visuals. SMEs in this setting need to rely on OpenSpace running smoothly. Generally, the SME is not the pilot of the OpenSpace software, allowing them to concentrate on the narrative and to be responsive to audience questions. SMEs bring a depth of scientific knowledge to the presentation, and rely on others for production quality. SMEs spoke how these shows evoke awe in the audiences, increase knowledge, inspire interest in space, and help audience members shift their perspectives.

Examples of SMEs using OpenSpace to Showcase Data

Fun Night Programming for the Public

Our common motif would be an evening at the museum. The public would come in and have a snack and they'd watch the show. And sometimes we do two shows per night, but it isn't as if it's a scientific meeting. It's not. It's a public venue. For example, we do the history of beer and we had three samples of beer. And then we've done wine tasting. They're sitting in the planetarium with three wines and then we're traveling to the places to show them the places where the wine comes from. And then we do things like bark beetle infestation and we put everybody in there to show them the demise of the forest of the west. I don't want to understate the fact that you can turn around and go into space. Of course, we'll do that from time to time. We'll say, "Well, let's compare ice patterns on Earth with ice patterns on Jupiter's moon or something." And we'll go from Antarctica to Ganymede or something. From a storytelling point of view, it's wonderful to have the base map and then we put all kinds of things on top of it. I've even shown PowerPoint on top of OpenSpace. It sounds horrible, but it works. They've got a bunch of slides, or I want to intersperse some images that are just simple images, that works.

Request for More Earth-based Datasets

I think there's a huge advantage to being able to use OpenSpace to explore what's going on in our Earth. I mean, it's ... There are so many data sets that are very rich. You've got land-set data that are earth imaging data over 20 years.

An Analogy: Bus Drivers and Tour Guides

One SME likened an ideal program dynamic to a bus driver and a tour guide working together. The bus driver (who we have called *pilot* up to this point) is adept at flying in OpenSpace; they transition fluidly, turning on and off layers, and can smoothly navigate a storyline. The tour guide is a subject matter expert; they are also familiar with OpenSpace. Because the goal of a big planetarium presentation is evoking a mixture of insight and awe, and the full visual power of OpenSpace is possible in the dome, there are two things at play: the excellence of the bus driver, and the artistry with which the bus driver and tour guide interact. This dynamic is afforded through practice, preparation (and a bit of personality). It's the space where OpenSpace can "move mountains."

We're humans so we respond very well not just to the spectacular on a big screen, so to speak, and beautiful music or something like that, but also to human interactions and the exchange of information and knowledge through human interactions as well. And these kinds of venues such as OpenSpace or even your simple computer are tools by which to communicate with. ***And how they're used is what is the elegant art at AMNH, which involves engineering science and of course art. Blending those together and having the kind of open communication such as I experienced*** *when I did it for the launch, where each one of us was able to engage, ask questions, talk out loud, answer people's questions, And it was really fluid and really just a lot of fun. It was built, I think, in part with OSIRIS-REx mission, at least me as the frontrunner, but it really was the three of us engaging.*

Where I saw OpenSpace really moving mountains was in the collaboration between myself and Carter and company, AMNH.

One time Carter and I went to the lower east side Girls Club in New York, and they have a planetarium there, and so the two of us went, and he drove the software, and I answered questions and talked about Pluto. But one thing I want to get across ... It's not only am I the tour guide and Carter's the bus driver, but I think in some ways the audience is driving the whole show. The kids would ask certain questions and be like, oh, well, here. Let me show you. And Carter could queue up what I was talking about, and then we could answer the very specific question that came from the 11-year-old little girl in the audience in a very visual visceral way. ***We could just video tape it and show it over and over. That would be one thing. But that's not ... Hasn't been how we've done it.*** *We'll have a plan. We're going to show this content, but then we take questions, and that allows it to open up even broader. And I feel like, when you're talking to the public, it's critical to make sure that you're answering the questions that they want to know because they all come with different backgrounds of information. And so, it's important to meet them where they are and answer their questions which is what this capability helps to do.*

From my point of view, we cook up a story and the story, it can be anything from soup to nuts and then throw out a flight path and we have a pilot and we have a speaker and the ***speaker speaks and the pilot pilots and the audience is mesmerized in a very comfortable situation in a planetarium****. So it's a good thing for everybody.*

These SMEs speak with almost a tone of reverence for the experience of partnering in this way; they are thrilled to be in the role of a visiting storyteller. Working in partnership with AMNH saves them time and lets them do public programming that has a big impact. Together with an expert pilot, they can navigate on the fly and build responsive storylines tailored to participants' questions. In these situations, they rarely want to learn to fly. This lack of desire is a factor of being too busy, not perceiving a need, and having a sense that the road from being a good pilot to being an awe-inspiring pilot is a long one.

Historically, I've always worked with AMNH to put content together like this. And so, I've never tried to use OpenSpace on my own to produce something like that. And I couldn't, so I wouldn't have the least idea how difficult it would be. But also, ***I've really enjoyed working with the folks there. So I can't see why I wouldn't engage them to work with them to begin with****. I don't have it on my computer, and it works best in a planetarium, although you can display it in other ways. And so, what I've done is partnered with Carter to give presentations at ANMH. I've done remote things where they were just ... He was running it, the presentation, and I would be speaking over it.*

> *Driver & Tour Guide… it's a good metaphor. And I would say that I feel like I am a tour guide. I'm not proficient in driving, in running OpenSpace.* ***I'm sure I could be if I needed to, but I haven't needed to. And so, I think it works out well, the partnership.***

SMEs also recognize (and carry) a high level of expectation around the quality of visuals that parallel their narration. They've seen what's possible when partnering with super pilots.

> *If you're going to go put out a product, you really want it to look exactly right.*

One SME voiced a desire to become a more proficient bus driver. This person is already using OpenSpace deeply for their scientific work, and sees value in not being so reliant on a pilot.

> *I personally feel like the subject matter experts should be proto-drivers. I think that the ideal relationship would be that I can substitute drive, or at least drive most of the way there, and then get support from the full-time drivers as needed…I would rather emphasize training drivers. I would much rather not be a passenger but actually work towards becoming more proficient myself, since I just would rather be less reliant on just a few people who know the most.*

Potential Barriers to Use

Barriers To Increased Use for Scientific Research

Technical Issues

SMEs say that saturation is not high in the community because of the technical barriers to downloading the software and getting it installed [Windows or Linux platform required as opposed to Mac], and the challenges with learning how to use it, and difficulties with bringing in new data relevant to their research (such as specific SPICE kernels, etc.).

> *I would just say OpenSpace is not there yet in terms of broader adoption among our cohort*[SMEs]. *Mostly because of the platform issue and it's hard to pilot in OpenSpace- though that can be overcome once you see what visuals it has.*

Perhaps OpenSpace Is Seen as Primarily a Public Outreach Tool

SMEs say that those who gravitate to OpenSpace are the ones who already lean into public engagement and already see value in visualizing their data for educational purposes. Some interviewees noted the SMEs doing public outreach are in the minority of Subject Matter Experts. Those SMEs are a minority.

> *In my experience, the space science community, let's see, most people I know in the planetary sciences community are not aware of OpenSpace, who are working on the technical side and don't do public-facing work, and I think there's a couple of reasons for that. The first is that OpenSpace is a little difficult to use. That's part of it, but that doesn't explain the whole thing*

because these are a lot of people who are perfectly happy to learn how to use very difficult, complicated, finicky software. I think the bigger thing is that where OpenSpace offers a distinct edge over the competition is in the visuals. It looks good. The output looks good, when done right. The thing is that a lot of space scientists, I think, are aesthetically impaired or aesthetically apathetic. They just don't know how to make something look good, at least a lot of them, a lot of the workaday planetary scientists. And I think that if I were to say to them, "You can make things look great," they'd be like, "That's cool," but they're not going to necessarily put in the effort. I can't even convince a lot of my colleagues to learn how to use Illustrator properly, and this is something that would have a tangible and direct input on the legibility of their work. But they're like, "Well, I'm not going to spend all this extra time making my stuff just look better." I think they like the idea of it. I think it's kind of like how a lot of people like the idea of I'm going to learn how to cook. I'm going to learn how to draw. I'm going to pick up some useful life skill. And they love the idea of it, but when it comes to actually making a commitment, they end up not following through.

Barriers for Getting More SMEs (Who Want to be Pilots)

Sense of Public Expectation

SMEs say that public expectation is high. Working with an expert pilot ensures your product will be excellent.

I think the main barrier is, it's easy to do a lot of the main stuff well in OpenSpace. I can move things back and forth and I can change colors and sizes of everything. Getting from proficient to excellent level is I think probably the largest barrier. It just involves practice, but all the basic stuff I feel like I can do. If I want to make a cinematic masterpiece and have all the transitions be perfect and all of the rendering be perfect, that's where I haven't gotten totally there yet. Going from good to great, is I think the hardest part.

Time

Most SMEs don’t want to learn to drive if they have others who already do it for them. They are busy, and happy to be the tour guide and not the bus driver.

To me, it's about time. There are limited resources for everything. And I tend to find that time is my most precious resource. And so, there's no doubt I could learn to use open space. It probably isn't even that hard, but I've never even sat down and said, hey, I want to learn how to do this because I don't necessarily have the time to add that to my plate as well as do all the other things, because the other thing is I do outreach. Basically, I do outreach because I love to do outreach and not necessarily because it's my job. And so, that makes it even more time constrained. I think it's all about time and priorities and not about technical difficulty. Now, of course, like I said, I've never sat down and tried to learn it. Maybe it is very hard, but I actually have total confidence that I can learn any tool that's out there because it's just a matter of time."

SME Requests for Future Development

When asked what they would wish for future development of OpenSpace, SMEs envisioned a variety of potential changes that would further support their work. In order of number of requests, they requested the following:

- A lightweight version,
- Increasing the Number of Data Formats,
- Support for large-scale datasets,
- More Earth-based content, and
- Expansion to other public venues.

Lightweight Version

These SMEs don't believe OpenSpace has reached a satisfying level of saturation in the field because of its technical barriers. They believe that a lightweight, web-based version would make OpenSpace more accessible to them for their own work and help expand its use. All of these SMEs want a web-based, lightweight version of OpenSpace. They recognize that different computing power is needed to *make* visualizations vs *interact with* visualizations. One SME likened it to the evolving accessibility of digital maps. As they described it, very few people need command-line GIS to do cartographic analysis and design new maps. More people might need a downloaded version of Google Earth, to add new layers at will. But almost everybody needs Google Maps, where they can zoom, navigate, turn on and off set layers, and interact with. What they recommend is a Google Maps version of OpenSpace, for masses of people to use.

> *One of the key elements that we would love to work on with OpenSpace is a web-based version, maybe that doesn't have all the bells and whistles for producing depictions, but is slimmed down so you can visualize things on a web browser. Because we think 99% of the people, their use case is simply to look at a depiction of an orbit that somebody else has generated. Only 1% at most are people who would be generating those, they'll want the full OpenSpace package on their own machines. I think a web-based visualization tool based on OpenSpace would be critical. If you really want to get this in the hands of a lot of people.*

> *I think the thing that would really make the software more useful for scientists would be to have a very light software package that could do, at least at a very lightweight level, some of the measuring utilities that Arcsine is capable of, because Arcsine is a 3D map viewer that we use sometimes in our research.*

> *We would most love to pull up recent events of past events easily and on the fly.*

> *I would like a lightweight OpenSpace that would have measurement tools.*

Increasing the Number of Data Formats

Right now, I see, right here in front of me, I'm sitting on a little Mac Air in my basement in Colorado and I've got Google Earth at my fingertips. So I feel like if you wanted to make OpenSpace even better, there's always issues of resolution improvement. There's always issues of updating timeliness, so you've got up-to-date imagery. There's always issues of bathymetry. I can't remember if you've got bathymetry or not. So there are things that you could keep fine tuning OpenSpace.

There were struggles with visualizing volumetric data, including: 1. pulling out eruptions as separate from the wind behind it. 2. We are in a spherical coordinate system 3. visualizations don't cover both poles of the sun. There have been challenges to show scientific phenomenon in a way that makes sense but we've overcome them in realms of visualization.

Back-end set up. Getting things approved [from provider], gathering the right data. "Some of it was we need to get the kernels and put them together. And there's processes for doing that depending. It includes a large distributed team, navigation, mission design, and we had some of the kernels and then also getting approval to make sure that those kernels are the ones that you want to share.

Support for New Large Data Sets To Be Easily Incorporated

I would want to make sure in the future that OpenSpace has the support for adding personally very large data sets. I haven't done this yet, but I would want to make sure that that was something that was possible in the future, because data sets will be getting larger and larger and it's not always possible for OpenSpace to add every single data set you would want to add and have it built in. And so having support and making it fluid to be able to incorporate even larger and larger data sets that are on the horizon would be a priority for me.

Incorporate More Earth-Based Content

I think there's a huge advantage to being able to use OpenSpace to explore what's going on in our Earth. I mean, it's ... There are so many data sets that are very rich. You've got land-set data that are earth imaging data over 20 years.

If there was some way that NOAA datasets could be more easily used or something on OpenSpace, that might be something that ... Because to be fair, that's something that I can't pull up ... I can pull up Science on a Sphere on my laptop and look at little things, but I can't overlay NOAA or pull it up on my laptop in OpenSpace.

As the quotes above note, SMEs have been interested in using OpenSpace with Earth-based datasets. The OpenSpace team has since made it possible to access NOAA Science on a Sphere datasets, and continues to expand that capability.

Expand OpenSpace into More Public Venues

Here's a great fantasy on my part. But I'd like to walk into the new Penn Station and see a big screen right there that's OpenSpace and a lecture going on right there while people are waiting for their trains, rather than just looking at the bullshit that happened. This is the thinking, this is what needs to happen in my opinion, is you're walking into some business, whatever area, and they've got a screen in there that has an OpenSpace lecture being live. You can get a TED Talk channel, but this is different. What about tuning in on an OpenSpace in the middle of Nebraska?

OpenSpace Year 7: Collaboration Memo

July 2022

Methods & Interpretation

During May and June of 2022, 22 core team members completed a 52-question survey which was mostly closed-ended, 1-to-7 rating scale questions. The goals of the survey include examining the health of the team collaboration, as well as pinpointing areas of strength and areas of possible improvement. The majority of team members also had completed a previous collaboration survey in 2021. Comparisons of the 2021's responses are included in the comments of this report, with Year 6's data in parentheses.

This survey instrument was derived from prior work focused specifically on Science Center collaborations *Collaboration: Critical Criteria for Success* (Dierking, 1995) and more general collaborations via the *Wilder Collaboration Factor Inventory* (Mattessich, Murray-Close, & Monsey, 2001).

There are eight categories which the questions are grouped in:

1. Trust, Listening, & Personal Investment
2. Goals & Roles
3. Project Management
4. Expectations of Investment
5. Leadership
6. Capacity
7. Value & Effectiveness
8. Communication

Understanding These Results

In the scale used, 1 represented "Strongly Disagree," 7 represented "Strongly Agree." A 4 is neutral.

- A rating between 5.5 and 7.0 does not require special attention at this time, and indicates **a very strong and healthy collaboration;**
- A rating between 4.0 and 5.4 indicates a borderline aspect of the collaboration, and **may require special attention**;
- A rating below 4.0 is italicized, indicating an area of concern for the collaboration and **would need to be addressed**.
  (No average ratings below 4.68 are in this year's data.)

Minimum ratings indicate the lowest rating on this question, and can be useful in examining divergent opinions. A bolded, blue minimum rating means 2 or more individuals showed significant dissatisfaction (i.e., rated **3** or lower).

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Overall Collaboration 2022 Ratings

Once again, the OpenSpace team continues to rate itself highly overall in each of the eight categories. Even the lowest-rated category—communication—is over 5 out of 7. The rating changes from last year are not significant, demonstrating the project is consistently strong.

Variance between category averages is small: in the tenths of a point. While it is notable that the averages have changed in *ranking* this year from last (see Year 6 ratings in parentheses), only slight rating differences mean that we should not put too much emphasis on this change. Nevertheless, Value & Effectiveness was ranked highest last year, with Goals and Roles at almost the same level, highly valued for their clarity. Trust, Listening, & Personal Investment rose from third-highest to the top. Capacity ratings increased from the lowest-rated category, with Communication falling to the bottom.

Again recognizing only a slight change, half the categories were more positive than last year; the other half were more negative. Only the 3 lowest-rated categories fall below 5.5 and therefore in the "may require special attention" grouping, explained in the previous slide. **The big picture from these data is that OpenSpace collaboration continues to be strong with some smaller elements to continue to improve.**

		Average Rating in Category
	**Trust, Listening, & Personal Investment** 6 questions which focus on the personal interactions within the collaboration including trust, respect, and ability to listen.	**5.91** (5.85)
	**Goals & Roles** 3 questions which measure whether project goals, roles, and responsibilities are clear.	**5.79** (5.91)
	**Project Management** 7 questions which focus on how well the project is being managed.	**5.73** (5.74)
	**Expectations of Investment** 5 questions which focus on whether organizational and expectations are clear and realistic.	**5.69** (5.51)
	**Leadership** 2 questions which assess capabilities of the collaboration leadership.	**5.66** (5.62)
	**Capacity** 5 questions which focus on whether individuals and organizations in the collaboration have the necessary capacity.	**5.41** (5.33)
	**Value & Effectiveness** 5 questions focused on whether the team member believes the project is worthwhile at an institutional and societal level.	**5.21** (5.95)
	**Communication** 7 questions focused on how well the members of collaboration communicate, including regularity and decision-making.	**5.28** (5.44)

1. Trust, Listening, & Personal Investment

	Average	Min Rating
I have a lot of respect for the other people involved in the OpenSpace project.	6.55 (6.65)	5 (5)
Everyone who is a member of our collaborative group is invested in the process and success of the project's outcome.	6.05 (5.94)	3 (4)
Other OpenSpace project members listen and consider *my* opinions and point of view.	5.73 (5.94)	1 (4)
OpenSpace project members listen and consider *other team members'* opinions and point-of-view.	5.77 (5.88)	1 (4)
People involved in the OpenSpace project trust one another.	6.05 (5.82)	4 (3)
My ideas about what we want to accomplish with the OpenSpace project seem to be the same as ideas of others.	5.32 (4.88)	1 (1)

This category has only very slightly improved in rating over the past two years, but has the highest overall rating.

Notable comments included:

- Each Museum is different and each team has its own opportunities and challenges. The OpenSpace program probably benefits most when different Museums have the opportunities to do different things.
- I think overall MOST members of the team are excellent and collaborative. There does seem to be some gap between the leadership team and the ISI Partners and development teams, however, which prevents a complete environment of trust and respect.
- It's an excellent team, overall. I have no problems with anyone and really like the combination of curators, education, visualization, and exhibits people.
- As a team we are highly motivated to ensure accuracy of visualizing the data, and while some points of view may differ, they are discussed frequently with resolution in mind.

Note that the three statements with a minimum rating of 1 represent ratings of the same team member.

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2. Goals & Roles

	Average	Min Rating
I believe that there are shared goals across the partner organizations involved in the OpenSpace project.	5.91 (6.17)	4 (5)
People within the OpenSpace project have a clear sense of their roles and responsibilities.	5.50 (5.83)	3 (3)
My role is clearly defined in the OpenSpace project.	5.95 (5.72)	3 (2)

Organizationally we are strong, and we strive to make it better. Growing pains tend to show off shortcomings which are discussed and then planned for improvements.

This category dipped slightly lower than last year, when it was rated a half-point higher than the year before that.

Two respondents rated the statement "People within OpenSpace have a clear sense of the roles and responsibilities" as a 3 out of 7 (in blue), with one explaining:

- I think as I've put on surveys for the last several years the goals of the project are still vague, we still need more clarity on what the long-term goals and benchmarks for the project are and how we can each help to specifically contribute to their realization.

Other comments included:

- There is a lot of variation in how much effort each institution brings to the project. Also, I wish I had much time to devote to this project and to fulfill my role as Project Director.
- I think that the clarity of expectations of roles across the project is very strong, particularly given the variation in the types of institutions involved (universities, smaller ISIs, larger ISIs, etc.)

One respondent said that they don't know enough about other organizations to assess their capabilities; another explained that they don't feel comfortable stating their views about others.

3. Project Management

	Average	Min Rating
I know with whom to talk to when I need clarification.	6.27 (6.29)	5 (5)
I am given regularly scheduled means for sharing progress, updates, ideas, changes.	5.94 (5.91)	4 (4)
I have had regular and easy access to shared documents.	5.55 (5.76)	2 (2)
OpenSpace meetings are well-run.	5.73 (5.71)	3 (3)
OpenSpace meetings generally last the right amount of time.	5.64 (5.71)	3 (3)
I have been regularly informed about updated project timelines.	5.64 (5.53)	3 (2)
The OpenSpace Project has had the right number of meetings to do the work needed.	5.36 (5.29)	3 (2)

This category is rated the same as last year. For each of the three statements with blue minimum ratings, there were two respondents rating the statement under a 4.

One person who rating three statements as a 3 wrote:

- Overall Micah is excellent at running the monthly Micah Mondays, although these are generally technically oriented. These are the most valuable and well-structured OpenSpace meetings I participate in. All other meetings often seem somewhat lacking in direction and are fairly infrequent so that the ability of these meetings to achieve goals is unclear.

Another respondent complimented management:

- This is an extremely well-managed project and I feel that there is great communication for the team and it's very clear what's needed. The meetings are excellent and extremely well-run. I find the diversity of skills and people in the partnership to be very helpful in thinking about new OpenSpace ideas and learning from one another. It's been one of my favorite projects to-date.

Another had a small request: “Micah Monthlies run long; it is good information but I have to run to other meetings after.”

4. Expectations of Investment

	Average	Min Rating
The expectations of my organization's participation are realistic.	6.00 (6.00)	4 (3)
The expectations of my participation are realistic.	5.86 (5.88)	3 (3)
The expectations have been clearly communicated on what I need to bring to the OpenSpace Project to make it successful.	5.77 (5.83)	4 (3)
The other organizations within OpenSpace invest the right amount of time and effort to meet our goals.	5.36 (5.00)	4 (4)
The time commitment expected from me to make OpenSpace possible is appropriately compensated.	5.45 (4.82)	1 (1)

Overall this category ranked slightly higher than last year. Ratings for compensation based on time commitment were higher this year, with only one person rating it below a 4, compared to multiple low-scale ratings last year. That single low-rater noted that it would be "way different for other jobs."

Comments included:

- Organizations have sometimes been challenged to come up with the time & resources needed to make meaningful contributions. This includes my institution; we have been short-staffed as we emerged from pandemic reductions and changes.
- I think it has been difficult to make progress toward our goals given the ongoing uncertainty of the pandemic but, given that reality, partner institutions are putting the right type of capacity forward to achieve our goals.

The same respondents as in Goals & Roles (slide 4) said that they don't know enough about other organizations to assess their capabilities or don't feel comfortable stating their views about others. Clarification may be needed about how to understand and answer this survey.

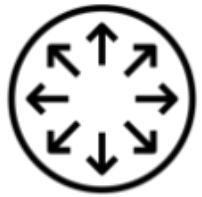
5. Leadership

	Average	Min Rating
The people in OpenSpace Project leadership positions have good skills for working with other people and organizations.	5.95 (5.94)	2 (4)
OpenSpace Project leadership knows how and when to delegate tasks.	5.36 (5.29)	2 (3)

This category was also ranked very similarly to last year, which was a couple tenths of a point higher than the year before that.

The two minimum ratings of 2 were made by the same respondent.

No comments were made directly about leadership.



6. Capacity

	Average	Min Rating
The time commitment expected from me as an active member of this collaboration is realistic.	5.86 (5.82)	2 (4)
OpenSpace partner organizations have the organizational commitment needed for this project.	5.23 (5.59)	4 (4)
I believe that the OpenSpace partner organizations have the staff capacity to make adequate contributions necessary for this collaboration.	5.32 (5.41)	3 (3)
OpenSpace partner organizations are currently able to keep up with the work necessary to coordinate all the people, organizations, and activities related to the OpenSpace project.	5.18 (5.12)	3 (3)
The OpenSpace project has the funding that is necessary to complete the project goals.	5.45 (4.71)	4 (1)

This category has also improved in rating over the past two years by at a tenth of a point each year.

A compliment:

- Because our management is good in my opinion, the capacity is well apportioned at AMNH. Partner realities may effect use, but all are using it and plan to use it more.

The development team could benefit from increased capacity. They do great work, but they seem bandwidth limited. The money we receive as an ISI partner covers partial compensation for our OpenSpace work, but because we use the software in virtually all our live programming, there is a lot of work that is not paid for by the grant.

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7. Value & Effectiveness

	Average	Min Rating
OpenSpace contributes support to the mission of my organization.	6.14 (6.35)	4 (5)
OpenSpace provides an opportunity to deepen the content available to my audiences.	6.14 (6.06)	3 (2)
OpenSpace provides better or alternative ways of doing things.	5.73 (5.88)	1 (4)
OpenSpace enhances the reach, societal value, and leadership of my organization.	5.77 (5.88)	2 (4)
OpenSpace provides access to resources not normally available.	6.00 (5.47)	3 (1)

The promise of OpenSpace as an widely available visualization tool has a strong appeal for my organization. The tool remains a work in progress, but real progress has been made. We remain interested to participate to experiment using it for our science and general public communities.

There was a drop on this overall rating by 7-tenths of a point this year, more than any other category. One team member rated four statements below a 4, explaining their ratings:

- The problem with OpenSpace from its very foundation was that it is a flawed system. It was created because one person could not get a for-profit company to do everything they wanted. Instead of being more flexible and working together they decided to create their whole brand new program in a way that works best purely for them and without taking serious consideration of other institutions needs.

Two comments were made about the work being worth it, even though they are sometimes “chores.” One spoke to the value to education and public programs, the other to the clout and validity gained via NASA. More generally:

- OpenSpace has amazing use and potential already and I want us to be on a clear course to what the capabilities of the final product should be and how we achieve them.

Two comments were made about the increased value and interest from audiences due to the software being free and open-source.

One person stated that they are “not sure what societal value and leadership have to do with the utilization and implementation of OpenSpace,” which implies that clarification may be needed with the team. They also made this statement in another section:

- Our programs are driven by opportunities within the Museum and the capacity of OpenSpace. Our progress is determined most by identifying opportunities within the Museum to reach visitors. It's not what we want to produce, but what the public wants to consume that drives our utilization of OpenSpace.

8. Communication, part 1

	Average	Min Rating
Communication regarding tasks, responsibilities, and deadlines are clear.	5.50 (5.82)	4 (4)
There is a high level of clarity in communication across the OpenSpace collaborating institutions to date.	5.50 (5.82)	4 (4)
The OpenSpace project has a high level of clarity in its stated goals to date.	5.50 (5.59)	1 (2)
Communication regarding decision-making process is clear.	4.82 (5.41)	1 (1)
There is a high level of overall communication effectiveness across the OpenSpace collaborating institutions to date.	5.23 (5.29)	3 (3)
There is a high level of regularity in communication across the OpenSpace collaborating institutions.	5.73 (5.18)	3 (2)
I frequently feel that I am out of touch with what is happening in the OpenSpace project. *	3.32* (3.00)	1* (1)

*This is a reverse-coded item: the lower the rating, the more positive the experience. In the average table at the beginning of this report, the score of *3.32* is reverse coded, equivalent to a *4.68*.

Communication dropped in both rating and ranking this year, again only slightly. However, more people wrote comments about communication than any other category.

Seven respondents mentioned things that are working well: Micah Mondays, the recruitment and efficient performance of the new project coordinator, regular weekly meetings, direct communication with developers, and the spreadsheet.

Individual concerns were around too many communication modes, delays in communication, and a personal lack of interest in communication:

- I feel like there is far too much disparaging lines of communication. The face that there are ELEVEN different options for communication means that there are too many options to find the information that you are looking for. Not to mention some of them are not updated enough because there are just too many.
- There's been a drop off in other channels of communication since Corrie Roe's departure.
- For me the success of this project is measured in products produced and visitors reached -- not in the internal communication experiences. Just don't have the time for much chatting or show-and-tell.

8. Communication, part 2

Five respondents mentioned feeling out-of-the-loop, especially around project goals and communication between and from partners, which for some were explicitly connected:

- I continue to feel that the specific goals of the project are not clearly defined. We don't have a clear roadmap on what the features and content of the software should be so that we can break out what features should be prioritized in each release, nor do I feel there's always adequate leveraging of expertise from partner institutions to provide feedback and input on the function and content of the software until sometimes fairly late in the process. I think direct communication with the developers is excellent and I rely very heavily on that, but there's no clarity on how the overall direction of the software is being set and how partners can have full participation in that process.
- I don't tend to know what other institutions are doing but there seems to be positive feedback on what I'm doing so I think I'm on the right track in terms of fulfilling overall project goals. We don't really see the other projects, except at annual meetings.
- End-users (daily show presenters) don't seem to be as well informed of the scope and expectations of the project as those at the decision-making level.
- Since I don't work with overall development or work with other ISE partners, I can't speak to how well the overall project goals are being met.
- The spreadsheet is good to see the programs others are doing but I can imagine partners might have felt more out of the loop at times this past year due to the staffing change.

Most Useful Means of Communication
(Respondents could select up to 4 answers)

The Micah Monthly	14
OpenSpace Team Slack (private)	14
Individual calls with other team members	9
OpenSpace Support Slack channel (public)	9
Megan’s monthly partner emails	7
OpenSpace Wiki	7
Github	5
Other partner telephone or Zoom meetings	5
OpenSpace website	3
OpenSpace social media	3
OpenSpace newsletter	1
Other*	2

* “The increasingly user-friendly OpenSpace software” and
“ Internal AMNH weekly OpenSpace project meetings”

Challenges

TIME (5 respondents)

- Challenges are knowing the technical vocabulary and a desire to dive deeper into the technical side. I need to set aside more time to look over the Wiki.
- Lack of time is my biggest challenge since I oversee multiple projects.
- Time, specifically having available time to carve out to dedicate to OpenSpace-related work.
- I think our biggest barrier is the amount of time and expertise required to implement bespoke content in OpenSpace. It might be something to think about in terms of the uptake of OpenSpace in the research community.

PROJECT MANAGEMENT / LEADERSHIP (4 respondents)

- How to maintain the project long term. To address this, funding the project for another five years would help.
- Would be good to have more structure regarding testing before deadlines (e.g. releases). More systematic check ins and testing periods.
- Thinking about how to transition our primary focus from developing the software to providing support materials and guides for using the software for novice/new ISI staff.
- As a colleague and I have been stating from the very beginning of this grant, there is no way to actually use this in a dome without there being a support structure in place. To this day there is NOT instructions that are written and clear that explain how to set up the initial install of OpenSpace in your theater. There are NO technical specifications on what to build in order to run the software. There is NO proper documentation for theaters to run the system efficiently and troubleshoot when there are problems. Currently we have to have a developer come in and troubleshoot the issues in order to get it up and running. This is something that is supported and documented from every other major planetarium software out there and it is in fact backed up by a paid for-profit company that has a support department. OpenSpace currently doesn't have any of that and it will doom this entire project to the dustbins of history unless it is addressed.

TECH (4 respondents)

- I don't think there are significant barriers to using OpenSpace and showing the visualizations in a variety of ways. It's great how with the last few versions of the software things have gotten easier to set up and port in the older files. If there was a way to make a light version that didn't require high-end computing, then I think it would reach the widest possible audience. The biggest barrier right now is simply that many people don't have the computers to run it.
- I think the only current barrier is the software is still relatively new and changes are being made to core functions here and there.
- Computing requirements remain high for OpenSpace to work. Not a serious barrier within our institution, but it is a challenge out there in the real world.
- We have many challenges, e.g. old thesis projects not yet offered in release, GUI simplification ideas, preparation of content in backlog, and software issues well documented on GitHub. But, we discuss priorities and build releases around those. The barrier is always time / staff / $. I feel we are doing a great job, considering.

COMMUNICATION (3 respondents)

- My current barrier is staying connected to partners and offering adequate support while they balance other roles and responsibilities.
- I wish there was more opportunity to provide feedback ahead of the development of features to better clarify what the user needs for these features might be and get data visualization input from multiple users to take different perspectives into the final product and/or build out more options proactively.
- I'm not the main point person or even top 3 at my institution, so I often feel a bit disconnected from the project. That's more on our end of things, not really something OpenSpace is doing wrong.

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Suggestions

TECH (7 respondents)

- If there was a way to make a light version that didn't require high-end computing, then I think it would reach the widest possible audience. The biggest barrier right now is simply that many people don't have the computers to run it.
- I think OpenSpace's GUI continues to need simplification. I also think that installation and support for the software could continue to be made easier to encourage widespread adoption without direct support from the development team or seasoned users.
- The HTML button-set that our team have come up with has made operation very easy, although that requires a predetermined set of targets and isn't as open to free-flight.
- Focus more on perfecting existing functionality and less on new features.
- Maybe more WYSIWYG, less menu dropdowns and sliders.
- Easier tutorials in the Wiki.

PROJECT MANAGEMENT / LEADERSHIP (5 respondents)

- The ISI partners don’t seem to do much in collaboration with one another. It would be great to think about how we could work together more closely on specific projects.
- I think it would be useful if all folks involved in management/leadership had basic comfort with using OpenSpace however time is a barrier there (and also the issue with new Macs is not helping).
- As the project grows in reach, we need to find ways to get more resources.
- I would like more information about the number of active users, and summaries of how they are using OpenSpace.

GOALS (2 respondents)

- There continues to be a strong gap in the core question of whether OpenSpace is a high-end visualization platform or an accessible piece of software anyone and everyone should be able to use.
- You had ideas of what OpenSpace could be. Give it room to grow and see what it can become. Let Museums figure out the best way to use the software and create an OpenSpace experience that works in their institution. Adjust your measures of success to the realities of what partners can do. Our Museum receives no public money from the city or state. Our programs must drive attendance. Other Museums may have different criteria for success and other opportunities to use OpenSpace. And that's how it should be.

COMMUNICATION (2 respondents)

- I'm still learning how the collaboration functions, but communication across leadership, developers, and partners could be improved. It would be interesting to know each partner's preference of format when tasks need to be completed (Google form, email, Slack, etc.). There are many channels of communication, but some are not utilized frequently.
- Listen to your dome technician partners and actually IMPLEMENT what they are suggesting instead of paying lip service to them during meetings and the completely ignoring any talk of sustainability of this opensource project beyond the scope of the grant funding.

IX. Appendix C: Agendas

- OpenSpace Developer Meeting Agenda
- OpenSpace ISI Network Meeting Agenda

OpenSpace Developers Meeting 2022 –Agenda

Feb 14th (10:00 – 1:00 ET / 1600-1900 CET)

10 – 10:30

Creating a shared vision for OpenSpace 2025

- Who are the users? How many of them are there?
- How do we support them?
- How are they using OpenSpace?

10:30 – 1:00

Creating a road map for getting there

- Operating Systems
- Technical support
  - System compatibility
  - Ongoing support
- Feature set (e.g. rendering tools)

Feb 15th (11:00 – 1:00 ET / 1700-1900 CET)

11:00 – 12:00 0.18.0 release

- Schedule for 0.18.0
- Features for 0.18.0 (review identified feature list with demo & or detailed description)

12:00 – 1:00
0.19.0 release

- Schedule (release date vs. feature completion)
- Review & revise priorities from last year's board

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Annual ISI Partner Meeting
July 14-15, 2022
American Museum of Natural History
79th Street at Central Park West, New York, NY 10024

Thursday, July 14

12:00-1:00 pm	**I. Lunch and Introductions** (1 hour)	*Lead: Ro*
1:00-2:00 pm	**II. SciAct Grant Updates and Planning** (1 hour)*	*Lead: Ro & Vivian*
	Zoom available for virtual attendees: https://amnh.zoom.us/j/95996115003	
2:00-3:00 pm	**III. Release Updates and Goals** (1 hour)*	*Lead: Micah & Alex*
3:00-3:20 pm	Break (20 min)	
3:20-4:10 pm	**IV. Upcoming NASA Communication Priorities** (50 min)*	*Lead*: *Carter & Micah*
4:10-4:30 pm	Make your way to the Planetarium! (20 min)	
4:30-5:00 pm	**V. Worlds Beyond Earth** (30 min) *Screening in the Hayden Planetarium*	
5:00-7:00 pm	**VI. Dome Show** (2 hours)	*Lead*: *Micah & Carter*
7:30 pm	Dinner *The Milling Room*	

- Houston and Adler to present on flat screen
- Cal Academy, Denver, and NCMNS to present on dome
- OpenSpace team present bespoke show highlighting research
- Improv!

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Friday, July 15

9:00-9:30 am	Breakfast (30 min)	
9:45-11:00 am	**I. ISI Partner Program Activity Share Outs** (1.25 hours)* *Up to 10 min each partner* ● 2021 and 2022 to date ● Program type ● Reach and demographics	
11:00-11:15 am	Break (15 min)	
11:15-12:15 pm	**II. Evaluation Findings & Data Collecting Strategies** (1 hour)*	*Lead*: *Kate & Madeleine*
12:15-1:30 pm	Lunch (1.25 hours)	
1:30pm-2:30 pm	**III. New Funding Opportunities Brainstorm** (1 hour)* *Bring your ideas to share!*	*Lead: Ro & Vivian*
2:30-3:00 pm	**IV. Closing**	*Lead: Ro*
3:00 pm	**Tour of the Mignone Halls of Gems and Minerals**	*Lead: Denton Ebel*

*Session available on Zoom
Topic: OpenSpace ISI Partner Annual Meeting
https://amnh.zoom.us/j/95996115003
Meeting ID: 959 9611 5003
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+16469313860,,95996115003# US